New trends in physics teaching

Tendances nouvelles de l'enseignement de la physique

(1965-1966)

Vol. I

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Unesco

The teaching of basic sciences
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AVANT - PROPOS

L'Unesco a la lourde responsabilité d'aider, sur demande, les pays en voie de développement à améliorer leur enseignement des sciences. Ces pays savent que leur progrès économique est fonction de la possibilité qu'ils auront de former d'importants contingents d'hommes de science, d'ingénieurs et de techniciens. Ils savent aussi qu'ils leur faut ouvrir toute la population à la science, pour établir les fondements solides d'une société technologique moderne. Or, les outils mêmes avec lesquels il leur faut mener à bien cette tâche - leurs écoles, instituts techniques et universités - n'ont pas l'efficacité voulue en raison des méthodes désuètes employées, et ils sont d'ailleurs dépassés par les évènements : la forte poussée démographique et l'accroissement rapide des connaissances scientifiques.

Aussi nombre de ces pays ont-ils accordé la priorité absolue à la modernisation de leur enseignement scientifique. Ce faisant, ils sont en quête de réponses à un certain nombre de questions d'importance vitale pour la réorganisation de l'enseignement des sciences selon des critères modernes, rationnels et fonctionnels : Qui faut-il instruire ? Que faut-il enseigner ? Quand faut-il l'enseigner ? Comment faut-il l'enseigner ? Quel équilibre faut-il maintenir entre la formation purement théorique et l'apprentissage strictement pratique ? Quelle doit être la part de l'enseignement magistral et quelle doit être celle des études individuelles ? Quel doit être le rôle, dans l'enseignement des sciences, de la discussion en petits groupes, des applications pratiques en classe, du travail de laboratoire individuel, des auxiliaires audio-visuels y compris de la télévision ? Etant donné la nécessité de donner un certain niveau de culture scientifique à la population tout entière, pour asseoir la société technologique de demain, quelle est la forme d'enseignement scientifique général qui donnera à cet égard les meilleurs résultats ?

Cherchant à trouver réponse à toutes ces questions, l'Unesco a élaboré un programme d'enseignement des sciences dont les objectifs principaux sont les suivants :

a) Favoriser les échanges de renseignements sur le contenu et la méthodologie de l'enseignement des sciences ;
b) Réaliser des projets expérimentaux en vue de la mise au point de méthodes et de matériels nouveaux pour l'enseignement des sciences ;
c) Organiser, en collaboration avec les Etats membres, des programmes internationaux d'études universitaires supérieures et coopérer avec les Etats membres à l'établissement de centres de hautes études à l'intention des hommes de science, des enseignants et des chercheurs des pays en voie de développement ;
d) Stimuler l'intérêt porté à la science et à l'enseignement des sciences, et faire mieux comprendre l'influence que la science exerce sur les affaires humaines en patronnant des tournées de conférences faites par des savants éminents et en décernant des prix internationaux comme le Prix Kalinga.

La publication de la nouvelle collection biennale, "L'enseignement des sciences fondamentales", répond au souci de ménager un échange d'informations sur le contenu, la conception générale, les programmes et les techniques modernes de l'enseignement de ces sciences. La collection complète comprend quatre volumes consacrés respectivement à la physique, à la chimie, à la biologie et aux mathématiques.

Le présent volume, "Tendances nouvelles de l'enseignement de la physique", insiste sur les innovations introduites au cours des six dernières années et sur les additions ou modifications qui ont été apportées aux anciennes méthodes durant cette période. Les textes présentés sont tantôt des extraits de revues et ouvrages scientifiques, tantôt des rapports, dont certains ont été spécialement rédigés pour ce volume. Ils sont reproduits ici tels qu'ils ont été publiés ou écrits. Les phrases de liaison ont été rédigées par M. Knecht, qui a préparé cet ouvrage.

Le chapitre par pays donne des détails sur les points suivants :

i) nouvelles conceptions de l'enseignement de la physique et amélioration du contenu de cet enseignement, ce qui pourrait donner lieu à la création de centres nouveaux chargés de la formation ou du recyclage des professeurs et des élèves ;
ii) réforme du programme ;
iii) ouvrages présentant un intérêt spécial pour l'amélioration de l'enseignement de la physique ;
iv) matériel nouveau pour la classe et le laboratoire, auxiliaires du maître, nouvelles méthodes pédagogiques faisant appel aux moyens modernes, appréciation des connaissances acquises par les élèves ;
v) revues consacrées à l'enseignement de la physique.

Ce volume a un caractère expérimental. Des renseignements ont été demandés à de nombreux pays. Les textes sont une synthèse des réponses reçues. On s'emploie à recueillir des données supplémentaires auprès de pays nouveaux, afin de ne négliger aucun aspect des efforts déployés en vue d'améliorer l'enseignement de la physique. Aussi l'Unesco serait-elle reconnaissante aux lecteurs qui pourraient lui envoyer des renseignements, observations et documents susceptibles de servir à la préparation du prochain volume. Le présent volume est destiné aux professeurs de physique exerçant dans les universités, les écoles normales et les établissements secondaires, ainsi qu'aux rédacteurs d'ouvrages scientifiques et au personnel des sections de physique des associations d'enseignants.

L'Unesco exprime sa vive reconnaissance aux directeurs et éditeurs de revues et de livres, qui ont bien voulu autoriser la reproduction d'articles ou de chapitres extraits de leurs publications.

FOREWORD

Unesco faces a heavy responsibility in helping the developing countries, at their request, to improve their science teaching. These countries are aware that economic development depends upon their ability to train large numbers of their own people as scientists, engineers and technicians. They know, too, that they must bring about a widespread understanding of science among the entire population if they are to create a sound basis for a modern technological society. Yet the very instruments with which they must carry out these tasks - their schools, technical institutes and universities - are weakened by obsolete methods and overloaded by the vast increase in population and by rapid growth in scientific knowledge.

Understandably, many of these countries have given the highest priority to a thorough modernization of their science teaching. In this, they are searching for answers to a number of questions of basic significance to the reorganization of science education along contemporary, rational and functional lines : Who should be taught ? What should be taught ? When should it be taught ? How should it be taught ? What balance should be kept between purely theoretical training and strictly practical apprenticeship ? How much oral instruction from the teacher and how much individual study by the student is required ? What is the role of the small group-discussion, the classroom demonstration, the individual laboratory experiment, of audio-visual aids, including television, in science education ? In view of the need for scientific literacy among the entire population as a basis for a technological society, what form of general science teaching can best bring about a widespread understanding of science ?

In its search for answers to such questions, Unesco has developed a programme in science teaching whose main objectives are the following :

(a) to promote exchanges of information on the content and methodology of science teaching ;
(b) to conduct experimental projects for developing new science-teaching methods and materials ;
(c) to organize, in collaboration with Member States, international post-graduate training programmes and to co-operate with Member States in the establishment of advanced training centres for scientists, teachers and research workers in developing countries ;
(d) to stimulate interest in science and science teaching and to promote understanding of the impact of science on human affairs, by sponsoring lectures by distinguished scientists and by granting international awards such as the Kalinga Prize.

With the publication of the new biennial series "The Teaching of Basic Sciences", Unesco aims at providing an exchange of information on modern content, approaches, curricula and techniques in the teaching of the basic sciences. One volume on each of the sciences - physics, chemistry and biology - and one on mathematics, make up the complete series.

This volume, "New Trends in Physics Teaching" concentrates on innovations introduced within the last six years and substantial additions or modifications made to older teaching methods during this period. The information presented consists partly of reprints from scientific journals and books, and partly of reports - some of which were specially written for this publication. The contributions and extracts are reproduced in the original language, as received. Introductory and explanatory notes are by the editor, Mr. W. Knecht.

The section classified by countries gives details of :

i) new approaches to physics teaching and improvement of course content, which could lead to the creation of new centres for training and retraining teachers and students ;
ii) curriculum reform ;
iii) books of special interest for the improvement of physics teaching ;
iv) new materials for use in classroom and laboratory, aids for teachers, new teaching techniques using modern media, testing of student performance ;
v) journals devoted to the teaching of physics.

This volume is to be considered as experimental. Information was requested from many countries. The texts included here are a synthesis of replies received. Work is now in progress to increase the number of countries covered and ensure that all aspects of work done towards better teaching of physics are examined. Unesco would therefore be grateful to readers for sending information, comments and documents which might help in the preparation of the next volume. It should be borne in mind that "New Trends in Physics Teaching" is intended for use by physics teachers at universities, teacher-training institutions and secondary schools, as well as by science editors and the staff of physics sections of teachers' associations.

Unesco gratefully acknowledges the kind co-operation of the editors and publishers of journals and books who have given permission for the reproduction of articles or sections from their publications.

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ACTIVITES INTERNATIONALES / INTERNATIONAL ACTIVITIES

Les publications suivantes résultent d'activités développées sur le plan international./
The publications listed below were produced as a result of activities at the international level.

INTERNATIONAL EDUCATION IN PHYSICS

International education in physics, proceedings of the IUPAP(1) international conference on physics education, Unesco House, Paris, July 18th - August 4th 1960, edited by S. C. Brown and N. Clarke. Cambridge (Massachusetts) and New York, London, The Technology Press and John Wiley & Sons, Inc. 1960, xvi + 191 p.

Contents (abstracts) :

- Physics as a part of general education
  Mr. N. Clarke (U.K.)
- Examinations in physics
  Dr. H.F. Boulind (U.K.)
- The selection of students
  Professor G.K.T. Conn (U.K.)
- The work of the American Physical Science Study Committee
  Professor J.R. Zacharias (U.S.A.)
- The place of laboratory work in physics teaching
  Professor M.R. Gavin (U.K.)
- The training of teachers
  Professor B. Rosen (Belgium)
- The post-graduate training of physicists
  Dr. C.G. Suits (U.S.A.)
- The use of television and films in physics teaching
  Professor H. White, Dr. W.C. Kelly (U.S.A.)
- The teaching of physics to engineers, chemists, and other science students
  Professor P. Aigrain (France)
- The teaching of mathematics
  Professor J.P. Mathieu (France)

A MODERN APPROACH TO SCHOOL PHYSICS

A modern approach to school physics(2), Paris, OEEC(3), 1960, 23 p.

This report has been prepared as a contribution to the above mentioned international conference by a working group whose membership is as follows :

Mr. Norman Clarke (United Kingdom), Chairman ; Professor A. Michels (Netherlands) ; M. A. Renaud (Switzerland) ; Professor D. Sette (Italy) ; Professor S. Sikjaer (Denmark) ; Dr. J. Topping (United Kingdom) and Professor L. Weil (France).

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1. International Union of Pure and Applied Physics.
2. La version française est intitulée Une conception moderne de l'enseignement de la physique.
3. Organization for European Economic Co-operation, 2 rue A. Pascal, Paris 16e

Contents :

- The teaching of physics in schools
- Defects of present physics courses
- Children for whom our course is intended
- The approach to the teaching of physics
- Practical work
- The teaching of mathematics to physics students
- Examinations
- The supply of physics teachers
- Textbooks and teaching aids
- Conclusion

WHY TEACH PHYSICS ?

Why teach physics ? based on discussions at the IUPAP international conference on physics in general education, Rio de Janeiro, July 1st - 6th 1963, edited by S. C. Brown, N. Clarke and J. Tiomno. Cambridge (Massachusetts) . The MIT Press, 1964, XXV + 97 p.

Summary of the Conference (reproduced from Why teach physics ? pp. 1-2)

This Conference was held to discuss some particular aspects of general education. By general education we have meant the broad training to be given to all children up to about the age of sixteen, a training that is not intended to prepare them for any particular occupation but which is the best preparation that we can devise for their entering into the adult world. It is inconceivable that in the modern technological age it could be seriously disputed that science should be an essential part of this education. Physics is the most fundamental of the sciences and therefore is clearly essential. Our view does not rest upon the obvious usefulness of physics in a technological world. On the contrary, we have stressed that the claim of physics to be part of the education of all children stems from the place that the subject occupies in the intellectual heritage to which we seek through education to introduce our children. Moreover, it is for this very reason that we are agreed that physics courses commonly given to children are inadequate and unsatisfactory. They fail to present in any convincing way the magnitude and grandeur of the intellectual achievements represented by modern physical theory, they fail to convey understanding of the more important concepts of physics, and they fail to show to young people anything of the approach which the professional physicist necessarily brings to his work.

We have discussed a number of actual developments in physics courses in various countries, and these we have welcomed. No single course will meet the needs of all countries with their varied educational systems and their different problems of finance and teacher supply.

We strongly recommend that in every country both educationalists and governments should be acquainted with the important work in this field currently being done in Europe, the USA and elsewhere, and should seek to use such of this work as may best be adapted to their own needs. We are not narrowly concerned with our own subject, which, in the context of general education, we recognize as but one facet of human culture and scholarship. Indeed, we have discussed the necessity to teach physics in such a way as to ensure an understanding of the many opportunities that it offers of links with other fields of learning. Since a very small proportion of the population of any country will be professional physicists, we have discussed how to teach science so as to make it a working tool in the life of the educated man. To do this, it is essential to make physics interesting so that children will want to learn. It is also vitally important to teach the conceptual framework of physics, which can be remembered throughout life, and not merely individual facts, which are easily forgotten.

We are unanimously agreed that physics must be introduced at an early age and must be taught throughout the education of the child. We have discussed for many hours how to accomplish these objectives in specific ways.

Finally, we discussed how to teach our teachers so that they themselves can understand the cultural nature of physics. Throughout there was unanimity that one must concentrate on a few subjects as illustrative of the scientific approach, and that it would be a grave error not to teach some branches of physics in depth. Physics must be taught as physics, even though one is teaching those who will not become professional physicists. It is impossible to learn physics without going deeply into the subject.

Various schemes were discussed whereby mere shallow surveys of physics could be avoided and selected branches taught in depth while presenting a good broad picture of the subject.

Specific schemes discussed in detail were the PSSC, the Nuffield Foundation Physics Project, which is in a way similar to PSSC but designed to cover several years rather than one or one and a half. We discussed the pilot project that Unesco is sponsoring with IBECC (the Brazilian Institute of Education, Science and Culture), and, under this heading, also the value of programmed instruction. We heard about many individual experiments, one of the most interesting being that of the Mobile Units in Sicily, which are applicable to countries which do not have an adequate supply of properly trained teachers or teaching apparatus,

We have had long discussions on the place of films. If it is not possible for students to have laboratory facilities or for an experiment to be done in the lecture, either because of lack of apparatus or for other reasons, films have great educational value, but a film should be made so well that it demonstrates the general philosophy in the film itself.

We also had an apparatus exhibit set up by various organizations to illustrate simple and available equipment for the teaching of physics.

Contents (extracts)

1. Physics Teaching in an Underdeveloped Country

Science Education in the Contemporary World, Jayme Tiomno (Brazil)
Summary of Resolutions Adopted by the First Inter-American Conference on Physics Education
Observations on the Teaching of Physics in Developing Countries, P.G.de Paula Leite (Brazil)

2. Science as a Part of Culture

Cultural Values in Science Teaching, Sanborn C.Brown (USA)
Science Education and the Humanities, F.X.Roser (Brazil)

3. The Contribution of Physics to Liberal Education

The Aims of Elementary - and Secondary - School Science, A.M.J.F. Michels (The Netherlands)
The Goals for Science Teaching, Gerald Holton (USA)

4. The Design of Physics Courses

Science in Elementary and Secondary Education, C.A. Michels-Veraart (The Netherlands)
Teaching Physics for Understanding in General Education, Eric M.Rogers (U.K.)

5. Experiments in Teaching Physics

The Brazilian Institute of Education, Science and Culture (IBECC), Isaias Raw (Brazil)
Some European Developments in Physics Teaching, D.Sette (Italy)
Curriculum Reform in the USA, Jerrold R.Zacharias (USA)
The Place of Atomic Physics in General Education, John Lewis (U.K.)

Unesco and Science Teaching, Albert Baez (Unesco)
Physics Teaching in Czechoslovakia, M. Valouch (Czechoslovakia)

6. Apparatus for Teaching Physics

Principles of Classroom Demonstrations and Laboratory Work, Eric Ingelstam and Karl Gustav Friskopp (Sweden)
The Exhibition of Apparatus

7. The Historical Approach in the Teaching of Physics

G.A. Boutry (France)

CATALOGUE DE FILMS POUR L'ENSEIGNEMENT UNIVERSITAIRE

Catalogue de films pour l'enseignement universitaire en physique, chimie, géologie, botanique, zoologie (1); Paris, Association internationale du cinéma scientifique (2), 1962-1963, 36 p.

Nous reproduisons ci-dessous la section "Physique" (pages 9 à 13 du Catalogue)

Lumière polarisée appliquée aux objets isotropes France, 1959
16mm. 165 m. 15 min., couleur, sonore

Producteur, Réalisateur : Pr. M.Françon, Institut d'Optique Théorique et Appliquée, Paris. Etude des objets isotropes transparents par la lumière polarisée. Présentation des méthodes et des appareils. Applications en macroscopie et en microscopie.
Appréciation : Recommandé pour la 1ère et la 2ème année d'enseignement de physique, en particulier pour les cours d'optique.
Distribution : Service du Film de Recherche Scientifique de l'Office National des Universités, 96, Boulevard Raspail, Paris VIème.

Ionisation des gaz France, 1961
16mm. 38 m. 4 min. couleur, sonore

Producteur, Réalisateur ; Pr. M.Françon, Institut d'Optique Théorique et Appliquée, Paris. Les courants de convection situés au-dessus d'une flamme et visibles par interférométrie contiennent des ions positifs et négatifs qui se sépareront en deux courants si la flamme est placée entre les deux plateaux d'un condensateur chargé.
Appréciation : Très court film qui démontre clairement un seul phénomène. Approprié pour illustrer une conférence sur ce sujet.
Distribution : Service du Film de Recherche Scientifique de l'Office National des Universités, 96, Boulevard Raspail, Paris VIème.

Die Bewegung der elektrische Geladener Teilchen
Allemagne, République Démocratique, 1956
(Le mouvement de particules chargées d'électricité)
16mm. 130 m. 12 min., N& b, sonore

Producteur : Veb Carl Zeiss, Iéna
Réalisateur : Gerhard Weidel
Conseiller Scientifique : Prof. Dr.Harald Straubel, Iéna
De grosses particules visibles sont utilisées à la place d'électrons agités par les champs électriques dans des tubes électroniques. Les particules sont chargées et déviées par des champs électriques de façon analogue. Leur comportement est illustré avec du courant continu et du courant alternatif.

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1. In English : A catalogue on films for use in university teaching on physics, chemistry, geology, botany, zoology.
2. 38, Avenue des Ternes, Paris XVIIème.

Appréciation : Le film a été estimé excellent et particulièrement approprié pour être montré à la fin d'un cours d'électrostatique au niveau "propédeutique". Il est d'une bonne longueur et certaines de ses parties sont d'une grande utilité pour démontrer en une minute ou une demi minute des phénomènes qui n'auraient pu être illustrés qu'avec beaucoup de difficultés.
Distribution : VEB DEFA Aussenhandel, Berlin N.58, Milastrasse 2
(Référence T-HF 178)
Prix : $ 50.

Ultraschallvorgange im Schlierenbild
Allemagne, République Démocratique, 1957.
(Utilisation de la technique Schlieren dans l'étude des phénomènes ultrasoniques)
16mm. 110 m. 10 min., N& b, sonore

Producteur : Veb Carl Zeiss, Iéna
Réalisateur : Gerhard Weidel
Conseiller Scientifique : Hans Vosahle
Explication de la technique Schlieren à l'aide de diagrammes. Le film étudie par cette technique la pression de l'absorption, la réflection, la réfraction et la radiation à des fréquences ultrasoniques.
Appréciation : Les images sont bonnes et certaines parties du film ont une grande valeur de démonstration. Dans son ensemble il traite de trop de sujets à la fois et peut être plus utilement employé en faisant des extraits des parties appropriées à l'enseignement de base. Il a été estimé que ce film pourrait être montré dans un cours d'acoustique ou d'optique, mais avec des explications préliminaires. Il pourrait servir utilement les spécialistes d'un niveau post-scolaire.
Distribution : VEB DEFA Aussenhandel, Berlin N.58, Milastrasse 2.
(Référence T-HF 210)
Prix : $ 42.
Note : Il existe également un film dans la même série : Stosswellen im Schlierenbild (Ondes de choc par la technique Schlieren). Prix : $ 70.

Forces Etats-Unis, 1960
16mm. 23 min., couleur, sonore

Réalisateur : Jerrold R. Zacharias, M.I.T.
Introduction à la mécanique. L'expérience montre la force de gravitation entre les petits objets. Cette même expérience sert aussi à comparer la force de gravitation à la force électrique.
Appréciation : Recommandé
Distribution : Modern Learning Aids, 3 East 54th Street, New York 22, N.Y.
Prix : $ 120.

Frames of reference Etats-Unis, 1960
(Systèmes de coordonnées)
16mm. 26 min. couleur, sonore

Réalisateurs et Conseillers Scientifiques : J.N.P. Hume et D.G. Ivey
Diverses expériences sur des plaques tournantes illustrent la différence qui existe entre un système de coordonnées avec ou sans force d'inertie et l'apparition de force fictive dans un système sans force d'inertie.
Appréciation : Recommandé.
Distribution : Modern Learning Aids, 3 East 54th Street, New York 22, N.Y.
Prix : $ 150.
Note : Il existe un extrait de ce film d'une durée de 5 minutes montrant que le mouvement d'un poids sans frottement sur une plaque tournante apparaît de façon tout à fait différente à un observateur situé à un point fixe au-dessus de la plaque et à un observateur assis devant la plaque et tournant avec elle. (Le prix de cet extrait peut être obtenu en s'adressant au Distributeur mentionné ci-dessus).

The size of atoms from an atomic beam experiment Etats-Unis, 1961
(Dimension des atomes d'après une expérience avec un faisceau atomique)
16mm. 27 min. N& b, sonore

Comment produire un faisceau atomique en partant d'un élément chauffé dans un tube à vide et d'une lame criblée. La force du faisceau est mesurée à certains points du tube à l'aide d'un détecteur. La mesure est prise à différentes pressions et des graphiques sont établis montrant l'intensité en fonction de la distance à des pressions différentes. Des calculs en série permettent de mesurer la dimension des atomes.
Appréciation : Le film se divise en deux parties : l'expérience et le calcul. La partie expérimentale est excellente et montre très clairement l'équipement utilisé. Elle justifie l'acquisition du film. La seconde partie serait mieux suivie si elle était accompagnée d'un texte.
Distribution : Educational Services Inc., 47 Galen Street, Watertown, Mass.
Prix : $ 125.

Electritcheskie svoistva polouprovodnikov U.R.S.S.
(Propriétés électriques des semi conducteurs)
16/35mm. 28 min. N& b, sonore

Producteur : Studio de Leningrad des films de vulgarisation scientifique
Réalisateur : G. Korotychev
Conseillers Scientifiques : Pr. B. Yavorski, L. Berman
Le film initie aux conceptions modernes des principes des propriétés physiques des semi conducteurs et de leur utilisation dans différentes branches de l'économie nationale (on y fait connaître l'essence physique et les moyens d'application des propriétés de la conductibilité des "trous")
Appréciation : Il a été généralement décidé que ce film était très bien fait et d'une grande valeur pédagogique. Il pourrait être inclus dans le Catalogue en tant que film profitable à l'enseignement technique supérieur (ingénieurs), mais pas pour les étudiants en physique car la partie théorique n'est pas considérée comme étant assez approfondie.
Distribution : Ministère de l'Instruction Supérieure et Secondaire Spéciale (Professionnelle) de la RSFSR.
Prix : Copie positive 35 mm. : $ 90,48
" " 16 mm. : $ 13,29
Version en langue étrangère par sonorisation : $ 450.

Kinokours avtomatika I telemekhanika magnitnye oussiliteli U.R.S.S.
(Cours cinématographique : Automation et télémécanique. Amplificateurs magnétiques).
16/35mm. 54 min. N& b, sonore

Producteur : Studio de Leningrad des films de vulgarisation scientifique
Réalisateur : P. Schmidt
Conseillers Scientifiques : Pr. B. Domanski et Pr. E. Yourevitch
Cette partie du cours initie aux domaines de l'utilisation de l'automation et de la télémécanique dans l'industrie. On fait connaissance avec les genres essentiels des amplificateurs, leur principe de fonctionnement, le fonctionnement des relais électromagnétiques, etc.
Appréciation : Le film a été estimé bon du point de vue technique et pédagogique. Cependant, c'est un cours hautement spécialisé qui convient mieux aux personnes qui utilisent les amplificateurs magnétiques, autrement dit les futurs ingénieurs.
Distribution : Ministère de l'Instruction Supérieure et Secondaire Spéciale (Professionnelle) de la RSFSR.
Prix : Copie positive 35 mm. : $177,36
" " 16 mm. : $26.
Version en langue étrangère par sonorisation : $ 750.

LE CINEMA AU SERVICE DE L'ENSEIGNEMENT DE LA PHYSIQUE

Le cinéma au service de l'enseignement de la physique(1), Paris, Unesco, 1965, 10 p.

Ce texte a été publié à la suite des travaux d'un groupe d'experts, réunis à Moscou du 29 septembre au 3 octobre 1964 en groupe de travail, sur les films d'enseignement pour la physique au niveau universitaire et pré-universitaire. Les participants à cette réunion étaient :

Professeur A.S.Ahmatov (Moscou), Professeur M.Y.Bernard (Paris), Dr.Thérèse Grivet (Unesco), Professeur J.Hurwic (Varsovie), Dr. N.Joel (Unesco), Professeur M.M.Koussakov (Moscou), Professeur D.M.Tolstoi (Moscou), Dr. E.J.Wenham (Worcester), M. L.Yust (Los Angeles).

Sujets traités :

De l'utilisation du cinéma dans l'enseignement de la physique

Avantages et inconvénients de la cinématographie
Application des techniques cinématographiques à l'enseignement de la physique
- films destinés à faire partie intégrante du cours
- films destinés à compléter les cours
- films remplaçant le cours
- films destinés aux enseignants

Production
Projection
Avantages du court métrage de 8mm. muet et sans fin
- les films éducatifs courts ont une plus grande souplesse d'utilisation
- les films éducatifs courts peuvent s'adresser à des élèves de différents niveaux
- les films sans fin sont d'un emploi facile

Quelques recommandations essentielles aux scientifiques désirant collaborer à la réalisation de films pédagogiques

Collaborez avec les producteurs
Préparez un scenario détaillé
Prévoyez des repères qui permettent aux spectateurs de s'orienter
Utilisez les gros plans
Choisissez le meilleur angle de vue pour le spectateur
Prouvez qu'il n'y a pas de truquage.
Vérifiez les réactions avant de sortir le film
Récapitulation

A SURVEY OF THE TEACHING OF PHYSICS AT UNIVERSITIES

A survey of the teaching of physics at universities, prepared under the auspices of IUPAP, Paris, Unesco, 1966, 396 p.

Introduction (reproduced from the Survey, pages 15-18)

The importance of the teaching of physics

The teaching of physics is of current concern to every nation. Aware of the fundamental role of physics in advancing the frontiers of scientific knowledge and in providing the groundwork for technological growth, both the scientifically proficient countries and the newly developing countries seek to provide greater opportunities for the study of physics by their citizens, and to make the teaching of physics more effective at every level of education.

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1. The title of the English version is Film and the teaching of physics.

Statements by national leaders in almost every country could be adduced as evidence. Three will suffice to indicate the emphasis being placed on science and science education :

"The physical sciences occupy chief place among the natural sciences and on their successful advance depends the progress of associated sciences and of the national economy. The future prospects for technical progress are today determined primarily by achievements in the main directions of physics". (1)

"My own belief is that science, and the scientific method, should be one of the pillars upon which education rests. It should be there from the first. It should never be disparaged. It should be an integral part of the whole". (2)

"Thoughtful men now see another role for science and technology - a new and creative role that is still only dimly grasped. Science is the one common language understood the world over. It is dedicated to the discovery of truth and to scrutinizing every new finding and hypothesis without fear or prejudice. In science, new beliefs and principles win out over earlier ones because they have behind them the irresistible force of logic and consistency. By exchanging scientific viewpoints and working on common scientific problems - as exemplified so admirably in the International Geophysical Year and the two International Conferences on the Peaceful Use of the Atom - men of all nations may be drawn closer together". (3)

The scope of the report

The present report contains the results of an international survey of the teaching of physics in universities. The report has two principal purposes : (a) to assist newly developing countries to launch programmes in university physics, and (b) to enable scientifically established countries to learn what other countries are doing and to compare educational practices in physics. Greater emphasis will be placed here upon the first of these purposes but it is hoped that both will be served. Although the teaching of physics will be discussed at each level at which physics is studied, the report will deal primarily with the teaching of physics at universities and other institutions of higher learning.

Contents of the report

Each of the following chapters is devoted to a particular aspect of the teaching of physics. The introduction to each chapter serves to define the problems to be discussed, and to orient the reader toward what follows. The main portion of the chapter is devoted to the various approaches to the teaching of physics in the countries participating in the survey, consisting in most instances of pertinent excerpts from the national reports. The reader will notice striking similarities and also striking differences among these approaches. Each chapter concludes with a summary stating the extent to which there seems to be agreement among the educational practices described.

Most of the detailed information in this report-syllabuses, lists of experiments, lists of books, and so on- appears in the appendixes. Since it was one of the chief objectives of this project to make available such detailed information, the national representatives offer the appended material without apology to the reader for its length. They believe that its availability may help to put discussion of the reform of physics teaching upon the firmer foundation of knowledge of specific national practices.

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1. "The Development of Science", The 1959-1964 Seven Year Plan of the USSR
2. "Scientific Education in a Scientific Age", Address delivered by the Rt. Hon. Viscount Hailsham, Q.C., United Kingdom Minister for Science, at OEEC Seminar, 7 May 1960.
3. Strengthening American Science. A report of the President's Science Advisory Committee, Washington, D.C., 1958.

This report deals primarily with physics and with those parts of mathematics that are a part of the education of the physicist. In these days of rapid growth of physics and its pervasion into many other fields of science, it is difficult indeed to decide where the boundaries of physics lie. The following chapters will attempt to make clear the prevailing opinions about these boundaries in the countries reporting. The reader's attention is also directed, however, to reports on the teaching of the other basic disciplines, including mathematics, now being prepared under the auspices of Unesco.

The requirement that the length of this report be kept within reasonable limits has resulted in the omission of much material that appears in the national reports and that would conceivably be of interest to those concerned with certain parts of physics education, for example, lists of experiments, examinations, post-graduate courses, and so on. It is hoped that this additional material will eventually be published elsewhere. Plans to accomplish this are being considered by Unesco and the IUPAP Commission on Physics Education.

The spirit of the report

It was the intent of the organizations sponsoring this project, and of the national representatives, that this report should help to improve the teaching of physics. Few countries, indeed, can say that their optimum standards of physics teaching prevail universally within their borders. Accordingly, a choice had to be made at an early stage of this project between a merely statistical description of education in physics - good and bad - within the countries reporting, and a presentation that would stress optimum standards toward which all educational institutions within these countries strive and which the leading institutions have achieved. The second of these approaches was selected as being more in keeping with the spirit of the project. Wherever possible, therefore, this report stresses strong programmes in physics - those existing at leading universities - in full realization that not all universities can quickly reach these standards, but in confidence that these are the standards at which all should aim. To compensate for this bias, the report contains a final chapter dealing with some very real problems of physics teaching in the countries reporting, and with efforts being made to solve these problems.

This report contains no universal solution to the problems of physics teaching. The hopes of those who have contributed to it will be fully realized if the information and suggestions contained here lead to thoughtful re-examination of physics programmes, and to the development of many individual solutions of how best to teach this basic and powerful science.

Contents (abstracts)

- Preparation for the study of physics in universities and related admission requirements of universities.
- The education of professional physicists in universities to the first degree.
- The role of physics in the education of school teachers, engineers and others.
- Advanced study in physics toward higher degrees
- Academic research in physics
- Special programmes in physics : continuing education, evening schools, extra-mural education
- Teachers of physics in universities
- Material
- The improvement of physics teaching

THE EDUCATION OF A PHYSICIST

The education of a physicist, an account of the IUPAP international conference on the education of professional physicists, London, 15th-21st July 1965, edited by S. C. Brown and N. Clarke. Edinburgh & London, Oliver & Boyd, 1966, x + 185 p.

Contents (abstracts)

- First-degree courses
  Preparation for graduate studies (S. C. Brown)
  First-degree courses in Britain (A. B. Pippard)
  The smaller centre (W. Schaefer)
  The role of the general physics course for training physicists in the Universities of the USSR (A. S. Akhmatov, V. I. Iveronova & M. M. Kussakov)
- Special problem areas
  Post-doctoral training (S. C. Brown)
  Active co-operation between University Departments and Government or industrial laboratories (P. R. Thornton)
  The training of physics teachers in Belgium (H. Sauvenier)
  Mathematics in the training of a physicist (B. Friedman)
  Teaching mathematics to physicists in France (M. Y. Bernard)
- Practical work, films and television
  The teaching of practical physics (R. G. Chambers)
  Techniques of teaching experimental physics to University students (E. Mendoza)
- Technical Universities
  The education of professional physicists at technical Universities in the Netherlands (R. Kronig)
- Relationships between Government, Industry and the University
  Essential features of the education of the physicist who will spend his career in Industry (G. S. Bosworth)
  The relations between Universities and Industries in the Netherlands (H. B. G. Casimir)
  Educational assistance provided by the United States Atomic Energy Commission (V. E. Parker)

INTERNATIONAL NEWS OF PHYSICS EDUCATION

International News of Physics Education (Bulletin international de l'enseignement de la Physique) published in collaboration with the International Commission on Physics Education by the American Institute of Physics, semi-annual, 335 East 45 Street, New York, N.Y. 10017 USA.

UNESCO'S ACTIVITIES

I. Unesco-sponsored international post-graduate training programme for research and education in science and technology

Unesco has launched an appeal to Member States with long-established scientific tradition, to collaborate in organizing a network of Unesco-sponsored international scientific and technological training programmes for the benefit of staff members of universities and scientific institutions primarily but not exclusively in developing countries. In order to help establish locally the necessary training facilities, this programme aims at upgrading the quality of science teaching and research staff by giving them the opportunity to strengthen their research competence and to introduce a strong laboratory orientation to their teaching.

The programme is a joint endeavour of Unesco and those of its Member States who agree to share their experience with other countries. Training programmes, including theoretical and practical teaching, as well as an initiation in individual research work, are offered in selected fields of the pure and applied sciences, particularly in new methods and techniques of scientific investigation, some of them of direct interest to economic development. These programmes are organized in the various participating Member States at universities and scientific institutions where higher education and research is of a recognized high level in the particular field considered. Courses may be organized both in developing and developed countries.

Two such programmes are devoted to physics (one in French and one in English) : Enseignement post-universitaire international à l'Institut national des sciences et techniques nucléaires, Saclay, France ; International Seminar for research and education in physics, Uppsala, Sweden.

II. Special Fund projects

Through the financial assistance of the Special Fund under the United Nations Development Programme, Unesco as executing agency is assisting Member States in maintaining teacher training establishments for secondary teachers and projects for the education of engineers or the training of technicians. Assistance is provided in the form of experts, fellowships and equipment. Experts teaching physics are present in the following projects :

Africa
- Cameroun, Ecole Normale supérieure, Yaoundé
- Congo, Ecole Normale supérieure, Brazzaville
- Congo (Kinshasa), Institut Pédagogique national, Léopoldville
- Congo, Institut du Bâtiment et des Travaux Publics, Léopoldville
- Congo, Institut des Mines, Léopoldville
- Côte d'Ivoire, Ecole Normale supérieure, Abidjan
- Ethiopia, Training of Secondary School Teachers, Haile Selassie I., Addis-Ababa
- Ghana, Secondary School Science Teacher Training, Cape Coast
- Madagascar, Institut supérieur de recherche et de formation pédagogique, Tananarive
- Mali, Ecole Normale supérieure, Bamako
- Nigeria, Federal Higher Teacher Training College, Lagos
- Nigeria, Secondary School Teacher Training College, Zariti
- Nigeria, Secondary School Teacher Training College, Owerri
- Nigeria, Secondary School Teacher Training College, Ondo
- Sénégal, Ecole Normale supérieure, Dakar
- Sierra Leone, Training of Secondary School Teachers at the Milton Margai College, Freetown
- Tanzania, Training of Secondary School Teachers at the Faculty of Science of the University Colleges, Dar-es-Salaam.
- Zambia, Secondary School Teacher Training, University College, Lusaka

Arab States
- Libya, Higher College for Teacher Training, Tripoli
- Maroc., Ecole Normale supérieure, Rabat
- Saudi Arabia, Secondary School Teacher Training College, Riyadh
- Sudan, Training Institute for Secondary School Teachers, Omdurman
- Syria, Technological Institute, Damascus
- Tunisie, Ecole Normale supérieure, Tunis

Asia
- Ceylon, College of Technology, Colombo
- India, Secondary Science Teaching, Delhi
- India, Centres of Advanced Study, Delhi, Madras
- Thailand, Technical Teacher Training, Thonburi

Latin America
- Brésil, Enseignement de la Technologie, Université de Brasilia
- Mexique, Ecole Normale d'enseignement technique, Mexico.

ACTIVITES REGIONALES / REGIONAL ACTIVITIES

Les publications et le matériel suivants résultent d'activités développées sur le plan régional entre des pays groupés par leurs affinités linguistiques ou des systèmes d'éducation voisins. / The publications and materials described in this chapter were produced on a regional basis by countries grouped by affinity of language or similarity of their educational systems.

PILOT PROJECT ON THE TEACHING OF PHYSICS

Pilot project on the teaching of physics, in Latin America, Unesco pilot project on new methods and techniques in physics teaching.

I. The objectives of the Pilot Project and its activities in São Paulo (1963-1964).(1)

The main objectives of the Project were to explore new methods and techniques for the teaching of physics and to train a group of Latin-American physics teachers in the development, production and subsequent utilization of an integrated set of learning materials based on new approaches and modern techniques.

Twenty-six teachers, from Argentina, Brazil, Chile, Cuba, Ecuador, Honduras, Peru, and Venezuela, most of them teaching at Universities and Teacher Training Colleges, were brought together by Unesco for one year (July 1963 to July 1964) in São Paulo, Brazil, to develop one part of a new course of physics at secondary school level. They worked under the guidance of a team of six specialists provided by Unesco, two of whom were physicists : Dr. P. Bergvall from the University of Uppsala, and Dr. N. Joel from the University of Chile. The other four were : two specialists on film and television, Mr. H. Engel and Mr. P. Robinson, and two specialists on learning theory and programmed instruction, Dr. F. Mechner and Mr. L. Xuan. The general supervision of the Project was the responsibility of Dr. A. V. Baez, Director of the Division of Science Teaching of Unesco, also a physicist, who conceived it and laid its foundations.

The host institution in São Paulo was the Instituto Brasileiro de Educacão, Ciencia e Cultura (IBECC) which is known for its several years of experience in improving science teaching in Brazil and which also has good workshop facilities for the production of simple inexpensive laboratory equipment. Other institutions have been associated with the Project, especially the Physics Department of the University of São Paulo, where laboratory, classroom and office space was made available to the Project ; the Centro Latino-Americano de Física (CLAF), Rio de Janeiro, which provided some of the fellowships ; and the Audio-Visual Center of the University of São Paulo, which participated in some of the film work.

The topic chosen for this Pilot Project was the "Physics of Light". This is one of the important topics of modern physics, and it is ideal as an introduction to an experimental physics course for it illustrates most of the important aspects of physics : the fundamental role of the experiment, the nature of physical laws, the use of theory for summarizing and predicting, that is, the interplay between experiment and theory, and the close connection between various branches of physics. The pioneering work of the Physical Science Study Committee (PSSC) was a great source of inspiration at various stages of the work of this Project.

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1. A detailed report in English (80 pages plus illustrations) on this phase of the Project can be obtained from the Division of Science Teaching, Department of Advancement of Science, Unesco, Place de Fontenoy, Paris 7e.

The most important component of any physics course are the laboratory experiments, which should be performed by the students themselves. For this, simple and inexpensive equipment is needed ; therefore, one of the main efforts of the Project participants has been the development of such equipment. Eight "kits" containing materials for a large number of experiments on the topic of the Physics of Light were developed by the group, and 200 sets of these kits had been produced by the end of the first one-year phase of the Project. Some of the experiments represent an adaptation or simplification of existing materials from other sources, some were developed from ideas in the literature, and some have sprung from original ideas of members of the group that participated in the work of the Project.

To get the students to do their own experiments in the oversized classes characteristic of regions with acute teacher shortage, poses severe problems. To make matters worse, the increasing number of students coming to school is not being compensated adequately by the increase in the number of new teachers. Clearly, the development of self-instructional materials has become an urgent necessity. Self-instructional texts, developed according to the technique of programmed instruction, ensure an active attitude of the student during his study, give him immediate confirmation of his comprehension of the subject and allow him to follow his own rate of study. These advantages, which have so far been demonstrated in other areas of training, must be explored also in science teaching at secondary school level. The text for the Physics of Light course was therefore developed by the Project participants according to the technique of programmed instruction. The preparation of the text included testing it on students, followed by revisions of the text. Two preliminary mimeographed versions, Spanish and Portuguese, were produced (1000 copies of each) for further testing under classroom conditions.

There are many important experiments, however, which are beyond the possibilities of simple inexpensive kits. They may require too expensive or elaborate equipment or may be otherwise too difficult or dangerous for the students to perform. Ideally such experiments should be performed as demonstrations by the teacher. But the teacher is often given too little time or no equipment to prepare such demonstrations. The Project, therefore, also dealt with the use of educational films in science teaching. A film of an experiment performed under ideal conditions, sometimes utilizing the possibilities of the medium to contract or expand space or time, has become a powerful aid to the classroom teacher ; especially the silent short (3 to 5 minutes) film which shows one experiment or a series of experiments illustrating a single concept. These short silent films are a more flexible and versatile tool : the absence of language makes them immediately applicable in all countries ; the teacher is left as the master of the class ; he chooses the context in which to show the film ; he may stop the film at any moment to ask questions or give explanations ; 8mm projectors and films are relatively inexpensive and handy to bring into the classroom, and there are projectors on the market which facilitate repeated projection of film loops as well as stopping the film at a critical moment. The Pilot Project produced 12 short silent films as well as a half-hour sound film, the latter in two versions : Portuguese and Spanish. Detailed Teacher's Guides were prepared for each of the short silent films, with suggestions for their use, subjects for discussion, etc. Copies of these films were given to the Project participants at the end of the year and to others (about 50 copies).

Television can reach a large audience ; but it is important also to note that the characteristics of this medium are such that a dynamic presentation of the subject can be made, and that the viewer can be guided to concentrate his attention on the points one wishes to stress. Television classes, showing a teacher on the screen, may also serve as models to other teachers on how to utilize simple experiments and short films in giving a physics class. With this in mind, the Project participants prepared 8 television programs to become an integrated part of the Physics of Light course. These programs showed live experiments and also utilised the films produced by the Project as well as films from other sources. The programs were broadcast in São Paulo in July 1964. The scripts of these programs have been mimeographed.

In experimenting with the above-mentioned teaching tools and techniques : laboratory experiments, programmed instruction texts, short silent films, long sound films and television programs, the Project participants have at all times attempted to pursue an integrated use of all, or at least some, of these techniques. It has been the basic philosophy of the Project that none of them is self-sufficient.

The resulting "Physics of Light" course was given to a pilot class of 30 students during July 1964, and simultaneously presented to physics professors, teachers and administrators from Latin America during a Regional Seminar of Physics Teaching. This Seminar also discussed the experiences of the Project on the development and production of new teaching materials, and the continuation of the Pilot Project activities in other countries.

II . Brief description of the course on the Physics of Light and of the materials for it developed by the Pilot Project.

The course is made up of four units, preceded by an introductory one.

"Experiments and graphs" is the introductory unit, designed to provide some prerequisites needed for the analysis of quantitative experiments to come in later units. The first chapter deals with how to read and obtain information from graphs on millimeter paper. The concept of proportionality and its graphical representation is then taught with many examples, including an experiment which the student does himself with weights and a spring, arriving at Hooke's law (kit number 1). The following chapter shows how experimental data are presented graphically resulting in various curves, how the curves can be rectified into straight lines by change of the variables, and how in this way the experimental data can be summarized in simple mathematical formulae or laws which represent the results of the experiments. The student performs an experiment measuring the time of oscillation of a pendulum as a function of its length and makes the graphical analysis, including the necessary change of variable, leading to the pendulum equation. An appendix teaches the use of tables. This unit can be used independently from the following units of the course.

Unit 1, "Some properties of light", starts with an experimental study (kit number 2) of rectilinear propagation in air, water and glass, regular reflection, diffuse reflection, refraction and diffuse transmission. The study of images includes many examples and leads to experiments relating to the position of the images formed by reflection and refraction, showing the need for a more quantitative study of these phenomena. This is carried out in the following chapters, where the law of reflection and the sine law of refraction are derived from experiments mainly with light beams. Reversibility of the light path and total reflection are included. A final chapter deals with colours. Spectral analysis of reflected and transmitted coloured light are made with the use of a prism, by direct vision or by means of a beam of white light. Absorption is also illustrated. What is meant by monochromatic light is shown with filters and with an experiment using a sodium flame.

In Unit 2, "A particle model for light" the behaviour of particles is studed quantitatively by means of marbles (kit number 3) and is found analogous to the behaviour of light, as far as regular and diffuse reflection, refraction, total reflection and reversibility of light path are concerned. The possibility of summarizing the behaviour of light by a particle model is then investigated. After treating the concept of generalization, the text shows how the model predicts new properties of light : the transport of energy and the inverse square law for the intensity of illumination as function of distance from a point source. The latter prediction is verified experimentally by a quantitative experiment using a paraffin photometer (kit number 4). However, it is found that the prediction of the model regarding the change of speed of light when refracted is not sustained, and that the model does not account for the phenomena which are observed when light passes through a narrow slit. As a conclusion, the particle model is abandoned.

Unit 3, "A wave model for light", begins with the study of wave phenomena, with the intent of finding a better model to account for the behaviour of light, in view of the difficulties encountered with the particle model. Experiments with strings and the ripple tank (kit number 6) illustrate the concepts of pulses and waves, what is a medium, velocity of propagation, wavelength and frequency of periodic waves, and the relation between wavelength, frequency and velocity. Quantitative analogies are established, regarding reflection and refraction, between the behaviour of waves in the ripple tank and the behaviour of light. Diffraction is then studied in experiments with light : as observed through a single slit, and the shadow of a needle (kit number 7). Other examples of light diffraction are shown. Diffraction of waves is then demonstrated by ripple tank experiments and the analogies between diffraction of waves and light are established. A wave model for light is developed and compared with the particle model. Interference of waves in the ripple tank and of light is then studied : the Young double slit and the Lloyd mirror experiments are performed. A quantitative measurement of the wavelength of red and blue light is made by the double slit experiments. Some limitations of the model are discussed.

Unit 4, "Electromagnetic waves . - Photons", is an attempt to broaden the electromagnetic spectrum and to introduce photons. Light propagates in vacuum. But if light is a wave, what is it that vibrates in empty space ? We know, however, that radio waves also propagate in vacuum. To illustrate the nature of radio waves, a few simple experiments with a compass needle, a magnet and a battery with a wire are made. Some properties of radio waves are discussed and their diffraction and interference are cited to prove their wave nature. The fact that both light and radio waves propagate in vacuum and with the same speed suggests a common electromagnetic nature. The photoelectric effect also indicates electric properties of light. Other types of radiation related to light and radio waves, but with different wavelengths, are presented : infrared radiation, ultraviolet light, X-rays, gamma rays. Experiments with suitable photographic emulsions (kit number 8) show that fairly intense red or orange light is incapable of producing photochemical reaction, whereas light from the blue or green parts of the spectrum even with lower intensity does carry the energy sufficient to initiate reaction. An argument relating to the photoelectric effect : expulsion of electrons from zinc by weak ultraviolet light but not by intense light from an ordinary bulb, similarly suggests that light behaves as if its energy were divided in packets which have higher energy the higher the frequency of the light. Photons are thus introduced.

The text for the course on the Physics of Light was written following the technique of programmed instruction. It takes a student about 50 to 60 hours of work to go through it. This seems a lot for only part of a physics course. But it should be remembered that this time includes the laboratory work, the home work and most of the class work. In fact most of the experiments of this course can be done at home as well as at school.

The laboratory kits(1) have been designed for the students to do the experiments themselves, at their own pace, as they go through the programmed text. In fact, the books and the kits are intimately interdependent, which means that lab-work and class-work are closely integrated. There are several reasons for experimenting with such an approach. It places the experiment (and observation) in its central position as the primary source of information and the means of testing theories and hypotheses. Furthermore, we can thus take better advantage of the experiment as a teaching aid for concept formation and make sure that the student understands the significance of each step as he is performing the experiment. It also becomes possible to introduce short, qualitative experiments in the middle of a longer theoretical argument. In addition, teaching by means of only the blackboard and the copy-book of the student, a type of class unfortunately still abundant, is thus made much less probable.

The experiments had to be designed so that they would not require spacious and elaborate laboratories. The student should be able to perform most of them in a conventional classroom or in his home. This requirement is a challenge to an optics course, where usually darkness is required. Several features of the kits of the Physics of Light course have been designed to

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1. Complete details of the content of each of these kits are given in the report mentioned earlier.

enable work in an ordinary classroom with normal desk space, and all the experiments can be carried out at home. Furthermore, the materials for these kits have been kept as simple as possible to enable teachers to produce them locally.

There is one kit in this series, "the pinhole camera", to which the text makes no specific reference as these experiments - being rather long - were considered optional. Therefore, a short film was also made on this subject and text material is at present in preparation. This kit contains a cardboard "tin", a series of six pinholes ranging from 2mm to 0.1mm (all except the 2mm one are photographic pinholes on high contrast film), a roll of standard 35mm film, two small lenses, a Fresnel zone plate, materials for developing and fixing, etc. Starting with the large pinhole, the student discovers that the resolution of the image improves at first as the pinhole diameter decreases, but then begins to deteriorate again. The kit is thus suitable for introducing the concept of diffraction. As additional experiments, photographs are then taken covering the 2mm hole with a lens, and then with the Fresnel zone plate.

The twelve short silent films produced by the Project included three for unit 1, three for unit 2, two for unit 3, and four for unit 4. The wave model for light received less attention in this series, for two reasons : first, there are quite a number of short silent films already available on wave experiments in a ripple tank ; and secondly, a half-hour film (with sound) on the single-slit diffraction of water-waves, of sound, of microwaves and of light was also produced by the Project.

The short silent films were shot on 16mm, and then reduced to 8mm. Consequently, it will be possible to make them available in three different forms : 16mm on standard reels, 8mm on standard reels, 8mm loops in automatic cartridges.

The half-hour sound film : "Light ... is it a wave ?", begins with a short motivational incident in which Silvia and Hector, the two students that appear in the film, approach a corner riding their bicycles along two intersecting streets. They do not see each other in time, and they collide. The scene is then repeated but this time Hector sounds the horn of his bicycle. Silvia hears this before seeing him, and avoids the collision. So, sound can bend round the corner, says the narrator. And how about light... does it ? In order to investigate this, they go to their physics teacher who takes them to the laboratory. Most of the film is then devoted to showing the teacher and these two students investigating together the diffraction of waves. They do single-slit diffraction experiments, first with waves on the surface of water (ripple-tank), then with sound waves and radio waves, and finally with light. They investigate the effect that the width of the slit and the wavelength have on the diffraction phenomena. The students discover in this way that light shows the same diffraction effect as the water waves, sound waves and radio waves. This is another step in the building up of the wave model for light.

The film attempts to contribute towards the formation of the concept of wave : a wave is neither wet, nor noisy, nor luminous, etc. It is something abstract ; it has several properties, diffraction being one of them. The film suggests that one can test if "something" is a wave by trying out diffraction experiments. This is a rather important point for the student to remember when he comes later to electron diffraction and neutron diffraction.

Another important objective of the film is to show how a teacher can lead his students to investigate a problem, and how he can answer some of their questions by suggesting experiments to be done by the students themselves. For instance, in the ripple-tank experiments, Hector investigates the effect of changing the width of the slit, after which Silvia investigates the effect of changing the wavelength ; the two variables are analysed separately. The film gives information, but it also tries to show how this information is acquired. It tries to build up an active teacher-student relationship in which the elements of scientific discussion and scientific inference have been introduced.

This film is in black and white, 16mm. Its original version is in Portuguese ; but a Spanish version was produced too.

Each of the four units of the course has two television programs, of 30 minutes each. The structure of these programs is intimately connected with the general plan of the course, as one of the fundamental objectives of the Project was to experiment with the integrated use of several media.

The teacher that appears on screen (one of the participants of the Project) performs some "live" experiments ; and shows other experiments by means of films, most of them produced by the Project. The teacher gives continuity to all this experimental and visual material, and provides the necessary explanations, questions and discussion.

The programs were broadcast in São Paulo in July 1964, during the Regional Latin-American Seminar on New Methods and Techniques in Physics Teaching. They were seen by the 60 physics teachers that took part in this Seminar and by a pilot group of 30 High School students who followed in July the Physics of Light course. Obviously, the programs were also seen by a good fraction of the general public, though no survey of this could be made. No videotapes were made, but the scripts have been mimeographed.

As a summary, the set of materials developed and produced by the Project includes :

(A) A programmed instruction text in five units (Portuguese and Spanish versions) :
  0. Experiments and graphs .
  1. Some fundamental properties of light.
  2. A particle model for light.
  3. A wave model for light.
  4. Electromagnetic waves - Photons.

(B) Eight kits of inexpensive laboratory equipment :
  1. Experiments and graphs.
  2. Some properties of light.
  3. Light and particles.
  4. Photometry
  5. Pinhole camera.
  6. Ripple tank
  7. Diffraction and interference.
  8. Photons.

(C) Twelve short silent films (average time, 4 minutes each) :
  0. Cock with mirror image.
  1. Two experiments with images.
  2. Reflected light : glass in liquids.
  3. Rectilinear propagation (of light, drops in air, atoms in vacuum and electrons in vacuum).
  4. Reflection of light and particles, I (flat and parabolic surfaces).
  5. Reflection of light and particles, II (elliptic surfaces).
  6. The pinhole camera.
  7. Pulses.
  8. Infra-red radiation.
  9. Light, X-rays, and gamma rays.
  10. The photo-electric effect.
  11. Light and electrons.

A booklet containing Teachers'Guides for these films has also been produced.

(D) A 16mm film with sound, 30 minutes duration, on the subject "Light... is it a wave ?", showing single slit diffraction experiments with waves on water, sound, radio waves and light. (Versions in Portuguese and Spanish have been produced).

(E) Scripts for eight television programs on which items (A) to (D) were used together with live experiments and some other materials :
  1. Images.
  2. Some properties of light.

3. Light and particles.
4. Photographing without a lens.
5. Waves.
6. Is light a wave ?
7. Beyond the visible.
8. Electromagnetic nature of light - Photons.

III. Follow-up activities.

The teachers who worked in São Paulo during this one year Pilot Project are carrying on with the work in their home countries. They took with them kits, texts and films in order to try out the Physics of Light course with groups of students, to show it to their colleagues and discuss it with them, and in general to promote innovation in the teaching of physics. Some of these teachers are improving the original text on the basis of their trials with students. Some are reproducing the kits. Some are organizing working groups, seminars or summer courses for other teachers. Some are developing materials (kits and text) for other sections of a physics course. Several are involved in national projects aimed at modernizing the teaching of physics in their countries.

Further production of the kits developed in São Paulo is taking place in Brazil and Argentina, and also in Spain. There are arrangements in progress for extending this work to other countries as well and for the adaptation of the text into French and English.

Regional (Latin-American) Seminars on New Approaches and New Methods in the Teaching of Physics are now being sponsored by Unesco. The first was held in São Paulo in July 1964 immediately after the end of the one-year collective activity of the group. The second was held in Caracas in September 1965 in cooperation with the Ministry of Education of Venezuela. A third took place in Montevideo in November 1965 in cooperation with the Department of Scientific Affairs of the Organization of American States, and there are plans for continuing the series.

These Regional Seminars are not limited to a mere presentation of the ideas and materials developed by the group that worked in São Paulo. Much more important is to present the pattern of the activity that took place in São Paulo, that is, the operational characteristics of the Pilot Project : a group of physics teachers actively engaged in curriculum reform through making a concerted attack on content, methods, techniques and materials. This pattern of curriculum reform is conveyed in an active way to the teachers who come to those Seminars by the utilization of the new materials (including participation of a pilot class of genuine pupils) and by discussion of the underlying ideas with some of the Pilot Project participants who are invited to the Seminar for this purpose.

An additional aim of those Seminars has been to acquaint teachers with some of the leading movements in physics teaching reform, e.g., PSSC and the Nuffield Physics Project. Participants in these Seminars should grasp the concept of curriculum reform and some operational tools for promoting it, as a result of witnessing these and other examples of innovation and reform in physics teaching. It can be estimated that probably between 700 and 800 teachers have, through these Regional Seminars, and through the subsequent work of the Pilot Project participants and Regional Seminar participants, been able to become acquainted with the work of the Pilot Project and in general with some of the new approaches to the teaching of physics.

The long-term aim of the Pilot Project has not been simply to produce some new course materials or to try out new techniques. It has done these things. But of greater significance has been the involvement in this curriculum reform activity of a group of Latin-American teachers, working in Latin-America. In planning this Project, Unesco has been guided by the conviction that improvement of science teaching can be most efficient if it is conceived as a continuous process with the active participation of science teachers ; and that important features within this process are a willingness to explore new techniques and other results of recent educational research, as well as a dialogue between science teachers and research scientists directed toward clarifying the main concepts in each field of science.

PHYSIKUNTERRICHT UND PHYSIKLEHRER

Physikunterricht und Physiklehrer (Enseignement de la physique et professeur de physique), rapport sur la session de travail régionale allemande de l'OCDE consacrée à la physique, Kiel, 13-18 mai 1963, Ministère fédéral des Affaires économiques (Bonn) et OCDE (Paris), 1965, 76 p.

Table des matières (extraits)

- L'inachèvement des tâches éducatives dans les établissements secondaires d'Allemagne par suite d'une déviation du concept d'enseignement.
  Prof. W. Kroebel (Allemagne)
- L'enseignement de la physique suivant le programme du PSSC.
  Recteur S. Stenshold (Norvège)
- Interaction entre l'aptitude, l'éducation et l'éducabilité.
  Prof. K. Mierke (Allemagne)
- Situation de l'enseignement de la physique dans quelques pays européens.
  Prof. M. Dreyfus (France)
  Inspecteur général J. Mielants (Belgique)
- Objectifs et problèmes de l'enseignement de la physique.
  Prof. A. Dworak (Autriche), Dr. G.K. Hansen (Danemark), Prof. J. Rekveld (Pays-Bas), Prof. H. Schilt (Suisse), Dr. H. Schoene (Allemagne), Rector S. Stensholt (Norvège)
- Normalisation des unités et des symboles.
  Dr. K. Hecht (Allemagne)
- Formation des professeurs.
  Prof. Franziska Seidl (Autriche), Prof. W. Kroebel (Allemagne)
- Formation des professeurs en fonction.
  Prof. Franziska Seidl (Autriche), Dr. K. Hecht (Allemagne)

SESSION REGIONALE DE SEVRES

Session régionale de Sèvres, du 28 septembre au 3 octobre 1964, session régionale de travail d'expression française consacrée à l'enseignement de la physique, rapport édité par l'OCDE, Paris, publication hors commerce de l'Institut pédagogique national (1), 1966, 142 p.

Table des matières (extraits)

- Incidences de l'introduction de la physique moderne sur l'enseignement de la physique classique
  M. E. Hoffmann (Luxembourg), Dr. G. Schuster (Allemagne)
- Limite des difficultés à ne pas franchir dans l'enseignement de la physique au niveau supérieur du secondaire.
  M. A. Faestraets (Belgique)
- Relations entre l'enseignement de la physique et de la chimie.
  Inspecteur général R. Dechène (France)
  Professeur R. Nasuhoglu (Turquie)
- Coordination des enseignements de la physique et de la mathématique.
  M. W. Knecht (Suisse)
- Rôle des travaux pratiques dans l'enseignement de la physique.
  Inspecteur général G. Lazergues (France)

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1. 22 rue d'Ulm, Paris

- Formation et information des professeurs de physique
  M. T.Tomaz (Portugal)
- Nature électromagnétique de la lumière
  Conférence donnée à l'Institut pédagogique national par M. le Professeur R.Mercier de l'Ecole polytechnique de l'Université de Lausanne
- Le problème du manuel de physique
  Inspecteur J.Lohisse (Belgique)
- Emploi du manuel PSSC
  MM. J.Barcelo et E.Nagore (Espagne)
- Création d'un manuel commun aux pays de structures scolaires comparables
  M. A.Mayor (Suisse)

En extrait de cette publication est reproduit, ci-après,le texte de la conférence de M. G.Lazerges :

Rôle des travaux pratiques dans l'enseignement de la physique

Monsieur le Directeur général Capelle, qui a ouvert ce colloque et qui a une vaste information sur l'enseignement de la physique, non seulement en France, mais aussi dans les autres pays du monde, M. le Directeur général Capelle faisait la description suivante en ouvrant notre congrès. Il y a en somme, disait-il, trois époques dans l'enseignement de la physique. Dans une première, les professeurs dessinaient des expériences au tableau, ou, en d'autres termes, les expériences n'avaient pas lieu. Ensuite les professeurs se sont mis à faire des expériences réelles. Enfin, les élèves eux-mêmes ont fait des travaux pratiques, en allant du qualitatif au quantitatif. En écoutant ces propos, je pensais aux historiens qui distinguent eux aussi des époques ou des âges dans la progression de l'humanité, l'âge de pierre, l'âge de bronze, l'âge de fer, ou, pour faire plus grand et remonter plus loin encore, l'ère primaire, l'ère secondaire, l'ère tertiaire, pour ne pas parler pour le moment de notre ère quaternaire ; et je me disais que, lorsqu'il s'agit de l'histoire de la physique, on peut donner des noms à ces ères successives. Il y a donc eu l'époque des expériences virtuelles, c'est-à-dire des expériences qui n'ont pas lieu. Puis nous avons connu l'ère des expériences magistrales, et je veux simplement dire par là : faites par le maître, sans prétendre que ces expériences soient nécessairement dignes de l'admiration des foules. Enfin est venue l'époque des expériences individuelles, faites par les élèves en travaux pratiques. Nous sommes en principe dans cette ère tertiaire et nous essayons ensemble de nous avancer vers une ère quaternaire, meilleure encore.

Ah! certes, il y a des survivances, de même qu'il y a dans l'âge de fer des survivances de l'âge de pierre. Il y a encore des expériences qui n'ont pas lieu ; il y a encore des élèves qui ne font pas de travaux pratiques ou qui se dispensent d'y prendre part. C'est que les mutations importantes sont difficiles. En France, par exemple, sous Napoléon III, l'administration a été épouvantée quand les professeurs se sont mis à faire des expériences et, en 1860, le Ministre de l'Instruction Publique envoya à tous les recteurs la circulaire suivante, pour les mettre en garde contre de pareils errements : "Les leçons (de sciences physiques), si le professeur n'était pas suffisamment secondé par un aide intelligent, pourraient donner lieu à des accidents...
"Vous aurez, en conséquence, à vous assurer que les précautions suivantes ont été prises... et qu'elles continuent à être observées...
"Pendant la durée des leçons, le professeur sera toujours assisté d'un préparateur en état de surveiller les appareils, de s'assurer que leur marche n'est point entravée et de prévenir toutes les difficultés auxquelles elle pourrait donner lieu."

Et ce ministre sage ajoutait des prescriptions sur la nécessité d'une hotte et d'un "fourneau d'appel" à mettre en activité avant la leçon... le tuyau de la cheminée devant être large et droit, avec une section égale au seizième ou au vingtième de la section de l'ouverture de la hotte...(1)

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1. Circulaire Rouland, Ministre de l'Instruction Publique et des Cultes du 25 mai 1860, reproduite par Journal de Physique Elémentaire XXIe année, 1905, pp. 115, 116.

La circulaire ne disait pas comment on recruterait ces aides ; ils devaient simplement remplir deux conditions : être intelligents, comme si le professeur ne l'était pas, et être sans cesse en état de surveiller les appareils, ce qui semblait exiger d'eux des habitudes de sobriété.

Nous avons fait des progrès depuis, et, en général, le professeur exécute lui-même les expériences magistrales, bien que disposant par ailleurs d'aides pleinement qualifiés. Les travaux pratiques d'élèves ont été institués plus tard, sans créer d'émotion. La partie expérimentale de notre enseignement comporte ainsi deux éléments; et il faut nous mettre d'accord sur le vocabulaire :

- il y a, d'une part, des expériences faites par le professeur, devant la classe assemblée, que j'appelle <u>expériences magistrales</u> ou <u>expériences de cours</u> ;
- il y a,d'autre part, des expériences faites par les élèves eux-mêmes, travaillant seuls ou par groupes de 2 ou 3 au maximum, sous la direction de leur professeur ; ce sont ces expériences que j'appelle <u>travaux pratiques</u> (ou séances de manipulation).

Dans ces conditions, il faut se demander :

1°) Pourquoi les expériences magistrales, ou expériences de cours, ne suffisent pas.

2°) Si les travaux pratiques d'élèves peuvent suppléer à ces insuffisances, pourquoi, et dans quelle mesure ; je souhaite pouvoir discuter ce dernier point : dans quelle mesure.

3°) Suivant quels principes il faut conduire les travaux pratiques pour atteindre cet objectif et, éventuellement, quels sont les détails d'exécution les plus indiqués.

I - <u>Insuffisance des expériences magistrales</u>

Je crois que les expériences magistrales ont deux sortes d'insuffisances, une évidente (A) et une autre (B) dont les causes sont cachées, sont cryptogéniques si l'on veut, et doivent être recherchées.

A. Une insuffisance évidente : les expériences magistrales sont en général impropres à la vérification quantitative d'une loi ou à la découverte d'une loi au moyen de mesures. C'est dû à ce que toute mesure doit être faite avec beaucoup de soin, en prenant tout le temps nécessaire, parfois même le temps de répéter une mesure ; et, puisque c'est le maître qui opère, l'exercice devient fastidieux ou décourageant pour l'ensemble de la classe. On n'améliore pas les choses en faisant effectuer les mesures une à une, par des élèves successivement appelés ; ce qui est d'ailleurs, au point de vue métrologique, une mauvaise méthode. De toute façon, les vérifications quantitatives faites devant la classe assemblée sont des plus aléatoires. J'ai vu plusieurs fois, par exemple, dans la vérification de la loi de Joule en électricité, la température s'abaisser à mesure que le courant passait ! (l'eau devenue trop chaude, parce qu'on ne prenait pas le temps de la renouveler, perdait plus de chaleur que le courant ne lui en apportait).

Ce premier défaut est évident, mais il doit exister des défauts plus graves et plus profonds, puisque, même quand il ne s'agit pas de découvrir une loi, les élèves sont pratiquement indifférents au résultat de l'expérience magistrale ou à la preuve qu'elle prétend apporter. Oh ! certes, les élèves aiment voir des expériences et ils sont terriblement déçus si le professeur n'en fait pas ; mais c'est en général pour des raisons étrangères à la physique.
Il faut avoir le courage de s'en apercevoir : nos expériences de cours mettent en jeu les intérêts ludiques beaucoup plus que les intérêts intellectuels ; bien souvent, les enfants ont plus de plaisir quand l'expérience ne réussit pas que lorsqu'elle est conforme aux prévisions du maître. En tout cas, il ne leur arrive presque jamais de discuter sa valeur en tant que preuve, et on peut leur passer à cet égard toute la fausse monnaie que l'on voudra sans soulever de protestations. Si le professeur, ayant rencontré un échec, dit qu'il recommencera la prochaine fois, puis "oublie" de le faire, personne ne le lui rappelle. Les élèves sont consentants devant les expériences de cours, alors qu'ils protestent devant la moindre faute de calcul.

Voilà le fait. Cherchons les causes.

B. Cette indifférence devant l'expérience et ces enfants consentants, que je viens de décrire, sont un des échecs de notre enseignement, puisque l'enseignement éducatif doit, au contraire, créer un esprit de rebellion, de rebellion intellectuelle j'entends ; et je crois pouvoir signaler au moins cinq causes de cet échec qui tiennent à la nature même des expériences magistrales ; la discussion qui suivra en fera peut-être apparaître d'autres :

1°) Les élèves assistent trop souvent à des expériences dites "manquées" ou "ratées" : une image, en optique, qui n'est pas au rendez-vous qu'on lui a fixé par raisons démonstratives, ou un 4 qui est égal à 7, quand on veut vérifier une loi quantitative...

Ces expériences, quand on les accepte sans autre forme de procès, déshonorent notre enseignement et suffiraient à expliquer l'indifférence des enfants vis-à-vis de toutes les expériences magistrales, même "réussies".

En réalité, je le sais, il n'y a pas d'expériences "manquées" : une expérience qui ne prouve pas ce qu'on attendait d'elle reste une expérience, qui prouve autre chose et voilà tout, mais il faut en débattre. C'est tout au plus une expérience qui n'atteint pas son but. Le chasseur maladroit, qui tue le garde-chasse au lieu de blesser le lièvre, pourrait dire qu'il a fait une expérience manquée ; mais la trajectoire de son projectile a été rigoureusement ce qu'elle devait être, en vertu des conditions initiales et des lois de la balistique ; c'est donc de ce point de vue une expérience parfaitement réussie ; mais, comme ce n'était pas le but qu'on se proposait, on en débat : des experts examinent le fusil du chasseur et le chasseur lui-même ; d'autres examinent le garde-chasse...; puis, rassemblant tous ces éléments, on fait une expérience témoin, qu'on appelle une reconstitution. De même, le résultat de nos expériences magistrales est toujours conforme, pour le moment, à certaines lois ; et s'il n'est pas conforme à ce qu'on aurait aimé, il faudrait pouvoir en débattre, et procéder aux reconstitutions, comme dans l'expérience dite "manquée" que je viens de décrire ; mais, devant une classe assemblée, en général, on n'a pas le temps ou l'on n'a pas le courage de le faire ; et les enfants s'en vont avec l'impression que, les expériences de cours étant pleines de fantaisie et d'aléa, ce n'est pas la peine de s'y intéresser.

2°) Il faut dire aussi - et c'est une seconde cause d'indifférence - que bien souvent ces expériences sont invisibles pour la plus grande partie des spectateurs ; seuls les deux élèves assis au premier rang et de face peuvent en suivre toutes les phases. Il est vrai que ce défaut n'est pas inhérent aux expériences magistrales et que, théoriquement, on peut y remédier. Il n'en est pas moins exact que, lorsque le maître annonce qu'il va se passer quelque chose de sensationnel, on voit les élèves se dresser, le premier banc mis à part ; ce qui prouve bien que, lorsqu'ils restent sagement assis, ils ne voient rien ; et ce qui confirme aussi qu'en général ils se désintéressent de l'expérience, puisque le plus souvent ils restent assis.

3°) Voici en tout cas un défaut qui tient à la nature même des expériences magistrales : ces expériences comportent toujours une part de dogmatisme et une part d'abstraction.

Elles sont dogmatiques parce qu'elles sont choisies à l'avance par le maître, presque jamais suggérées par les élèves, et il est difficile qu'il en soit autrement. Or un enseignement dogmatique, celui qui procède de l'adulte vers l'enfant, ne laisse pas de traces durables, quelles que soient les apparences du moment ; le seul enseignement solide est celui qui procède de l'enfant vers l'adulte, par redécouverte, en prenant comme point de départ les connaissances que l'enfant possède déjà.

Quand le professeur n'a pas ce souci, les élèves ont bien souvent l'impression que nos expériences prouvent l'évidence ou des faits bien connus et que, par conséquent, elles sont du temps perdu. Ecoutez, par exemple, le souvenir qu'a gardé de nos expériences, un romancier contemporain bien connu :
"Dès la rentrée", écrit-il à propos d'un de ses personnages, "le garçon s'était pris de passion pour le briquet à air, la machine pneumatique et tous ces instruments ténus et précieux, faits de bois verni, de verre et de cuivre et qui servaient, en classe de physique, à démontrer des évidences. Sa vocation fut foudroyante... Ah!... Prouver la pesanteur des objets, la chaleur de l'eau bouillante, la fraicheur de la glace... Poser, après mille préparatifs, un

objet sur un plan incliné et le voir rouler comme prévu... C'était dit : il serait professeur de sciences physiques !"[1]

4°) Les expériences magistrales risquent aussi de comporter une part d'abstraction, même si le maître les croit concrètes, parce que le concret de l'enfant est sans rapport avec le concret de l'adulte :
Un fait, un dispositif ne sont concrets pour un enfant que dans la mesure où il les connait par son expérience personnelle.

Laissez-moi évoquer un souvenir pour faire comprendre ce que je veux dire. J'ai vu toute une classe échouer sur un exercice, au cours duquel il s'agissait de porter à l'ébullition un mètre cube d'eau, puis la même classe traiter avec succès et dans l'enthousiasme le même exercice, en apparence, dans lequel on portait à l'ébullition un litre d'eau, et non plus un mètre cube : cette seule modification dans l'énoncé a rendu les élèves intelligentes ; c'était dans un établissement féminin. Pour un adulte, ces deux exercices sont identiques, "c'est le même", puisqu'on passe de l'un à l'autre par une opération mentale pratiquement instantanée, une division ou une multiplication par 1000. Pour des élèves jeunes, au contraire, ce sont deux exercices profondément différents, parce que différents par leur nature : l'un est concret, c'est celui dans lequel on fait bouillir un litre d'eau, puisque - vu la quantité d'eau mise en jeu - il évoque une opération que ces jeunes filles ont faite fréquemment ; l'autre est abstrait, parce qu'elles n'ont jamais eu l'occasion de chauffer sur un fourneau un mètre cube d'eau. Il ne s'agissait pas là d'une expérience ; mais il peut en être de même dans nos expériences magistrales si nous n'y prenons garde : un dispositif que les élèves n'ont pas manipulé eux-mêmes peut être une abstraction et il faut d'abord le leur rendre familier.

5°) Une cinquième justification de l'indifférence des élèves en face de l'expérience magistrale me paraît résider dans la possibilité qu'a le maître de débiter de la fausse monnaie expérimentale ou de la monnaie de singe.

La fausse monnaie, tout le monde sait ce qu'elle est. Quant à la monnaie de singe, c'est une absence de monnaie, une méthode pour ne rien payer ; les montreurs de singe, quand ils arrivaient dans une ville, avaient l'habitude, au lieu de payer le péage, de faire gambader leurs singes devant le péager pour détourner son attention. Reconnaissons que, bien souvent, nous faisons les montreurs de singe. Malheureusement, plus aigus que les péagers, ou moins occupés, nos élèves s'en aperçoivent.

Fausse monnaie, par exemple, une expérience que je vois faire pour vérifier la loi d'Ohm, $V = RI$, avec un voltmètre et un ampèremètre ; alors qu'on enseigne, aussitôt après, que ce voltmètre, et c'est le même que l'on montre, a été gradué en admettant la loi d'Ohm... On me dit en pareil cas : "Les élèves ne font pas le rapprochement". Peut-être, mais c'est bien ce qui m'ennuie, parce qu'ils montrent ainsi qu'ils ne s'intéressent nullement à nos expériences.

Fausse monnaie, plus scandaleuse encore, quand on fait l'électrolyse de l'eau pour montrer qu'elle contient oxygène et hydrogène. Quand cette expérience est faite sans aucun ménagement, on opère de la manière suivante. La cuve à électrolyse contenant de l'eau distillée, on constate qu'aucun gaz ne se dégage. On ajoute alors de la soude ; de l'oxygène et de l'hydrogène apparaissent ; et on conclut : donc l'eau contient de l'oxygène et de l'hydrogène. Or, un esprit ayant appris à bien conduire sa raison conclurait au contraire : l'eau ne contient ni hydrogène, ni oxygène ; mais la soude en contient. On pourrait d'ailleurs de cette façon prouver tout aussi bien, je veux dire tout aussi mal, que l'eau contient du chlore ou du cuivre... ; il suffirait d'employer comme ingrédient du chlorure de sodium ou du sulfate de cuivre... Nous pourrions prouver que l'eau distillée a une saveur sucrée. "Buvez cette eau. A-t-elle un goût ?" dirions-nous à l'élève, en lui offrant un verre d'eau distillée. "Non, elle est franchement insipide" répond l'élève. "Sans doute, mais attendez, j'ajoute un peu de saccharine et vous prie de boire à nouveau... Vous voyez bien que l'eau distillée a une saveur sucrée". Ce mode de preuve est exactement le même que précédemment. Pourtant, l'élève n'a pas le même

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1. Gilbert Cesbron, "Notre prison est un royaume" (pp. 100 et 101) ; La Jeune Parque, ed. 1948

comportement dans les deux cas. En classe, on lui dit : donc l'eau contient de l'oxygène et de l'hydrogène ; il l'inscrit, le souligne et l'encadre, en tirant la langue de plaisir. Essayez au contraire de lui faire l'expérience à la saccharine, il vous prendra pour un plaisantin...; ce qui montre que les enfants ont devant l'expérience magistrale une attitude pathologique.

Il est vrai que, le plus souvent, on ne se borne pas à l'expérience fausse monnaie pure que je viens de décrire, et on fait l'appoint avec de la monnaie de singe. On ajoute, par exemple, que les gaz ne proviennent pas de la soude, parce que, si on dosait la soude avant et après, on trouverait la même quantité...; mais cette expérience, on se garde bien de la tenter: ce n'est qu'une gambade de singe ; c'est une expérience virtuelle.

Voilà donc, au total, six défauts certains des expériences magistrales (A et B 1° à 5°), qui ne nous permettent pas d'atteindre les objectifs de l'enseignement expérimental au moyen de ces expériences seules ; ces principaux objectifs étant évidemment la découverte des lois et de leur complexité, des lois quantitatives en particulier, ainsi que la croyance à la preuve expérimentale, la croyance qu'il est possible d'atteindre la vérité, ou de s'en approcher, par la voie expérimentale.

II - Le rôle des travaux pratiques

Je voudrais montrer maintenant que les travaux pratiques, tels que nous les avons définis, n'ont aucun des inconvénients qui viennent d'être analysés. Ce sera vite fait, car c'est évident (A).

Je chercherai ensuite ce qu'ils apportent en plus (B).

Enfin nous verrons dans quelle mesure ils doivent être complétés par un enseignement magistral, en amphithéâtre, en vue de leur exploitation complète (C).

A. Avantages des expériences faites en travaux pratiques

Contrairement à ce qui a lieu pour les expériences de cours, les travaux pratiques permettent de faire des mesures sérieuses et, par conséquent, de découvrir ou de vérifier des lois quantitatives, sans qu'il y ait de temps morts.

De plus, en travaux pratiques, il ne peut pas exister d'expériences manquées. Si on dispose, dans une séance, de 10 groupes d'élèves, par exemple, on obtient à la fin de la manipulation, non pas une expérience ou une vérification, mais dix : si un groupe a échoué, d'autres auront réussi ; et, au cours de la confrontation des divers résultats obtenus, la loi ou la preuve cherchée ne peut pas nous échapper.

Il est évident aussi que les expériences sont vues de bout en bout par les élèves, puisqu'ils les font eux-mêmes.

Il est possible, en travaux pratiques, de réduire autant qu'on veut le dogmatisme ; on peut laisser beaucoup d'initiative aux élèves ; et toutes les expériences qu'ils font représentent pour eux du concret.

Enfin, il est impossible de passer aux enfants de la fausse monnaie ou de la monnaie de singe, puisqu'ils sont leurs propres monnayeurs.

B. La part des travaux pratiques dans l'enseignement

Les travaux pratiques ont d'autres justifications, à caractère intrinsèque :

1°) Une des règles de l'enseignement expérimental est qu'il faut aller du connu vers l'inconnu, c'est-à-dire de la connaissance confuse, que les enfants possèdent déjà, vers une connaissance scientifique. Cette connaissance confuse, les élèves l'ont avant d'entrer dans nos classes, soit parce qu'ils l'ont héritée, soit parce qu'ils l'ont acquise dans la vie de chaque jour, soit parce qu'un enseignement antérieur l'a créée en eux ; mais il ne faut pas se dissimuler que cette connaissance de base, d'où il nous faut nécessairement partir, est impure. D'origine empirique le plus souvent, faite d'observations plus que d'expérimentation, concrète ou imagée, pittoresque, elle peut être chargée d'idées fausses, au point de constituer un véritable obstacle, si l'on n'y porte remède, sur la route de la culture scientifique. Il faut donc, avant de construire sur elle, purifier cette connaissance empirique en obligeant les enfants à observer soigneusement, sans idée préconçue, un grand nombre de phénomènes. Il faut aussi, sur bien des sujets, enrichir la connaissance préalable. L'observation rigoureuse, contrôlée et discutée, qu'exigent cette épuration et cet enrichissement ne peut être réalisée qu'en travaux pratiques. Je prends acte au passage que les travaux pratiques correspondant à cette première justification doivent chronologiquement précéder les leçons du maître.

2°) Une autre règle de l'enseignement expérimental veut que l'on procède du concret à l'abstrait. J'ai dit combien le concret de l'enfant diffère de celui de l'adulte ; le concret d'un enfant est ce qu'il connaît par expérience personnelle. Les travaux pratiques sont donc le meilleur moyen que nous ayons pour assurer à notre enseignement, dans toutes ses zones et de façon permanente, une base concrète, pour l'imprégner de concret, et pour enrichir ou élargir la connaissance concrète dont les enfants disposent. Or cet enrichissement et cet élargissement sont une nécessité ; car, comme il a été fort bien dit ici même ces jours-ci, "plus on s'élève dans l'abstraction, plus il faut que le laboratoire apporte du concret", ou encore : "si on veut s'élever dans l'abstraction, il faut faire provision de concret". De toute façon, les élèves mettent plus de croyance dans les expériences qu'ils ont faites eux-mêmes que dans celles qu'ils ont vu faire.

3°) Enfin, par l'action individuelle qu'ils provoquent, les travaux pratiques sont susceptibles de donner à certains enfants le goût de la physique. Bien souvent, tel élève qui scolairement est réputé médiocre, se révèle tout autre en travaux pratiques et, par là, se valorise vis-à-vis de lui-même. De plus, comme il y a toujours dans les manipulations une part de travail manuel, bien que ce ne soit pas leur objet, les travaux pratiques peuvent développer l'habileté manuelle et, ce qui est plus important, ils peuvent créer le respect de cette habileté ; ils peuvent montrer combien le travail manuel de qualité est difficile, en inculquant ainsi aux enfants une grande estime pour ce genre de travail. Toutes ces préoccupations sont légitimes.

C. Les travaux pratiques ne sont pas cependant tout l'enseignement.

N'allons pas trop loin cependant. On ne peut pas tout faire en travaux pratiques. En France, quand nous sommes entrés dans l'ère tertiaire, dont M. le Directeur Général Capelle saluait l'avènement, certains de nos collègues ont cru que tout était accompli et qu'on pouvait supprimer les cours en amphithéâtre, ou tout au moins les traiter avec désinvolture. C'est ainsi que,dans la construction des nouveaux lycées, on a édifié des salles dites de "TP-Cours", qui devaient servir en principe à la fois pour les travaux pratiques et pour les cours, mais qui sont spécialement incommodes pour les élèves quand il s'agit de suivre un cours... L'idéal serait en réalité de pouvoir disposer simultanément d'un amphithéâtre pour les cours et d'une salle de manipulation pour les travaux pratiques ; car, quoi qu'on fasse, même dans une ère quaternaire et au delà, les leçons de physique, faites par le professeur, resteront indispensables. Après avoir conquis le terrain en travaux pratiques, il faut en effet l'organiser et l'occuper. Il faut entrainer les élèves à appliquer les résultats obtenus et les lois qui ont été découvertes ou vérifiées ; il faut faire des exercices ; il faut corriger les devoirs faits par écrit...; toutes choses qui ne peuvent être réalisées que dans une classe avec des élèves assis, pouvant écouter ou écrire confortablement. Certaines expériences d'ailleurs ne peuvent être effectuées que par le professeur.

C'est pourquoi, très sagement, les programmes prévoient en général une répartition de l'horaire entre les "cours" et les "travaux pratiques".

Il y aura certes interpénétration et nous y reviendrons ; mais il faut rendre à chacun ce qui est à chacun.

Prenons un exemple simple - l'étude de la loi de Mariotte ou loi de Boyle - pour illustrer cette proposition, pour montrer que les possibilités des travaux pratiques sont limitées, ainsi que pour analyser quelles peuvent être dans une pareille étude les parts respectives des travaux pratiques et de l'enseignement magistral en amphithéâtre.

L'étude peut débuter en travaux pratiques : les élèves mesurent les pressions et les volumes d'une masse de gaz ; c'est une opération concrète. On effectue ensuite les produits, chacun à chacun, des nombres obtenus. On débat des incertitudes en vue d'arriver à l'affirmation que ces produits sont égaux, soit qu'on fasse découvrir ce résultat par les élèves, soit que, plus honnêtement peut-être dans bien des cas, on le donne comme un résultat à vérifier... Toute cette progression me paraît saine ; et, comme elle ne comporte aucun élément abstrait, elle peut se dérouler entièrement dans une séance de manipulation ; mais les travaux pratiques ne peuvent pas davantage et il faut maintenant qu'ils passent la main à l'enseignement magistral en amphithéâtre. Il reste, en effet, bien des choses à faire :

a) Il faut énoncer la loi, ce qui ne va pas de soi, le passage de résultats numériques à un énoncé général, contenant tous les mots nécessaires et point de mots inutiles, est, en effet, le passage du concret à l'abstrait, passage auquel il faut entraîner les élèves avec beaucoup de soin ; c'est en même temps un exercice de langage, un exercice littéraire en somme, qui n'est pas à sa place dans une séance de manipulation.

b) Il faut aussi s'assurer que les élèves savent passer de la loi énoncée en langage ordinaire à son expression mathématique, $pv = K$, et inversement. C'est là un exercice de traduction, un exercice littéraire encore, un thème ou une version, qu'il faut pratiquer sans cesse dans l'enseignement de la physique : une loi étant énoncée en langage ordinaire, trouver son expression mathématique ; ou encore : quand on dispose d'une part de l'expression en langage ordinaire, d'autre part de l'expression mathématique, s'assurer que cette dernière contient tous les mots de l'expression en langage ordinaire.

Dans le cas présent, si un enfant a compris l'énoncé de la loi de Boyle ou Mariotte, il doit pouvoir indiquer exactement les facteurs dont dépend la constante K ; et, s'il n'est pas capable de le faire, ce qui est extrêmement fréquent, c'est qu'il n'a pas compris l'énoncé, même s'il le récite de façon sublime. Il est évident qu'un semblable débat ne peut pas être poursuivi utilement dans une salle de manipulation.

c) Il faut encore faire appliquer la loi sur des exemples numériques ; et, pour ce faire, en mettant les résultats au concours, il nous faut des élèves assis, en mesure d'écrire et de calculer, s'offrant tous simultanément à la vue du professeur. Une salle de manipulation ne convient pas.

d) Il faut enfin compléter la découverte faite en travaux pratiques en indiquant les conditions d'approximation de la loi ; le temps nécessaire pour cet exposé, qui peut être dogmatique, ne doit pas être pris sur l'horaire des travaux pratiques.

III - L'exécution des travaux pratiques - Principes et modalités

Le rôle des travaux pratiques et les objectifs qu'on peut leur proposer étant ainsi définis, leur organisation ne peut pas être quelconque : certains principes doivent être respectés.

Il ne s'agit pas, sous prétexte de faire des travaux pratiques, d'ajouter quelque chose à l'enseignement ; il ne s'agit pas non plus de substituer les travaux pratiques à autre chose ; il faut, tout au contraire, les intégrer dans l'enseignement :

Ni addition, ni substitution ; mais intégration.

A. Pour l'intégration des travaux pratiques

J'ai donné tout à l'heure, à propos de la loi de Boyle-Mariotte, un exemple d'intégration; mais l'intégration peut être réalisée de bien des façons, et de bien des façons simultanément, dans une même classe, à une même époque. Voici quelques possibilités.

1°) Beaucoup de sujets peuvent ou doivent être explorés en travaux pratiques avant d'être exposés par le professeur dans un cours magistral. Ce sont des "travaux pratiques préalables". La question dont il s'agit est défrichée en manipulation, les élèves bénéficiant d'une assez large initiative : puis, dans les cours qui suivent ces séances de manipulation intégrées, le maître, s'élevant du concret à l'abstrait, se borne à mettre en place, de façon nette et systématique, les résultats qui ont été obtenus par les élèves sous sa direction. Il reprend lui-même au besoin certaines des expériences exécutées - celles notamment qui ont échoué entre les mains des élèves - les complétant s'il y a lieu par celles qu'il est seul en mesure d'effectuer avec profit.

J'ai décrit tout à l'heure, à propos de la loi de Boyle-Mariotte, un exemple de travaux pratiques préalables, en montrant comment l'étude de cette loi, attaquée en manipulation, sera ensuite poursuivie dans le cours fait en amphithéâtre.

2°) Quelques sujets peuvent même être étudiés entièrement en travaux pratiques, la mise en place dont il vient d'être question étant alors effectuée au cours même de la séance. En France, nous considérons, par exemple, qu'il en est ainsi dans notre classe de Seconde, classe de débutants, pour des sujets tels que la mesure des longueurs ou les qualités de la balance...

3°) Il est possible aussi de traiter expérimentalement en travaux pratiques des compléments du cours, ou d'utiliser la séance pour faire résoudre expérimentalement la première question d'un problème qui sera achevé ensuite sous forme de devoir, ou de faire étudier une expérience qui fera ensuite l'objet d'un problème, ou inversement, une expérience qui a déjà fait l'objet d'un problème...

Il y a dans tous ces cas intégration et, en même temps, allègement du cours magistral. Avec les travaux pratiques préalables, en particulier, le maître n'a pas à refaire dans son cours les expériences que les élèves ont déjà exécutées avec entier profit en manipulation.

B. Conséquences pratiques

Ces principes étant dégagés, quelques conséquences pratiques en résultent.

1°) Un seul professeur

L'intégration exige que le même professeur soit chargé du cours et des travaux pratiques.

Dans l'Enseignement Supérieur, il y a des professeurs et des chefs de travaux, qui agissent en fait indépendamment les uns des autres, les uns dans les amphithéâtres, les autres avec leurs assistants dans les salles de travaux pratiques.

Il ne peut pas en être de même au niveau qui nous occupe.

2°) Un seul sujet

Pour que ce professeur unique puisse vraiment diriger et animer la séance de manipulation, pour qu'il puisse confronter les résultats et en tirer profit, pour qu'il puisse intégrer dans son enseignement les conclusions obtenues..., il faut que, au cours d'une même séance, tous les élèves ou groupes d'élèves traitent le même sujet.

Il faut donc que le matériel disponible soit en quantité suffisante pour permettre de réaliser autant d'exemplaires d'un montage donné qu'il y a de groupes travaillant simultanément.

Tout autre dispositif doit être considéré comme un pis aller ne se prêtant pas à une véritable intégration des travaux pratiques.

Si tous les élèves traitent le même sujet, il paraît inutile de leur remettre une feuille de manipulation comportant le programme de la séance et la description du matériel. Je crois que la parole du maître est beaucoup plus efficace pour donner verbalement, au début de la manipulation, puis à mesure qu'elles sont utiles, les explications nécessaires.

Mon expérience personnelle - mais d'autres ont peut-être fait des expériences contraires - est que, lorsqu'on remet une feuille à l'avance, les élèves ne la regardent pas ou ne la comprennent pas. C'est assez naturel ; car comment pourraient-ils bien comprendre la description schématique, donc abstraite, d'un matériel qu'ils n'ont pas encore vu de façon concrète ? Il est certain, en tout cas, qu'ils comprendront beaucoup plus rapidement quand ils auront le matériel en face d'eux, surtout si le maître commente cette feuille rapidement, de manière à la rendre vivante par sa parole.

La feuille de manipulation ne paraît utile que lorsque les élèves ne traitent pas tous le même sujet, le professeur ne pouvant pas en pareil cas donner toutes les explications utiles simultanément, dès le début de la séance ; mais, même dans ce cas, je pense qu'il ne faut pas demander aux élèves d'étudier cette feuille à l'avance, puisqu'ils ne peuvent alors rien y comprendre ; il suffit par conséquent de la remettre à chacun au début de la séance.

3°) Une conclusion

Les résultats obtenus devant être utilisés ensuite dans l'enseignement magistral, ou devant compléter cet enseignement, il importe que les résultats de la manipulation soient nettement arrêtés ; en d'autres termes, il faut que la séance ait une conclusion. Il faut de plus qu'elle soit prise au sérieux par tous, à l'égal d'une leçon magistrale. On y parvient en prévoyant dans le programme du jour au moins une opération contrôlable, constituant un critère de la qualité du travail effectué, permettant de reconnaître ce qui est bien ou ce qui est mal, et se prêtant à une discussion collective.

On peut, par exemple, proposer une même détermination à tous les groupes. En ce cas, il est facile de faire inscrire au tableau les résultats de chacun, à mesure qu'ils sont obtenus, puis de procéder sur place, en fin d'opérations, à une critique de ces résultats. Cette critique doit être immédiatement exploitée ; c'est-à-dire que les groupes qui ont échoué, ce que la critique a révélé, doivent être invités à recommencer de manière que tout le monde puisse découvrir la faute commise et s'instruire de cette faute.

Il n'y a guère de sujet où l'on ne puisse introduire ainsi un élément permettant un affichage, une critique et une exploitation collectives. Les exemples seraient faciles à donner. Il faut évidemment ménager le temps utile à cette discussion, qui comportera très souvent un débat sur les incertitudes.

4°) Un compte rendu

Il est généralement d'usage que les élèves établissent un compte rendu de la manipulation qu'ils ont effectuée. Dans la conception des travaux pratiques intégrés, ce compte rendu peut avoir diverses formes, et même figurer suivant les cas dans des documents différents. Il peut être un simple procès-verbal indiquant les résultats de quelques expériences, ou une fiche de laboratoire relatant les nombres obtenus dans quelques mesures, ou un bref exposé figurant en tête d'un devoir, ou un additif porté à la fin d'un devoir, etc... Il peut même ne pas exister si le sujet ne comporte pas de compte rendu...

Je pense que, de toute façon, le compte rendu doit être rédigé au cours de la séance, les élèves n'ayant que trop tendance à gaspiller un temps précieux, en dehors de la manipulation, à faire de beaux comptes rendus, sans aucun intérêt quant à la physique. C'est du moins mon expérience personnelle.

5°) Une durée suffisante

Une séance de manipulation conçue comme il vient d'être dit doit avoir une durée minimale qu'on peut évaluer à une heure et demie ou deux heures ; il faut, en effet, qu'elle puisse contenir, outre l'exécution des expériences à proprement parler, les explications préalables du professeur, la discussion des résultats et s'il y a lieu la reconsidération de telle ou telle expérience, la rédaction du compte rendu.

Si la séance dure moins d'une heure et demie, le compte rendu ne peut pas être établi séance tenante et la discussion est toujours trop précipitée.

A l'opposé, je ne crois pas qu'à ce niveau de l'enseignement, il soit utile de prévoir des séances durant plus de deux heures : il faut, en effet, que les élèves n'aient jamais la sensation de perdre leur temps ou de l'occuper à de vains travaux ; il faut aussi éviter de donner l'impression qu'on fait du remplissage pour occuper le temps, ce remplissage qui consiste par exemple à faire mesurer les masses volumiques de 3 substances sans rapport entre elles, au lieu d'en faire déterminer une sérieusement avec une discussion complète.

IV - Notre conclusion

Il est clair que tout ce qui précède exige un horaire suffisant pour l'enseignement des Sciences Physiques, mais aussi des locaux appropriés et un matériel abondant ; en somme, pour dire les choses grossièrement, tout cela exige du temps et de l'argent ; car, en ce qui nous concerne, le temps n'est pas de l'argent, quoi qu'en dise le proverbe. Il nous faut l'un et l'autre. Des horaires, aussi importants soient-ils, ne nous serviront guère si nous n'avons pas d'installations scientifiques ; et, inversement, de ces installations nous ne ferons à peu près rien si le temps consacré aux sciences physiques ne nous permet pas de donner aux travaux pratiques l'importance qu'ils méritent.

TEACHING PHYSICS TODAY

Teaching physics today(1), some important topics. Paris, OECD publication(2), 1965, 269 p. (New thinking in school science X).

This book contains papers prepared for the international working sessions held in Milan (1963) and Uppsala (1964). The papers were discussed at the conferences and revised by working groups from the conferences.

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The book is not a textbook in physics but rather one designed to give the teacher a general perspective of the teaching of physics in present-day school and also some aid on special subject matter topics. The last five chapters are on advanced topics that may be included in some physics classes for students 16-18 years of age. Many schools have not in the past included these topics at the level proposed in the papers written for this book.

The paper by Dr. J. Lewis is reproduced below.

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1. La version française est intitulée Enseignement actuel de la physique
2. 2 rue André Pascal, Paris 16ème

AN APPROACH TO ATOMIC STRUCTURE

by

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INTRODUCTION

It is widely accepted that a school physics course in the second half of the Twentieth Century must necessarily include some knowledge of the atom and atomic structure. The days when this work was left to the Universities, while schools concentrated on the basic principles of classical physics, have passed, as agreed in earlier O.E.C.D. papers on physics education. A high proportion of those studying physics at school will not, in fact, be reading physics at the University and some knowledge of the atom should be a part of the general education of boys and girls of the future, whether they are to be scientists, engineers, bank managers or nurses. Atomic energy is now part of our lives and some knowledge of it should be imparted as a part of everyone's education.

The introduction of atomic structure into school courses presents considerable difficulties for teaching. Nothing is easier than the dogmatic assertion of facts, formal information which the pupil learns by heart for reiteration in examinations. This, however, gives no understanding of what science is about and it is certainly dissatisfying for the pupil.

There is little value in a course which begins by stating dogmatically that the atom consists of a central nucleus made up of protons and neutrons with planetary electrons equal in number to the number of protons rotating around it: a series of dogmatic statements is seldom satisfying and is of little educational value—it is as close to science as a series of dates is to history.

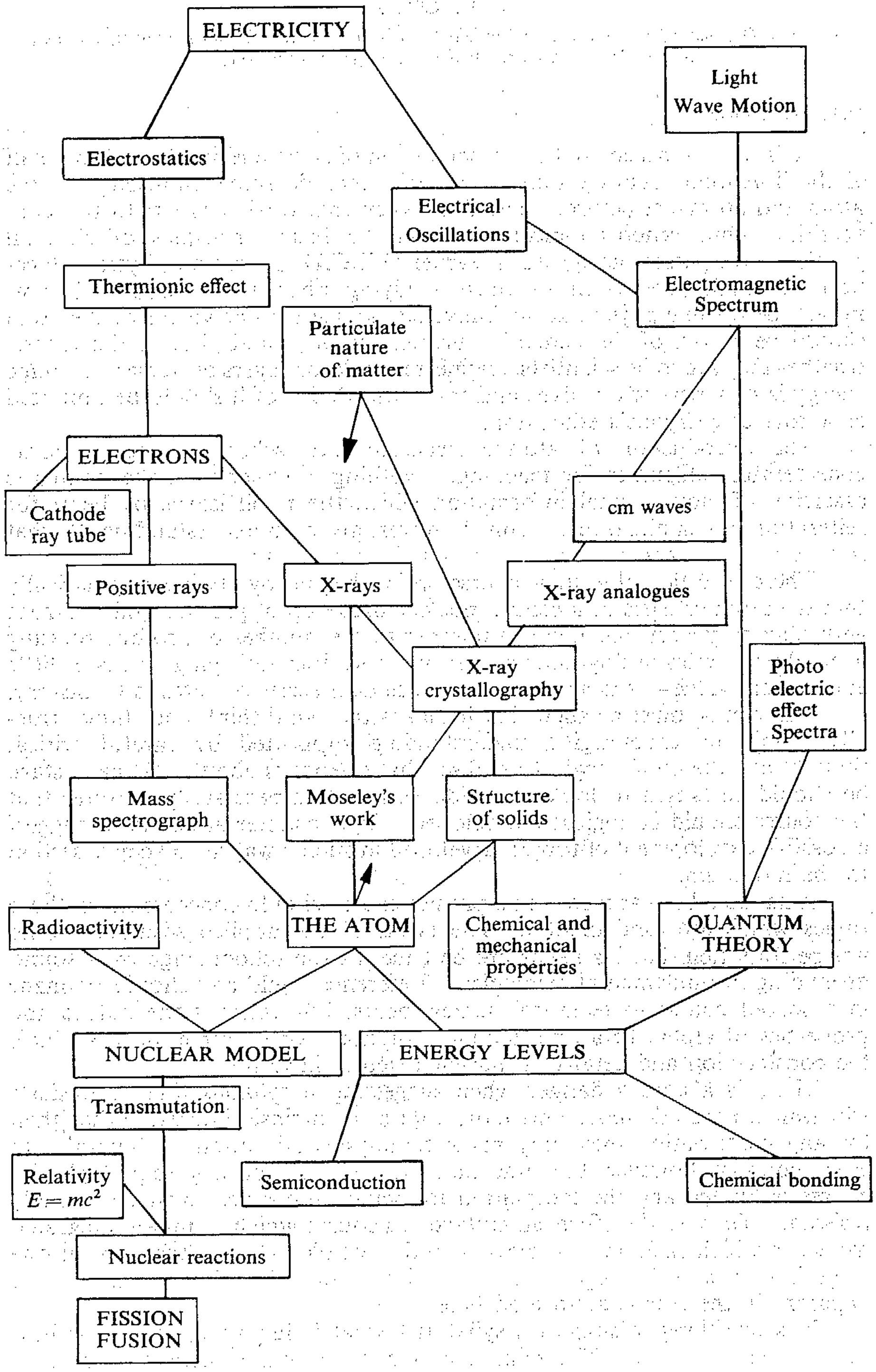
The course must be such that it makes the pupil think and think critically. Only by encouraging understanding supported by careful critical thought can the pupils begin to realise what science is about. At each stage he should be taught to look for evidence and this necessarily requires that the course should be logically developed. This chapter attempts to suggest a possible development of topics, developed in such a way as to keep assertion to the minimum.

It has also been argued that a physics course should concentrate on those topics which are fundamental. The needs of the applied scientist should not be forgotten, but his needs are best met at the school stage by a sound grounding in fundamental principles. Reference could and should be made in a school course to technical achievements, but whereas the nature and properties of alpha, beta and gamma radiation, for example, have a place, the construction and details of nuclear reactors have not.

There is always a danger when suggesting a syllabus that enthusiasts will want to include more and more topics of intrinsic interest rather than for any contribution they may make to physics education in general. In every country, however, the time that can be spent on any school physics course is limited and the temptation to include too much must be strongly resisted. There is, therefore, advantage in a course which forms an integrated whole, in which each item is relevant to that whole, where work done at one stage is used and developed again at a later one. It is hoped this will be apparent in the course advocated here.

It is one thing to suggest a syllabus—what is far more relevant is how the subject is taught. The climax of the programme advocated is some understanding of atomic structure, but such is the importance of the presentation that considerable attention has been given in this chapter to the necessary

Table 1


ELECTRICITY
Light Wave Motion
Electrostatics
Electrical Oscillations
Thermionic effect
Electromagnetic Spectrum
Particulate nature of matter
ELECTRONS
Cathode ray tube
cm waves
Positive rays
X-rays
X-ray analogues
X-ray crystallography
Photo electric effect Spectra
Mass spectrograph
Moseley's work
Structure of solids
Radioactivity
THE ATOM
Chemical and mechanical properties
QUANTUM THEORY
NUCLEAR MODEL
ENERGY LEVELS
Transmutation
Relativity $E = mc^2$
Semiconduction
Chemical bonding
Nuclear reactions
FISSION FUSION

introductory work. It is deliberately called "an approach" to Atomic Structure and reference will be made as to how work considered in other chapters fits in to the general pattern.

Some consideration is given at the end of the paper to the links with chemistry that the proposed work on atomic structure could imply.

DETAILS OF THE PROPOSED COURSE

The general outline of the course is shown in Diagram I, the central position being occupied by Atomic Structure. The pattern inherent in the scheme does show the pupil the relevance of each part to the whole, an aspect of a teaching programme which has perhaps been too often ignored in the past.

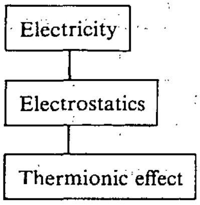
It is assumed that the pupil will already have had a good training in the topics of *electricity*, as he will also have had in the phenomena of *light* and *wave motion*. It is also necessary that he should have studied *mechanics* including collision processes and have some knowledge of kinetic theory. Associated with *electricity* will have been work on *electrostatics*. Some prefer to develop current electricity first and lead to electrostatics, others prefer to start with electrostatics and lead to current electricity. Both approaches are quite feasible, but at the end of the work it can be expected that the pupil has some idea of the concept of electric charge and that movement of charge is associated with electric current. The traditional experiments on electrostatics will have established charge as being of two kinds, conveniently called positive and negative, though the experiments provide no evidence as to the nature of the charge, whether it is particulate or fluid.

An essential experiment is one showing that the flow of charge from one body to another through a conducting link between the two is accompanied by a current in that conductor.

It is then logical to enquire whether this charge can be got out of the conducting wire. The example of the boiling of water may suggest that it is worth trying to heat the wire to see if the charge can be "boiled out" and so we are lead to the *thermionic effect*.

A hot filament diode tube is essential for the demonstration of the thermionic effect and a series of demonstrations is necessary to show the properties of the radiation given off by the hot filament: a Maltese cross tube to show the radiation travels in straight lines, a deflection tube to show the influence of electric and magnetic fields, a Perrin tube experiment to show it carries a negative charge.

Table 2



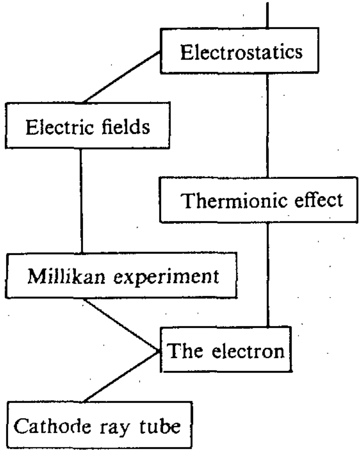
Traditional tubes for these experiments were usually discharge tubes, but the discharge tube presents considerable difficulties for the pupil in these early stages and the use of hot-filament tubes is desirable in their place.

Class experiments in which the pupils themselves investigate the properties of a diode can be conveniently done at this stage and such applications as rectification can be studied. Work however on the triode is irrelevant to the main stream advocated here.

The work on the *thermionic effect* combined with the *Millikan experiment* leads to a knowledge of *electrons*. The Millikan experiment is fundamental to the course for it is only that experiment which shows that charge is in fact particulate.

Ideally every pupil should do the Millikan experiment himself as it is of such a fundamental nature. Apparatus for this is available commercially in several European countries—see *Appendix* at the end. Others may have to rely on film.

Table 3



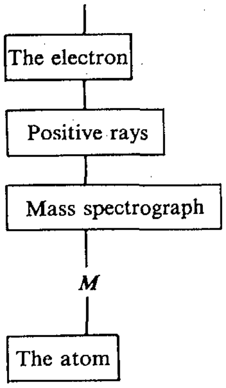
The measurement of e/m for thermionic electrons is another essential experiment. A variety of methods are possible and are commercially available—see *Appendix*. This experiment combined with the Millikan experiment enables a value to be obtained for both the charge e and the mass m of the electron.

Such is the importance of the Cathode Ray Oscilloscope in any physics laboratory today, that this work on thermionic electrons should necessarily lead on to a discussion of the cathode ray tube as an important application.

In order to lead from the study of the electron to *positive rays*, it will be necessary to introduce the discharge tube. A measurement of e/m should logically be performed in order to identify the electrons in the discharge tube with the thermionic electrons already studied, though time will probably here require an appeal to the work of others.

If the discharge tube contains a perforated anode and cathode, it can be shown that not only are there easily deflected electrons beyond the anode, but also that positively charged particles are penetrating the cathode, though they are much more difficult to deflect than the electrons.

Table 4



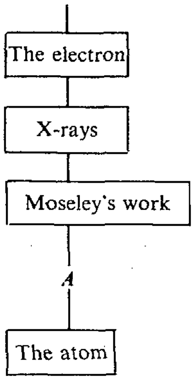
An account of the historical work of Thomson on positive rays, perhaps illustrated by means of a film (see appendix), provides evidence for the relatively heavy nature of the positive particle as well as for the existence of isotopes.

The work on *positive rays* in turn leads to the *mass spectrograph.* At present no suitable mass spectrograph is available for school purposes, though it is hoped that some day there will be. (It is not necessary to have a precision instrument, it will not be needed for analysis purposes: it would be sufficient if it just showed the existence of more than one isotope of a particular substance.) For the present there will have to be a dependence on film—see *Appendix.*

The mass spectrograph not only confirms the existence of isotopes, but enables a value of M, the mass of the atom, to be determined. This therefore is the first important approach to our knowledge of *the atom:* the development has lead to one of its important properties.

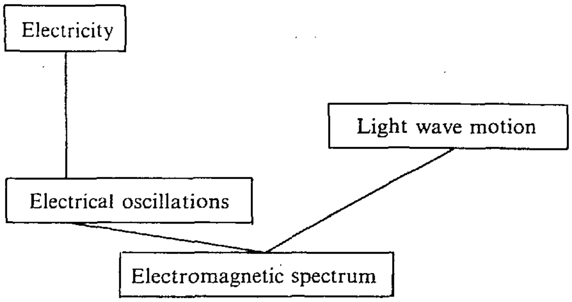
The second important approach to our knowledge of the atom also leads out of the work on *the electron.* An historical account of the discovery consequent upon the collision of electrons on an anticathode leads to the properties of *X-rays* which in turn contribute through the work of *Moseley* to a knowledge of the atom, by ascribing a second property to it, the atomic number A.

Table 5



Further essential work which must have been studied in order to make a study of atomic structure comprehensible is the unity of the *electromagnetic spectrum.* Traditional school courses spent much time considering all the properties of light—and gave pupils great skill at deriving formulae and substituting in them—they failed far too often to bring out an awareness of the electromagnetic spectrum as a whole.

Table 6



Chapter 6 by D. C. F. Chaundy has suggested how an approach can be made to the *electromagnetic spectrum* by developing a study of *electrical oscillations* out of the basic study of *electricity*.

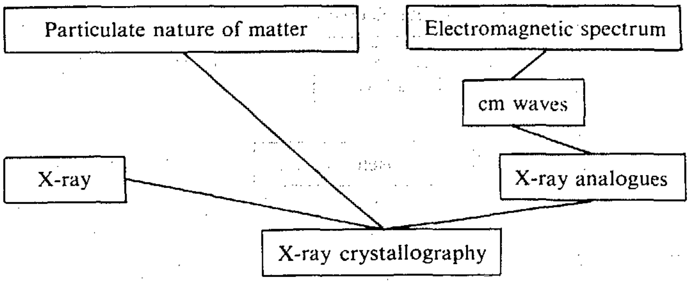
This important work enables the earlier work on *light* and *wave motion* to be seen in its broader context.

Earlier work on the structure, growth, cleavage and general properties of crystals, combined with such experiments as the spreading of an oil film on a water surface, have provided evidence, if not for atoms, at least for a *particulate nature of matter*. (It is incidentally a useful educational exercise to see how much evidence there is for a continuous nature of matter). The study of crystals can lead to a useful model of crystal structure using foamed polystyrene spheres.

The study of the complete *electromagnetic spectrum* will doubtless have included *centimetre waves* and commercially available apparatus in several European countries now makes these waves a useful aid in teaching—see *Appendix*—as a wavelength of 3 cm is much more convenient for demonstration purposes than the visible wavelengths.

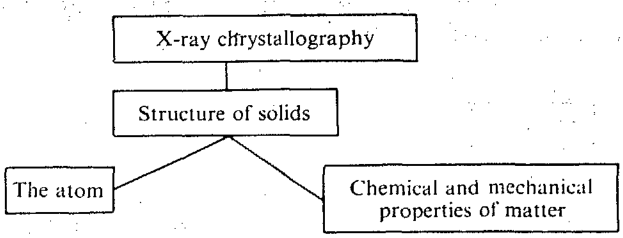
The combination of the centimetre waves with the "crystals" of polystyrene spheres enable quantitative X-ray diffraction analogue experiments to be done. The important *Chapter 9* by Dr. K. Hecht deals with *X-ray crystallograph* and further X-ray diffraction analogues, such as Bragg diffraction using water waves, are discussed in that chapter.

Table 7



Actual X-ray diffraction experiments using a fine beam of X-rays with a Geiger-Muller tube connected to a scaler as a detector are now possible as demonstration experiments in schools. This leads—as explained in detail in Dr. Hecht's chapter—to the *structure of solids*, information about arrangements of *atoms*, and is the basis for work explaining *chemical and mechanical properties of matter*.

Table 8



Having established the existence and significance of atomic mass M, atomic number A and something of the arrangements of atoms in solids, it is necessary to consider two aspects of atomic structure: the nuclear model of the atom and also the existence of energy levels. These will be considered separately here.

A study of *radioactivity*, already an accepted part of school physics courses, will have established the existence of three kinds of radiation, alpha, beta and gamma. Absorption experiments will have shown the different penetrative powers of the radiation. The alpha radiation will have been shown to produce considerable ionisation. Various ionisation experiments, together with cloud chamber photographs, will have illustrated the discrete range of the alpha particles, thus showing that they are emitted with discrete amounts of energy. The difficulty with which alpha radiation is deflected in a magnetic field will have been contrasted with the ease of deflection of the beta radiation, together with the impossibility of deflecting gamma radiation. The inverse square law will have been shown for a point gamma source, the failure of the inverse square law for a beta source will be evidence for the continuous range of energy of the beta radiation emitted.

This work must necessarily culminate in the identification of gamma radiation with electromagnetic radiation, of beta radiation with electrons, and of alpha particles with helium nuclei.

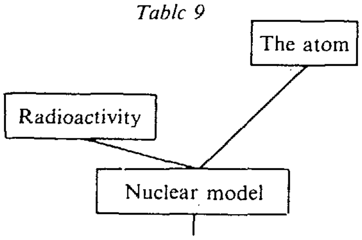
It would be helpful to be able to measure *e/m* for beta particles in the school laboratory so that they can be identified with thermionic electrons and cathode rays, already discussed, as well as with photoelectrons when the photoelectric effect is considered. But the continuous range of beta particle energies makes this important experiment difficult and in any case time will probably require an appeal to film and the work of others.

The Rutherford-Royds experiment which identified alpha particles with helium is another essential experiment in the logical development. Again it is an experiment unlikely to be realised in schools and once again there must be a dependence on film—see *Appendix I.*

Finally it is important that some experiment shows that, when a substance decays by the emission of an alpha or beta particle, there has been a change in the parent substance and that a new element has been produced. One such experiment is to show the production of $^{234}_{92}$ Pa on the decay of $^{234}_{90}$Th from a Uranyl nitrate solution:

$$^{238}_{90}\mathrm{U} \underset{\searrow\alpha}{\rightarrow} {}^{234}_{91}\mathrm{Th} \underset{\searrow\beta}{\rightarrow} {}^{234}_{92}\mathrm{Pa}$$

Tablc 9



The work on *radioactivity* combined with the knowledge of the *atom* already acquired leads first to the remarkable amount of "empty space" necessary in an atom to allow alpha particles to penetrate through thin foils of gold. Secondly the quantitative investigation of the scattering of alpha particles through the gold foil leads to the *nuclei model* of the atom.

The present developments of solid state detectors for use in schools for the detection of alpha particles suggests that the Rutherford, Geiger and Marsden experiment on alpha particle scattering may soon be feasible in school teaching. In any case evidence can be obtained through the use of film—see *Appendix I.*

Once the *nuclear model* of the atom is established, this leads to *transmutation* and with the aid of solid state detectors it is hoped that it will soon be possible to realise Rutherford's original transmutation experiment in which alpha particles were used to bombard nitrogen, thereby producing oxygen and protons, in the reaction:

$$^{4}_{2}\mathrm{He}+{}^{14}_{7}\mathrm{N}\rightarrow{}^{17}_{8}\mathrm{O}+{}^{1}_{1}\mathrm{H}$$

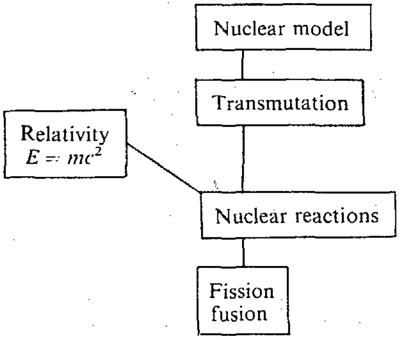
The protons are detected by the solid state detector positioned outside the range of the alpha particles.

As always in school work, there is no need to perform a whole series of such experiments: one instance clearly demonstrated is sufficient.

The work on *relativity*, discussed elsewhere in Dr. J. Rekveld's chapter *(Chapter 10)*, now becomes significant and the energy relation $E=mc^2$ becomes significant in considering *nuclear reactions* in general.

Work with neutrons is likely to be difficult in schools in most countries. It is hoped that perhaps it may be possible to produce them by bombardment of beryllium by alpha particles and then to detect them by producing protons in paraffin wax, which in turn are detected using the solid state detectors. Development work on this still needs to be done.

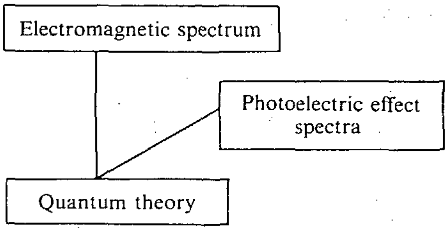
Table 10



This part of the course cannot end without reference to *fission* and *fusion*, though these are never likely to be demonstrable in schools! This application of the work on *nuclear reactions* has such obvious interest and relevance that it should be discussed, though this will necessarily be more by assertion than need be the case throughout the rest of the above.

A study of the *photoelectric effect* combined with a study of *spectra* provides evidence for the *quantum theory*. Evidence must be provided for the validity of the quantum hypothesis that $E=h\nu$.

Table 11



First experiments with electroscopes can be used to show that negative charge is released when an ultra-violet lamp is shone on a clean zinc or amalgamated plate.

It is then necessary to show that it is the wavelength (or frequency) of the incident light that matters and not intensity when exciting photoelectrons. This can be demonstrated using a neon lamp just on the point of discharge. The lamp will not flash when the plates are illuminated with light in the visible region however great the intensity, ultra-violet light is necessary.

Another essential experiment in the logical development is to identify the photoelectrons with thermionic electrons, cathode rays and beta particles, already studied. This could be done by a determination of e/m in the classroom, once again time probably necessitates the use of a film and reference to the work of others.

Finally the quantum hypothesis can be tested by a classroom experiment to measure Planck's constant h. It is shown that the cut-off potential for a photoelectric cell varies linearly with the frequency of the radiation used. From the graph, *Figure 8.1*, the value of h is estimated. This essential experiment confirms the validity of the quantum hypothesis that $E = h\nu$.

Once the quantum hypothesis is established, this combines with the knowledge of the atom already acquired to give information about *atomic structure* and the theory of discrete *energy levels*. This is considered in greater detail later in this chapter.

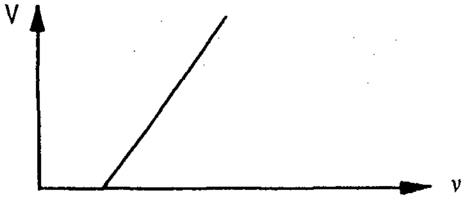
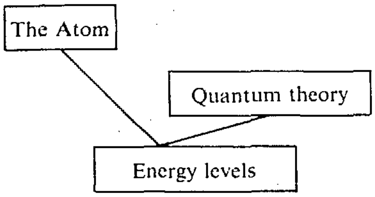


Figure 8.1.

This work on *atomic structure* will inevitably raise important issues about models and their place in science. This is a question also considered later.

Finally the work on *energy levels* makes contributions to other studies. It will be helpful to the study of *semi-conduction*, it makes a most important contribution to the study of the *periodic table* and to *chemical bonding*. It is one of the important links between the study of Physics and Chemistry in secondary school teaching.

Table 12



Evidence from Atomic Spectra

In the study of *spectra*, it is found that the spectrum of an element in an atomic state consists of sharp lines. The physics course will have already included the experimental measurement of the wavelength of one such line using a diffraction grating. Once one such measurement has been made, use can then be made of the measurements of others.

Consideration of the spectrum of atomic hydrogen shows that if one goes into the ultra-violet and the infra-red as well as the visible spectrum, several series of lines are found. It can be explained that spectroscopists have a habit of using the reciprocal of wavelength, called the wave number, to identify each line.

A table of wave numbers for the series in the hydrogen spectrum reveal a surprising empirical fact that each value is given by the difference of two numbers in the preceding series *(Table 13)*.

Reference can be made to the careful study of these experimental results, leading to a general formula for them all:

$$\tilde{\nu} = 109678.8\left(\frac{1}{n^2} - \frac{1}{m^2}\right)[\text{cm}^{-1}];$$

in the Lyman series, $n = 1$ with $m = 2, 3, 4$, etc.,
in the Balmer series, $n = 2$ with $m = 3, 4, 5$, etc.,
in the Paschen series, $n = 3$ with $m = 4, 5, 6$, etc.,
in the Brackett series, $n = 4$ with $m = 5, 6, 7$, etc.

Each series converges as m approaches infinity and the limits are given by $109{,}678.8/n^2$. The question is asked what is the significance of these limit quanta.

From the quantum hypothesis, $E = h\nu = hc\nu$. Thus ν is proportional to the energy lost by the radiating atom.

Table 13

Lyman	Balmer	Paschen	Brackett
82,259.1	15,233.2	5,331.6	2,467.7
97,492.3	20,564.8	7.799.3	3,808.2
102,823.9	23,032.5	9.139.8	4.616.6
105,291.6	24,373.0	9,948.2	5.141.2
106,632.1	25,181.4	10,472.8	...
107,440.5	25,706.0	...	...
107,965.1	...	...	
108,324.7	...		
108,582.0			
...			

If the wavenumber is plotted along a line, it is seen that less and less energy divides one line from the next until at the limit there is no significant difference.

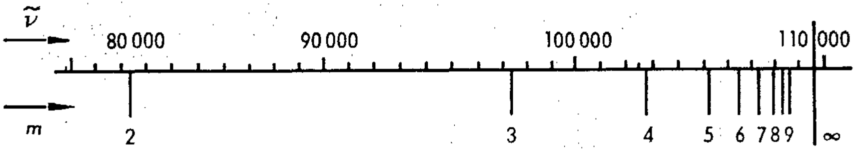


Figure 8.2. Lyman series.

These results combined with the different relations found from the other series lead to a theory of *energy levels*.

The picture of *atomic structure* at this stage is of a central positive nucleus with negative electrons to compensate, which are in some way disposed around it.

It is assumed that it is the electrons which absorb and release energy and as they release it they give out radiation of definite frequencies, thus producing sharp spectral lines. As an electron absorbs a quantum of energy it is lifted to a higher energy level in the atom. As the electron falls back from one level to another, it emits the appropriate quantum of energy, giving a specific spectral line.

The picture accounts satisfactorily not only for spectral lines, but also for the different series.

At the end of a series the steps grow infinitesimally small: no further energy seems to be necessary to "raise" the electron. It appears to be beyond the influence of the rest of the atom, it is free and the atom is said to be ionised.

If the wave numbers for the Lyman series illustrated in *Table 13* above are plotted against $1/m^2$, the limiting value of the series when m equals infinity can be determined and hence the ionisation energy deduced since it equals $hc\tilde{\nu}$.

It must finally be shown that similar lines and similar series occur in all atomic spectra as well as that of hydrogen.

As a classroom exercise, it would be helpful to get pupils to deduce an ionisation energy from the limit of a series using a photograph of a line spectrum. It would be advantageous if this could be done for helium so as to confirm the result to be obtained in collision processes on p. 145.

EVIDENCE FROM COLLISION PROCESSES

The above work has suggested a theory of energy levels on the basis of spectra. Important confirmation of the theory comes from a study of *inelastic collisions* in a gas filled tube.

Work in mechanics will have included a study of collision processes between macroscopic bodies, the momentum changes and the energy transfers concerned. It will have been found that when elastic collisions occur between a light body and a massive one, only a very small transfer of energy occurs from the light to the heavy. The pupils will therefore readily appreciate that if the light body is an electron and the heavy one as relatively heavy as, say, a helium atom (a factor of approximately 1: 8,000), a negligible transfer of energy will occur during elastic collisions when a stream of electrons flows through an evacuated tube containing helium at low pressure. When collisions are elastic, the electrons will behave as if the gas was not present.

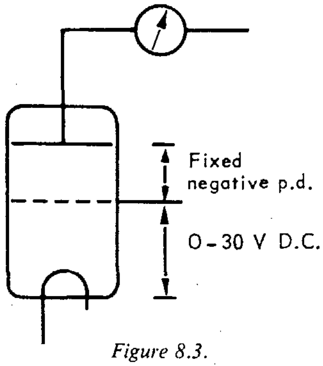


Figure 8.3.

The essential experiment is the Franck-Hertz experiment using helium. Commercial apparatus is at present available from Phywe in West Germany. In this electrons are given off by a hot filament and are accelerated to a grid by means of a D.C. potential difference, continuously variable from 0-30 v D.C. A fixed retarding potential of, say, 4 v D.C. is applied between the grid and the plate. The current reaching the plate is measured by a 100μA meter as illustrated.

As the accelerating potential between the filament and the grid is increased from 0 to 4 volts, no electrons reach the plate and there is no current as they have not enough energy to cross the retarding field.

As the potential is steadily increased, the electrons can now cross the barrier and the current increases by the usual $V^{3/2}$ law familiar from work on diodes. The electron current will be space charge controlled. All collisions with helium are elastic and negligible energy is transferred.

At a particular voltage however the accelerated electrons have sufficient energy to excite the helium atoms, to change them from one energy state to a higher one, and inelastic collisions occur. As soon as this happens, the electrons no longer have the energy to cross the barrier and there is a fall in current at the plate. Further increase in voltage once again enables the electrons to cross the barrier and the current increases again.

Direct evidence has thus been produced for discrete energy levels.

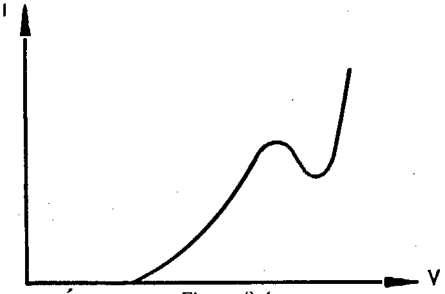


Figure 8.4.

On further increasing the accelerating potential, a stage is reached when the electrons have sufficient energy to ionise the helium, not merely to excite it. Further inelastic collisions occur, again the electrons cannot get across the barrier and the current falls. It will increase again as the voltage is further increased.

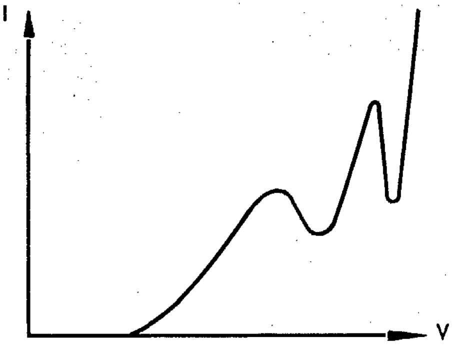


Figure 8.5.

The importance of this experiment is not only that it produces direct evidence for the existence of energy levels, but it does enable the difference between excitation and ionisation to be shown.

If a meter is inserted to measure the grid current, this will steadily increase as the voltage is increased. When inelastic collisions occur and *excitation* is produced, there is no change in the grid current. But when *ionisation* takes place, there is a sudden substantial increase in grid current revealing the presence of electrons released in the ionising process.

It will also be seen that the moment ionisation occurs, the tube begins to glow as recombination takes place—further evidence for ionisation. The re-radiation when the atoms are excited is outside the visible region.

The above experiment permits a determination of the ionisation energy and this should agree with the value determined by the pupils from the spectrum of helium.

Other experiments can be used to confirm the existence of energy levels. One is the original form of the Franck-Hertz experiment using mercury vapour and versions of this are commercially available for school use—see *Appendix.* The advantage of this method is that inelastic collisions can occur several times during the passage of the electrons through the tube and a series of peaks are obtained as shown. The disadvantages are first that it is not so easy for the pupils to see the difference between excitation and ionisation and second that to get the mercury vapour at the right pressure to see the peaks clearly the tube has to be in an oven and kept at precisely the correct temperature. The advantage is that it does permit a very precise value to be obtained.

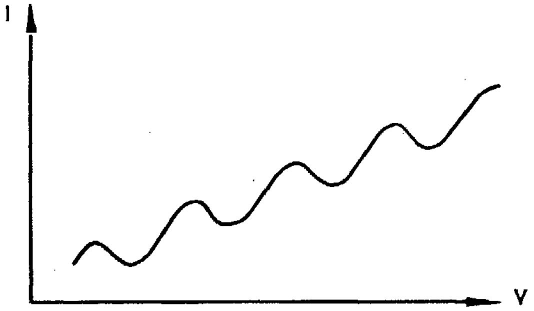


Figure 8.6.

It is also possible for individual pupils to do class experiments measuring excitation and ionisation energies using, say, Xenon filled thyratron tubes. Various commercial tubes are available—see *Appendix II.*

MODELS

The above work has concentrated on the existence of *energy levels* as the essential aspect of *atomic structure* that needs to be studied in a modern physics course in secondary schools.

In addition the pupils will require some sort of model to help them in their learning, but care should be taken to emphasize that this is only a model and not necessarily "what an atom is like."

It should be emphasized that a model is only important as long as it is useful and that what may be convenient now may be superseded by something different at a later stage. Reference will doubtless be made to the earliest historical models of atoms as it will also be made to the Bohr model. The beauty of the Bohr model can be stressed, but it should be explained that it has been found convenient to replace it by an orbital model, which in turn will be replaced by yet further models. This question of models provides a good opportunity for discussion of the whole nature of scientific investigation.

Although a detailed study of the Bohr model may be a satisfying mathematical exercise, it is suggested it should be avoided in such a course as is advocated here. What matters is the existence of energy levels, which in turn enables the physicist to provide powerful evidence for the chemist in his development of bonding and the periodic table.

An outline is given in the sections that follow of the information about atomic structure that can be obtained from a study of ionisation energies. This is one of the main contributions that the physicist can make to the work of the chemist.

IONISATION ENERGIES

Having measured an ionisation energy using inelastic collisions (as in *Figure 8.3.*) and having done the same using the limit of spectral series (as p. 143), an appeal can then be made to the work of others, obtaining a series of ionisation energies as follows (expressed in electron-volts):

Table 14

H	He	Li	Be	B	C	N	O	F	Ne
13.6	24.6	5.4	9.3	8.3	11.3	14.5	13.6	17.4	21.6
Na	Mg	Al	Si	P	S	Cl	A	K	Ca
5.1	7.6	6.0	8.1	10.5	10.4	13.0	15.8	4.3	6.1
Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
6.6	6.8	6.7	6.76	7.4	7.9	7.9	7.6	7.7	9.4
Ga	Ge	As	Se	Br	Kr	Rb	Sr	Y	Zr
6.0	7.9	9.8	9.75	11.8	14.0	4.2	5.7	6.4	6.9
Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn
6.9	7.1	7.3	7.4	7.5	8.3	7.6	9.0	5.8	7.3
Sb	Te	I	Xe	Cs	Ba	La	Hf	Ta	W
8.6	9.0	10.5	12.1	3.9	5.2	5.6	7	7.9	8.0
Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po
7.9	8.7	9	9.0	9.2	10.4	6.1	7.4	7.3	8.4
At	Rn	Fr	Ra	Ac					
	10.7		5.3	6.9					

INFORMATION ON ATOMIC STRUCTURE FROM A STUDY OF IONISATION ENERGIES

If Ionisation Energies are plotted against atomic number, the general form is observed to be as follows:

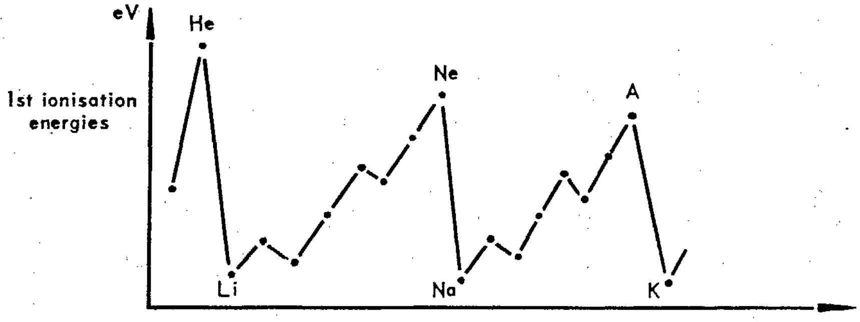


Figure 8.7.

The distinctive feature of the above plot is the series of peaks, each of which is followed by an immediate and substantial fall (He 24.6 falls to Li 5.4, Ne 21.6 falls to Na 5.1, A 15.8 falls to K 4.3). From this, it may be deduced that He, Ne, A... are particularly stable (it is not easy to ionise them), whereas each is followed by an element Li, Na, K... from which an electron is relatively easily detached (though it should be appreciated that the energies in kilocalories/mole are still considerable: for sodium, the specific heat, latent heat of fusion, and first ionisation energy are 6.4 cal/mol, 620 cal/mol and 119 *kilo*calories/mole [kcal/mol] respectively).

If the ionisation energies are plotted for the entire periodic table, it is noticed that the number of elements leading up to each peak give the series 2-8-8-18-18, later to be of significance to the chemist.

The chemists provide empirical evidence for grouping He, Ne, A... together—the rare gases—and likewise Li, Na, K...—the alkali metals—are grouped together as having chemical properties in common. This grouping appears to be confirmed by the above.

It is also to be noted that there is a fine structure to the plot between the peaks, a fine structure that is repeated between the first and second peaks and the second and third peaks, and to some extent later. From this fine structure it would not be unreasonable to expect that there would be similar chemical properties between Be, Mg, Ca, Sr, Ba and, say, between B and Al. This is confirmed to be the case by the chemists.

If the ionisation potentials of the rare gases are plotted against atomic number, the plot obtained is:

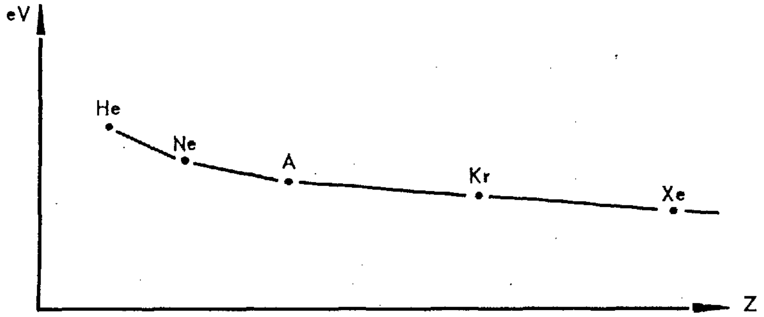


Figure 8.8.

Accepting the Coulomb law of force this falling-off suggests that the size of the atom is increasing: the electron, which is released on ionisation, is "further out."

A similar result is obtained if the alkali metals are plotted:

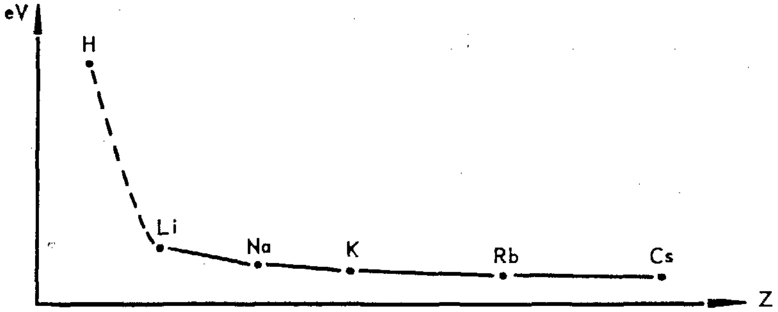


Figure 8.9.

It could be argued that hydrogen might also be included on this plot, as shown.

The fact that Na is easier to ionise than Li, combined with a knowledge of Coulomb's Law, once again implies that the electron, which is released on ionisation, is "further out," that the atom of Na is larger than the atom of Li.

The stability of the He atom, the fact that the Li atom is both larger and more easily ionised suggests that in some way the He atom represents a more complete whole, that with the Li atom the electron is added outside this whole.

Ionisation implies the existence of a number of electrons within the atom. This suggests that as one passes from Li to Be to B to C to N to O to F to Ne one may successively be adding one more electron. It would be reasonable to suppose that this additional electron might account for the different chemical properties.

Once Ne is reached, the plot of ionisation energies suggests that again something particularly stable is reached. The addition of one more electron giving Na again provides something which is easily ionised: this electron appears to be in a new outer region of its own. This model seems a convenient one and the ionisation plot suggests that completed states occur with He, Ne, A, Kr, Xe.

The idea of the stability of He, Ne, A, Kr, Xe is encouraged by the relatively inert nature of these elements as shown by the chemists.

Further confirmation for these ideas expressed on structure is given by a study of second ionisation energies. For the first 20 elements, these are as follows (expressed in electron-volts):

Table 15

	H	He	Li	Be	B	C	N	O	F	Ne
1st I.E.	13.6	24.6	5.4	9.3	8.3	11.3	14.5	13.6	17.4	21.6
2nd I.E.	—	54.4	75.6	18.2	25.1	24.4	29.6	35.1	35.0	41.1

	Na	Mg	Al	Si	P	S	Cl	A	K	Ca
1st I.E.	5.1	7.6	6.0	8.1	10.5	10.4	13.0	15.8	4.3	6.1
2nd I.E.	43.7	15.0	18.8	16.3	19.7	23.4	23.8	27.6	31.8	11.9

The feature of the 2nd Ionisation Energies most immediately apparent is that they are substantially larger than the 1st Ionisation Energies. This is exactly what might be expected, implying also that, however the electrons are distributed around the nucleus, they do have some sort of shielding effect. When the first electron of charge −1 unit is removed, the net charge on the remainder is +1. But when the second electron is removed, the net charge on the remainder is +2. It is therefore to be expected the second electron would be more tightly bound and require more energy to release it.

A second feature is immediately apparent if the second ionisation energies are plotted against atomic number *(Figure 8.10.)* as was done for 1st ionisation energies in *Figure 8.7.*

This too shows a series of peaks. However, the elements Li, Na, K which had low 1st ionisation energies, coming immediately *after* a peak, now provide the peaks themselves.

This confirms once more the ideas suggested on p. 148 of the relative completeness attained after 2, 8, 8, 18, ... electrons have been successively added. For example, it is relatively easy to remove one electron from Li and Na, but they then become relatively stable, like He and Ne respectively, and are difficult to ionise.

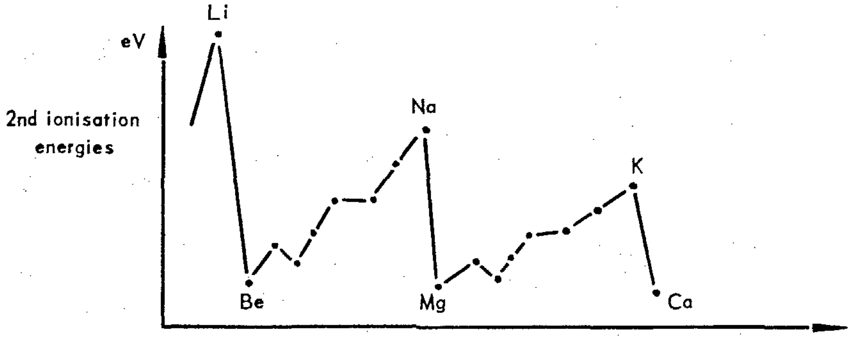


Figure 8.10.

If the third, fourth and fifth ionisation energies are also plotted against atomic number, it is again found that there are similar peaks, though the peaks move one to the right for each successive ionisation energy, as would be expected from the above.

CONCLUSION

This chapter has attempted to outline a possible teaching approach to atomic structure. It has tried to emphasize the significance of energy levels and the information to be obtained from them as opposed to the development of any particular model. It has outlined the kind of contribution that the physicist can make to the work of the chemist. Unfortunately the chemist is likely to want this contribution much earlier than the physicist is likely to be able to give it to his pupils and this is a difficulty which needs to be carefully resolved.

APPENDIX I

Audio-visual Aids

The following audio-visual aids are relevant to the course discussed in this paper:

1. 16 mm Sound Films

Millikan Experiment	P.S.S.C. — U.S.A.
Rutherford Atom	P.S.S.C. — U.S.A.
Photoelectric Effect	P.S.S.C. — U.S.A.
Franck-Hertz Experiment	P.S.S.C. — U.S.A.
Random Events	P.S.S.C. — U.S.A.
Electromagnetic Waves	P.S.S.C. — U.S.A.
Photons	P.S.S.C. — U.S.A.
Interference of Photons	P.S.S.C. — U.S.A.
Mass Spectrograph	A.E.I. — U.K.

2. 8 mm Cassette Films

Aston's Mass Spectrograph	U.K.
Positive Ray Parabolas	U.K.
Rutherford-Royds Experiment (alpha particles and helium)	U.K.
Millikan Experiment — in production	U.K.

3. Films for Science Teachers

(Produced in the U.K. by Esso Petroleum, Victoria Street, London, W.1.)

Use of Centimetre Waves in Teaching Optics	U.K.
Electrostatics: a modern approach	U.K.
Introduction to Radioactivity	U.K.
Further Experiments in Radioactivity	U.K.
Approach to the Electron	U.K.
Photoelectric Effect — in production	U.K.
Electrical Oscillations and the Electromagnetic Spectrum	U.K.

APPENDIX II

Teaching Apparatus Available

Apparatus for the following experiments is available commercially in the countries listed:

Millikan apparatus:	West Germany Scotland England
Hot filament and fine beam tubes:	West Germany U.K.
Centimetre wave apparatus:	West Germany U.K. Netherlands

Energy level apparatus:	West Germany (helium) West Germany (mercury) U.K. (Xenon)
Measurement of Planck's constant h:	West Germany Netherlands
Measurement of e/m for thermionic electrons:	U.K.
i) fine beam tube	West Germany
ii) magnetron method	U.K.
iii) magic eye method	U.S.A. (P.S.S.C.) U.K.
iv) deflection tube method	U.K.
X-ray apparatus:	West Germany Netherlands
Mass spectrometer:	U.S.A.
Solid state detectors for school experiments with alpha particles:	U.K.

APPENDIX III

Bibliography

The following literature is relevant to the discussion contained in this paper:

The Teaching of Modern Physics. Interim Report (2nd Edition) published by the Association for Science Education, 52, Bateman Street, Cambridge, U.K.

Chemistry Today—a guide for teachers, published by O.E.C.D.

Teachers' Guide—Physical Sciences Study Committee—U.S.A.

A REPORT ON THE LEVERHULME INTER-UNIVERSITIES CONFERENCE

A report on the Leverhulme inter-universities conference on the teaching of physics in Universities in Africa (1) held at the University College of Rhodesia and Nyasaland, June 10th to 21st, 1963. University College of Rhodesia, January 1966, IV + 95 p.

Papers as presented :

- The Purpose of the Conference, E.L. Yates
- Notes on the Educational Systems in the English, French and Belgian Universities, Editor
- Physics Departments in African Universities, D.G.Osborne and R.W.H.Wright
  1. Size and Structure
  2. Problems and Suggestions
- Motives and Incentives for Physics Teaching in an African University, D.M. Thomson
- The Orientation of the African Undergraduate to Scientific Attitudes, B.N.C. Agu
- The Teaching of Physics in African Universities, H. Masson
- The Improvement of School Physics Courses, N. Clarke
- The Teaching of Practical Physics, A.N. Hunter
- The Teaching and Examination of Practical Work in Physics, W. Schaffer
- Physics and Physic : The Natural Philosopher's Debt to Medicine, J.M.A. Lenihan
- The Physical Sciences Course at the Medical School, University College of Rhodesia and Nyasaland, A. Brock
- Humanity and Technology, or, Why Teach Physics ? J.M.A. Lenihan
- Technological and Technical Education in Physics in Britain, N. Clarke

Parts of two papers from this report are reproduced below :

Physics departments in African Universities, D.G. Osborne, University of Ghana, Legon, Ghana (now University College, Dar-es-Salaam), R.W.H. Wright, University of the West Indies, Kingston, Jamaica (Formerly of the University of Ghana)

Research

A list of research projects is given below. It may have been more instructive to ask for the number of workers in each field and the number of papers published in the last few years though neither is a sure measure of the quantity or quality of research.

Lovanium	Structure of organic molecules Structure of diamond
Cairo	Neutron activation ; gamma-gamma angular correlation Geophysics : geomagnetism and ionosphere
Addis Ababa	Separate geophysical observatory : geomagnetism, ionosphere, seismology, meteorology

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1. Copies of this report may be obtained from the editor, Professor E.L. Yates, Department of Physics, University College of Rhodesia, Private Bag 167H, Salisbury, Rhodesia.

Ghana	Geophysics : ionosphere, geomagnetism, earth current. Separate radioisotope unit and solid state physics unit.
Ivory Coast	Physical Chemistry
Nairobi	Geophysics : ionosphere, rock magnetism
Liberia	—
Ibadan	Geophysics, ionosphere, geomagnetism, atmospheric electricity, geophysical prospecting
Fourah Bay	Geophysics : geomagnetism, atmospheric electricity
Cape Town	X-ray crystallography : electron microscope studies of viruses ; electron diffraction ; plasma physics ; low-level radioactivity ; musical instruments
Witwatersrand	Solid state physics, low energy nuclear physics
U.C.R.N.	Rock magnetism Metal physics
Khartoum	Solid state physics ; cosmic rays ; vacuum physics
Makerere	Cosmic rays ; soil physics ; electron optics
Beirut	Electron spin resonance ; radioisotopes ; nuclear physics ; low temperatures
M.E.T.U.	Radioisotopes
Jamaica	X-ray crystallography ; cosmic rays ; geophysics ; ionosphere
Durham	High energy nuclear physics (fundamental particles) Solid state physics ; atmospheric electricity ; gas discharges
Exeter	Geophysics, upper atmosphere. Solid state physics
Brandeis	Fundamental field theory and elementary particles Statistical mechanics : high energy elementary particles (with M.I.T. and Harvard)
Northeastern	Plasma wave propagation High and low energy nuclear physics : relativity
Northwestern	Bubble Chamber and van der Graaf research ; Solid state ; Photoelectricity ; low temperatures.

Geophysics research is popular in many African universities because it takes advantage of the location. Other research is conducted often with small - even one-man - research groups working in relative isolation from other workers in the field, restricted by lack of funds and hindered by delays in getting new equipment shipped out or old equipment repaired. Much of the physics research is financed from outside the universities. At Lovanium Industrial Diamond Distributors aid research (which makes use of the nuclear reactor at the university). In Ghana research has been aided by the American National Bureau of Standards, by the Soviet Academy of Sciences, by the Ghana Army Signals Regiment, and the Ghana Academy of Sciences. Nairobi has received an American grant ; geophysics research in Ibadan was given a great impetus during the I.G.Y.; Salisbury receives a grant from the National Science Foundation of America and Khartoum receives one from the Rockefeller Foundation. Makerere received funds from the British I.G.Y. committee and (more recently) from Colonial Development and Welfare.

Outside Africa, physics research is - if anything - even more dependent on outside grants. In Beirut these come mostly from the United States (National Science Foundation, Research Corporation of America, Atomic Energy Commission) and in M.E.T.U. (Ankara) from N.A.T.O. and indirectly from use of the research reactor at Istanbul. The University of the West Indies has received recently a substantial grant from I.C.A.

In Britain and America physics research in the universities is financed largely by government departments and industry. Professor G.D.Rochester, at Durham, said that the choice of a main research emphasis for the department was guided by the need to tackle one of the "problems of the age" in physics. In this category he placed both high energy nuclear physics and solid state physics. One American professor suggested that the dependence of research on government funds ensured that research was geared to national needs.

Teaching

As may be expected, the teaching syllabus in physics does not need to be adjusted very much to suit African needs. Many universities include geophysics as part of the course. Nairobi indicate that they may introduce a meteorology course soon ; Salisbury have a syllabus that takes account of the need for more practical work and for more help in mathematics than would be given to physics students in many other universities.

The information about laboratory and lecture hours asked for proved too detailed for an easy summary to be given here. In order to draw a comparison between places with different entry standards the number of hours of laboratory (experimental) work and of lectures for the last three years of the general degree course are shown in table 4. At Lovanium students write a Memoire in their final year and the fifteen hours quoted for practical work include an estimate of 12 hours a week spent on the preparation of the Memoire.

The orientation of the African undergraduate to scientific attitudes, by Benson N.C. Agu.

A short while ago someone asked me : "Do you enjoy teaching ; at what stage in your life did you really make up your mind to be a teacher?" Without any hesitation I told him that I have been a teacher all my life. There was the time in the mid-1930's when I was the only person who could read at all in my father's compound of about ten families. When I came back from school, I spent my evenings teaching the younger ones how to read and write, and later in the evening I repeated to the older folks the stories of Titania, Oberon and Puck, or Ali Baba and the forty thieves that we read in the school readers. As in any formal class lessons, I was asked numerous questions which I had to answer in such a way as to raise plenty of laughter or else the story session would be pretty dull.

By the mid-1940's I had gone through a secondary school, and after obtaining the Cambridge School Certificate (1945), I went on to Higher College, Yaba, Lagos, to be trained as a teacher. After two years at this institution, the student body was moved in January 1948 to Ibadan to form the nucleus of the new University College, Ibadan. My teacher-training course ended in June 1949 with a Diploma award, but by October, I was back at the University College for a General Degree Course in Mathematics and Physics, and this Course lasted until June 1951, when I graduated. Throughout my undergraduate years at Higher College and at University College, I went back during the long vacations to teach in my former secondary school, D.M.G.S., Onitsha. With graduation I engaged in full-time science teaching in the above school until October 1953, when I went to the U.K. for a Special Degree Course in Physics. Armed with a London B.Sc. degree and a doctorate degree of the University of Leicester, I returned in September 1959 to join the staff of the Physics Department of the University College, Ibadan. Thus with four years experience in teaching physics in an African University behind me, I can now review what this assignment entails.

Need for Orientation

A year ago, when the question : "Does the electron feed ?" was asked in my second year Atomic Physics class, the whole class burst into laughter. I shared the amusement with the class at the time, but I could not help feeling that this question has raised a fundamental issue. With the passage of time, what this question portends appeared to me more and more as the teacher's dilemma rather than the student's problem. How has this state of affairs come about ? Somewhere along the line, some vital link was left out and this gap has now to be filled with the appropriate material before any further progress can be made. Clearly there is a need for an orientation of ideas.

Fifteen years previously, a similar incident took place in my student days at Higher College, but this time I provided the fun for the class and earned not a small measure of scorn from some of them. The teacher had just quoted that - "$\sin^2\theta + \cos^2\theta = 1$ and fresh as I was from a secondary school where we studied Latin, religious knowledge, history and even simple trigonometry, but no analytical geometry, I was perplexed and wanted a proof. I got my proof, but I was so stung by my apparent crass ignorance, that I resolved never to ask questions in class, and also to know all about this mysterious subject so as never to show myself up again. The effect of this was that I passed my exams, but this experience had robbed me of that spirit of free discussion which an intelligent student can often use to the best advantage of all in the class. These two cases suggest that there might be many more which never come to light, and before anyone attempts a solution to this vexed problem, the situation that gives rise to it has to be looked into.

Suggested solution

The solution to the problem of educating the undergraduate to scientific attitudes lies in the main outside the university campus. This orientation has to be tackled from various fronts which should be completed before he gets to the university to receive the final touch to this evolutionary process.

(a) Educating the Public

The student is very much a product of his environment. Social psychology has long recognized that neither a "culture" nor a "crowd" can be separated from the individuals who comprise it. It will be very difficult indeed to sell the idea of science to the undergraduate if his society does not accord a worthy recognition to fundamental research and intellectual achievements. This need to take the public along in the orientation towards science is slowly being recognised in many countries, old and new, but greater efforts should be made through all means of communication to disseminate scientific knowledge. The right attitude to scientific achievement will greatly facilitate the orientation of the younger generation to science.

(b) Secondary Schools Science

Very little science is taught in the elementary schools in many countries but this, in fact, need not be the case. This omission has been deliberate in the past because even the teacher himself has not had a scientific education, and the blind could hardly be expected to lead the blind ! But with the changing pattern of the society and improved means of communication, even the elementary school teacher should have had some years of science education.

However, the main battle-front is the secondary school. It is here that the science graduate teacher can get to work if the tools are given to him. This opportunity to give the students a sound scientific education can be denied him in many ways. First there are secondary schools where teaching of science does not exist at all due to lack of funds to employ the science teacher and buy expensive apparatus to keep him happy. Secondly, even in the schools fortunate enough to have the equipment and the science teacher, the school curriculum may be so biased by a religious or personal capriciousness that teaching of science has only an inconsequential part of the time-table. The last and not the least is the "bad" teacher. Most often the secondary schools for girls suffer most from this plague. Due to an unfortunate habit of sending people least interested or qualified to teach science in such schools, the future mothers of the nation who are bound to receive the first salvoes of the inquiring young minds in the family, are made to hate the very name of science due to the type of introduction they had into it. One will often hear such people declare : "I do not like physics. I found it rather too difficult at school, so I gave it up." "Our Science Mistress - Oh! she was horrible!" This type of thing no doubt goes on in boys' secondary schools also, but fortunately not so much. Therefore it follows that before these students, who had an unfortunate introduction to science, can be orientated to it again - if ever - one has first to undo the harm already done.

Fortunately a great measure of redress is now in view since most secondary schools are laying enphasis on science-teaching and greater efforts are being made to recruit qualified teachers from abroad.

(c) Emergency Science Schools

In addition to the post-School Certificate Course which is now being run by many schools to prepare students for entry into universities, emergency science colleges have been operated in some centres. As the name implies, the emphasis is on science and intelligent students who had not been privileged to obtain basic scientific education in many remote parts of the country are provided with the necessary opportunity. Such schools, like some post-School Certificate Courses, admit girls, and much salvaging work has to be done. With the better qualified teachers that one normally meets in secondary schools, the products of such schools amply justify their creation.

(d) The University Approach

Any gaps left in scientific education of the undergraduate show up most clearly when he gets into the university. For many years this university (Ibadan) has found it necessary to run a Preliminary Science Course for its students who come in by means of a Concessional Entrance Examination, since even now, enough qualified students cannot otherwise be found to fill the available vacancies. It is presumed that a year in the university atmosphere, and with better equipment and qualified teachers, instead of two in the post-School Certificate courses will be adequate to get a student ready to tackle the degree course. This practice which has proved so useful still goes on even though it is envisaged that it will finally go when enough students become available from the expanding post-School Certificate Courses in the country.

In conclusion, we see that the orientation of the undergraduate lies mostly outside the walls of the university. In fact, the university does not appear to have much part to play in this matter. However, if my observation of the results of this department over a few years could be used as a criterion of judging progress, then I have this one small point to add, a Nigerian scientist will better appreciate the handicaps and needs of his fellow countryman, and if he is worth his salt, will render an invaluable help to his students, perhaps a bit more than a scientist from a different environment who usually takes a lot of simple things for granted. This will be the case in the present situation, but as the dissemination of scientific knowledge in the younger countries improves, the disparity in the influence of the background on the undergraduate will gradually disappear and the problem of orientation of the undergraduate will become the same everywhere.

REPUBLIQUE FEDERALE D'ALLEMAGNE / FEDERAL REPUBLIC OF GERMANY

INSTITUT FÜR DIE PÄDAGOGIK DER NATURWISSENSCHAFTEN AN DER UNIVERSITÄT KIEL [1], (Institute of the pedagogy of sciences of the University of Kiel), by Dr. K. Hecht, director of the Institute.

Recently, a new Institute has been established at the University of Kiel for scientific research in the field of science teaching and education. The importance of recent developments in the teaching of science is appreciated, and in most countries, improvement is achieved through various associations, committees, groups and projects. The initiative for research in the pedagogy of science in the University originated from the experience Prof. W. Kroebel gained in the academic teaching of future teachers in a special demonstration course held at the Institute of Applied Physics in Kiel. In relation to modern scientific developments, appropriate methods of science teaching can also be thought of as a field of scientific investigation. Especially important is the application of recent psychological research to the advancement of science education at all school levels.

Another motivation for the new Institute grew from discussions with the German Union of Technical and Scientific Associations about the lack of emphasis on the natural sciences in German education and the increasing scarcity of science teachers. A group of leading scientists, convinced of the cultural importance of science education in the modern scientific and technical world, supported the proposal for a research Institute at university level. The Volkswagen foundation granted the funds for a new building to start the work at Kiel. The building is now being planned for four departments : physics, chemistry, biology and educational psychology. Each department will have sufficient space for laboratories, course-rooms, etc. to perform and develop experiments, tests and investigations. Common lecture-room, library and meeting room will help the staff to work together. Working places for guest-professors and for teachers in training are provided.

The aim and the purpose of the Institute are scientific research in the pedagogy of the natural sciences : physics, chemistry and biology. Science education, both content and method, are the subjects of the scientific research and development. The importance of that research is founded on the cultural value of science teaching in all fields of education. Good science education imparts as its contribution to a modern general education a good understanding of the nature, the methods and the results of modern science. The students learn in this way the typical methods of experimental work and of scientific thinking. This helps them to understand their environment and in particular to know how scientific developments and their technical consequences affect the increasing change of human affairs.

Science education is therefore essential for <u>all</u> children, not only for the future scientists or engineers who become interested in school, but also for those students who are interested in other professions and who do not have opportunities to learn more science after leaving

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[1] Mr. Hecht's article appeared under the above title in <u>Physikalischen Blätter</u>. The author has kindly translated the text into English for the present publication.

school. All children should know the principles of scientific investigation, and should understand that new phenomena in science are all the time being discovered by experimental observations. These discoveries cause scientists to re-think the fundamentals of science. and to correct or even completely re-formulate their previous reasonings. In physical science the human intellect is able to penetrate to the limits of knowledge. To understand such consequences of science it is necessary to follow a profound experimental course of science teaching. The ten years between the ages of 10-20 years are the most critical phase of human development in education. Science teaching has to take account of the development of the students throughout this period in relation to content and method. First, as an introduction to science, the youngsters may be helped to observe phenomena in their natural and technical environment and to collect their own first experiences by working with suitable material. The pleasure and interest aroused by finding out for themselves the relations between things and operations give them a good introduction to science.

In the course of the following school years science teaching proceeds by induction and deduction to find out the fundamental laws of nature. It extends over the most essential parts of natural sciences and is based on experiments. Fundamental knowledge of science and technology is based on observations and their quantitative treatment by means of more abstract methods and mathematical formulation. By careful study leading from observation of natural phenomena to a derivation of fundamental scientific laws and their relations, the students will come to realize the importance of science and its significance for the world in which he lives. This course is especially suited to students with good aptitudes for scientific work and thought. But consideration must also be given to the majority of pupils who are not talented for science, especially in its more abstract or mathematically formulated aspects. It seems therefore an essential task to prepare more descriptive courses of science understandable to students with talents in other fields ; even these students should have good information about the modern world and an understanding of the principles of science.

Another purpose of research is the incorporation of information on modern techniques in science education. The technical environment of today can supply the first introduction, and many good examples of applied science. But the real characteristic of technique is more than application and even of proofs of scientific investigation. The invention, the design, the construction, the manufacture and other human activities on the one hand and the permanent innovation and readiness to use all technical aids on the other hand, show some more significant features of techniques to be communicated in teaching.

Amongst other problems only programmed learning may be mentioned. The characteristics of this method which make it appropriate to mathematics teaching have to be adapted when it is to be accompanied by experimental work. The inclusion of practical work and measurement complicates the preparation of the programme, but at the same time the experiments and the active work constitute new motivations for the students. The items to be learned by this method are preferably the basic facts of observation. The programme seems to be most successful if it is used for only half the lesson, and is complemented by a discussion or a demonstration by the teacher. Special frames for the more able students have to compensate the inequality of the group or class. The facilities in the class-room or the laboratory must be designed for individual work.

These examples may explain some of the problems attached to research in the field of the pedagogy of science. The Institute has to stimulate the work on these problems. For this purpose the teaching of students or teachers and the tests in schools are part of the experimental field.

The numerous tasks of the promotion of science education can only be solved by close co-operation between natural scientists and educators, psychologists and sociologists, and in the same way with the teachers and the international or national groups and institutions established for similar purposes.

FRAME PROGRAMME IN PHYSICS

At its General Assembly in Nuremberg (1965) the German Association for Mathematics and Science Teaching adopted a "frame programme in physics"; we reproduce below the part devoted to higher secondary education(1)

General objectives

The students may, by means of overlapping guiding themes, gain an idea of the intellectual edifice of physics. Particular attention should be given to general and co-ordinating aspects. The following groups of problems should be treated as listed below:

Note : Themes marked + are intended for a treatment in Gymnasia of the mathematics and science line only. Domains not marked thus constitute the minimum programme of all other types of Gymnasium.

Kinematics

A thorough treatment of kinematics is indispensable as the prerequisite for any advanced teaching of physics. This part is more suitable than any other section of classical physics for the introduction of the students to the characteristic working methods in this science. Here it can be shown most clearly how an extensive range of experimental facts can be summarized and described by a few fundamental laws.

The following themes are to be treated in this chapter :

Rectilinear motion, velocity and acceleration. - The model of the point mass. - Free fall and vertical projection. - Horizontal projection and the superposition principle. - +Inclined projection. - Force and mass. - Momentum and energy, the conservation principles. - Uniform circular motion. - Mechanical oscillations and waves. - Planetary motion, Kepler's laws. - The law of gravity. - Gravitational mass. - The development of cosmography from Ptolemy, through Copernic, Tycho Brahe, Kepler, Galilei to Newton. - +Problems of space research. - The kinetic theory of gases. - The first law of thermodynamics. - +The second law of thermodynamics. - +Basic facts about the theory of relativity.

The field as a means for the quantitative description of phenomena

Through the concept of the field the students may become acquainted with one of the most important models in physics, a model which can be used successfully in a great variety of phenomena. This section is particularly suitable for historical elaboration. For this reason it should be shown again and again what efforts were necessary and what difficulties had to be overcome until the concept of the field could be formulated as it is to-day.

The following themes are to be treated in this section :

Newton's law of gravity. - Gravitational fields, field strength. - +Gravitational potential. - The electric field and the electric field strength. - Coulomb's law for electric charges. - Electric tension and potential. - The capacitor and its laws. - +Basic laws concerning electric fields in a vacuum. - +The electric field in matter, dielectrics. - +The energy of the electric field. - The magnetic field and the entities used to describe it. - +Fundamental laws for magnetic fields. - The homogeneous field of a solenoid. - +Biot's law. - Electromagnetic interactions. - Current-carrying conductors in a magnetic field. - The Lorentz force. - The laws of induction. - +The energy of the magnetic field. - +Displacement current. - +Electromagnetic oscillations and waves. - +The fundamental laws of the electromagnetic field.

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1. Dr. E. Baurmann (Karlsruhe) has kindly translated this text from the German for inclusion in New Trends.

The dualism of wave and corpuscle in the case of light

In this section it must be shown, following the historical development, how the corpuscular and the wave model were contradicting one another in the beginning, and how nowadays only the dual concept of wave and corpuscle meets the experimental findings known so far.

The following themes are to be treated in this section :

Basic considerations concerning the corpuscular and wave model. - Reflection and refraction as described by the corpuscular and the wave model. - Velocity of light. - Interference phenomena and their description. - The diffraction of light by a slit and by a grating. - The meaning of interference and diffraction for the models of light. - Polarization of light, light as a transverse wave. - Difficulties with the mechanical models of light. - $^{+}$The ether problem. - $^{+}$The Faraday effect. - The electromagnetic wave model of light. - The electromagnetic spectrum. - External photoelectric effect. - Planck's quantum theory, the elementary quantum of action. - The dual nature of radiation. - $^{+}$The correspondence principle.

The structure of matter

In this chapter the students will become acquainted with a group of questions which occupied man from ancient times till to-day. The experimental evidence for the modern concepts of the structure of the atoms as well as the usefulness of models for a comprehensive description of the experimental findings and the heuristic preparation of new questions to nature are to be treated here. This chapter is particularly suitable to demonstrate again the close interrelation of physics and to-day's philosophical, cultural, economical and political life.

The following themes are to be treated in this section :

The development of concepts of the atom up to Avogadro. - Avogadro's number (oil drop experiment). - The Millikan experiment. - The determination of e/m. - Faraday's laws of electrolysis. - The atom model of Rutherford and Bohr. - Energy levels in the atomic shell, line spectra. - $^{+}$Electron impact experiment of Franck and Hertz. - The structure of the atomic shell. - $^{+}$X-Ray spectra. - The structure of the atom and the periodic system. - Limitations of Bohr's model. - The wave properties of the electron. - $^{+}$Wave mechanical models of the electron and the atom. - Radioactive decay. - Structure and properties of the nuclei. - $^{+}$The laws of natural radioactivity. - Detecting radioactive radiations. - $^{+}$Dosimetry. - Neutron bombardment. - $^{+}$Artificial radioactivity. - Bonding energy and mass defect in atomic nuclei. - Energy by nuclear fission and fusion. - Nuclear reactors. - Atomic weapons. - Radiation hazard and protection. - Models of the atomic nucleus.

SÜDWESTDEUTSCHE SCHÜLBLATTER (Review of education in south-west Germany), quarterly. Editors: Oberstudienrat Bernard Lindauer, 68 Mannheim, Augusta-Anlage 17 ; Oberstudienrat Dr. Hans Joachim Stamm, 763 Lahr/Schwarzwald, Fichtestrasse 3.

AUSTRALIE / AUSTRALIA

UNIVERSITY OF SYDNEY DEPARTMENT OF PHYSICS AND ITS NUCLEAR RESEARCH FOUNDATION (1), by Oscar A. Guth

The creation of this Foundation - the Nuclear Research Foundation within the University of Sydney - was due to a young Canadian physicist, Dr. Harry Messel, who in 1952 at the age of thirty was appointed to the only vacant chair of physics in the University of Sydney. Immediately on his appointment it became clear to Prof. Messel that, faced with the generally increasing demand for education throughout the land, the Australian Government could not be expected to make available to him the large funds he would need for a vigorous development of his Department and of a postgraduate school in physics. However, the need was self-evident, as the number of students coming forward for degrees in physics were few, and of these the best, who were interested in pursuing postgraduate work, invariably went overseas. It was mainly with this "brain drain" in mind that Prof. Messel set himself the task to appeal to outside sources to help stop the drift of young Australians overseas, to bring back some of the best young Australians whohad left and, if possible, even to get some of the best overseas students to pursue postgraduate studies in his School. To do this it was necessary to establish a postgraduate group consisting of scientists of world repute to work in specially chosen fields - fields in which Australian research could lead and not just follow. The key, of course, was first-class staff respected for their scientific work the world over. But such staff could be attracted only if the research programme at the School was dynamic and challenging enough to command international interest.

Prof. Messel had both, a dynamic personality and a dynamic research programme, and the only thing he was lacking - in common with other scientists - was the necessary financial aid. He thus began to appeal to outside sources to contribute to a Foundation the Constitutional objectives of which would be "the support, promotion, fostering and development financially and otherwise of nuclear and associated research in the School of Physics of the University of Sydney ; and the support and encouragement of science education in the School and in Australia generally".

Parallel with the success of the Foundation's summer science schools has been the success of the books containing the entire lecture material of each school. These books are all edited by Profs. Messel and Butler under the same title as the general heading of the respective summer school. They are published each year before the start of January summer school so that scholarship winners and even members of the general public may read the lectures before listening to them at the summer school or in front of their television sets. The books are all initially published in Sydney - 3,000 copies of each are distributed free by the Foundation to scholarship winners, science teachers and high schools - but since 1960 they have also been republished world-wide each year (lately by Pergamon Press, Oxford).

As can be seen, Prof. Messel has thus developed the Sydney School of Physics not only in the undergraduate and postgraduate fields but also, with the help of the Foundation, he extended the sphere of influence of his School far beyond the confiness of the University deep into secondary education as well. As the director of the Foundation he had in all the full

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1. Extracts from Nature, vol. 206,No 4982, pp. 334-338, April 24, 1965.

support of the Foundation's Council which ex officio includes the top officers of the University, such as its Chancellor, its Vice-Chancellor, the Assistant Principal, etc. It is thus with the help of the University as well as with the financial aid of the Foundation that the School of Physics has come to play such a vital part in the development of science education generally in Australia - from the first year of high-school up to the Ph. D.

Significantly, it was in the secondary field of science education that Prof. Messel and his colleagues in the School of Physics and the Foundation met their greatest challenge in recent years. The problem arose in 1962 when, after years of deliberation, the New South Wales State Government adopted a secondary-school reform plan the science teaching aspect of which broke entirely new ground. This "Wyndham Plan" - as it became known, named after Dr. H. S. Wyndham, the State director-general of education, under whose chairmanship it was formulated - made science a compulsory subject in the first four of the new six-year high-school course. The new science syllabus provided for one four-year science course integrating the subjects of physics, chemistry, biology and geology.

In a far-sighted decision the Wyndham plan stipulated that the student should be able to view science as a whole and not look on it as "bits". In addition, the integrated course should provide a maximum amount of basic general knowledge for those whose only science instruction in life would be this course, and a maximum scope of specialization for those who wish to go further.

But it is one thing to conceive a unique course aiming to integrate four major science fields and to plan a syllabus for it, and it is another thing actually to teach it. The practical difficulty of the science course lay in the problems of who could teach and how could students learn the course - spanning four science fields - without a text-book ? Lastly, who could write such a book ?

The practical implementation of the Wyndham plan's science course thus hinged on finding the means to integrate experts in four sciences to perform the feat of creating, from the essence of their special fields, one course capable of imparting basic general knowledge of all four fields. In fact, it was soon evident that, within obvious limits, the larger and more representative the groups of writers would be, the more comprehensive would be the text-book. Moreover, it was apparent that not only was an experienced unifying force needed for such a large effort, but indeed considerable finance. In Australia, the body capable of undertaking both without delay was the Nuclear Research Foundation and, as its director, Prof. Messel offered the Foundation's and his School's help to the Education Department, an offer which was enthusiastically accepted.

The result was a 1,040-page, richly illustrated text-book, Science for High School Students, prepared by a group of thirty-two university professors, university lecturers, school inspectors, teacher college lecturers and science teachers, under the chairmanship of Prof. Messel, and a 470-page companion, Teachers' Manual. The text-book came into full use for the first time in Australian high-schools and secondary schools during the 1964 school year, and in New South Wales alone more than 90 per cent of all high-schools and secondary schools are now using the book (see Nature, 202, 1151 ; 1964).

The text-book, which was produced in co-operation with the Education Department, published by the Foundation itself, and printed and distributed by the New South Wales Government Printer, has greatly enhanced the prestige of the School of Physics and the University of Sydney in general. There is no doubt that its use by high-school students will stimulate their interest in tertiary science education. Realizing the fruitfulness of its co-operation with the Foundation and the School of Physics of the University of Sydney, the Education Department has invited Prof. Messel to produce follow-on text-books for the fifth- and sixth-year science course which will start next year. These books are now being written and will be available for the start of the 1966 school year, bringing into existence a complete six-year packet of science texts for students and teachers.

While the rapid expansion of thePostgraduate School in Physics over the past twelve years has been watched with growing interest by the academic world, the simultaneous efforts of the Nuclear Research Foundation and the School of Physics in the undergraduate university and secondary school level has also attracted world-wide attention. British and American educationists are examining Prof. Messel's Summer Science Schools and the new integrated science text-book, and Unesco has for some time been in close consultation with these Sydney efforts. Late in 1964, in response to widening overseas interest, the Foundation assigned to Pergamon Press, Oxford, the world-wide distribution of the high-school text-books and all foreign language editions of them, with translations into German, French and Spanish already being prepared.

The rapid growth of the School of Physics of the University of Sydney and its Nuclear Research Foundation and their increasing activities in Australian science education provide a good example of what a concerted effort between university and the private sector of the community can accomplish if this effort is properly co-ordinated and balanced in its academic and administrative aspects.

SUMMER SCIENCE SCHOOLS (1)

Eleven years ago, concerned by the growing shortage of scientists and technologists in Australia and by the small percentage of undergraduates who upon entering the universities enrolled in the Faculties of Science and Engineering, the Foundation felt that much could be done to help increase the percentage of students enrolling in science or engineering by the institution of refresher courses for the high school science teacher in the form of Summer Schools.

The Foundation decided that as a matter of policy no effort or expense should be spared in inviting to the Summer Schools only top-ranking scientists in the different fields even if this meant flying them to Australia half way around the world. It felt that this would not only ensure that Australian science teachers in these Summer Schools obtained the latest and best information of current developments, but that it would also underline the importance the Foundation attached to the problem.

Events have since proved that world class lecturers such as U.S. Professors George Gamow and Thomas Gold inspired science teachers and stimulated them to inspire their students more than had the courses been conducted exclusively by local and perhaps junior lecturers.

The 1962 Summer School for high school students thus became the norm for subsequent Summer Schools as both educationists and the public seemed to agree on the tremendous value of this Foundation effort for the education of the youth of Australia.

In January 1963, the annual Summer School was extended from a N.S.W. Summer School to an Australia-wide Summer School and scholarships were awarded for 140 students from N.S.W. and to two students from each of the other five Australian States.

The 1963 Summer School presented a lecture course entitled "The Universe of Time and Space" and dealt with subjects ranging from the structure and origin of the universe and the solar system to elementary atomic and nuclear physics, electro-magnetism and an introduction to the theory of relativity. The 19 lectures of that course were given by :

Professor Herman Bondi, Professor of Applied Mathematics, University of London ; Professor R.Hanbury Brown, Professor of Radio Astronomy, University of Manchester ; Professor Thomas Gold, Professor of Astronomy, Cornell University, N.Y. ; Dr. R.A. Lyttleton, Reader in Theoretical Astronomy, University of Cambridge ; Professors

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1. Extracts from The Nucleus, 1965, pp. 48-53.

S.T. Butler and H. Messel of the School of Physics, Sydney University ; and last but not least by Professor Julius Sumner Miller, of El Camino College, California, who gave a series of demonstration lectures which not only greatly inspired the students but, through their unique presentation and Professor Miller's extraordinary showmanship, became an unprecedented television success throughout Australia.

It would be difficult to describe here the success of the 1963 Summer School particularly after the unprecedented interest aroused by the previous year's Summer School, but it can be safely said that the 1963 result was even more spectacular and surprising than the 1962 reaction.

The January 1963 Summer School lectures were televised in Sydney every week day at 7 a.m. - a successful experiment by the television station to afford people of all walks of life an opportunity to view this programme before going to work in the morning. People who missed the programmes aroused so much clamour for it in the Press and in correspondence that the lecture series was hardly finished when it had to be re-screened all over again. The same held true for other Australian capital cities and it is now estimated that at least $3\frac{1}{2}$ million people throughout Australia - or one in every three - has seen some of these science programmes. And while one can say that in 1962 the Sydney Press devoted columns to the Foundation's Summer School, in January 1963, Sydney newspapers and magazines literally devoted pages to this form of science education.

In 1964, a Nobel Prize winner in medicine and one of the world's leading experts on the origin of life lectured to Australian high school students at the Summer School. The main part of the Summer School consisted of a course of 18 lectures under the general heading "Light and Life in the Universe", given by 1962 Nobel Laureate Professor James D. Watson, Professor of Biology at Harvard University ; Professor Martynas Ycas, Associate Professor of Microbiology at the State University of New York ; and Professors Messel and Butler.

Professor Watson lectured on the basic structure of the molecules of life and the way they reproduced themselves ; Professor Ycas lectured on the way in which life could have developed on earth and elsewhere in the universe ; and Professors Messel and Butler lectured on the fundamental properties of light and the essential role it plays in life processes.

In January 1965, two of the world's leading cosmologists - Professor Herman Bondi, of London University, and Professor Thomas Gold, of Cornell University, U.S.A. - lectured at the Summer Science School. A third distinguished overseas visitor to lecture was to have been Professor Julius Sumner Miller, of El Camino College, California, but illness caused his last-minute replacement by Professor C.B.A. McCusker, head of the School of Physics' Falkiner Nuclear Department.

The main part of the Summer School consisted of a course of 12 lectures under the general heading of "Time". In this series Professor Bondi gave four lectures on Time and Relativity ; Professor Gold four lectures on the Arrow of Time ; and Professors Messel and Butler four lectures on the Relation of Geological and Biological Time.

In addition, Professor McCusker held a course of six spirited practical lecture demonstrations.

THE SCIENCE FOR HIGH SCHOOL STUDENTS textbook series and the new secondary-education system in New South Wales, by Professor H. Messel

The series of books printed and distributed in Australia by V.C.N. Blight, Government Printer, Sydney, comprises :

- Science for high school students
- Science for high school students teacher's manual

- Abridged science for high school students
- Senior science for high school students - Part I : Physics
- Senior science for high school students - Part 2 : Chemistry
- Senior science for high school students - Part 3 : Biology
- Senior science for high school students teachers' manual

The new system of education in the State of New South Wales is known as the Wyndham Scheme, and before discussing the books published by the Nuclear Research Foundation for the six year science course within this scheme, it is perhaps worthwhile to describe in a little detail the scheme itself. This will then give the reader some idea of how the textbooks have been organised by the Foundation, prepared with the closest co-operation of the N.S.W. Education Department itself, and indeed with the inestimable help of Dr. H.S. Wyndham, the chief planner of this State's modern pattern of secondary education. New South Wales has followed and extended the trend set by the United States and Great Britain wherein the writing of modern scientific school textbooks is no longer left as a task for a few prominent scientists or teachers but is now undertaken as a national co-operative venture between the nation's leading scientists and teachers and the Government's own educationalists. The very magnitude and scope of scientific knowledge which must be mastered today has demanded nothing less.

In the Wyndham Scheme of Education the secondary school course has been increased from five to six years. The New South Wales secondary schools course is usually begun at the age of 12, and continues to the age of 18. It is split into two - a period of four years (12 to 16) followed by a further period of two years (16 to 18). At the end of the first four-year period students sit for the School Certificate examination - an examination set by the State. About 25 per cent of those students completing the four-year course go on to the final two years, at the end of which they sit for the Higher School Certificate. Passes in certain prescribed subjects at this level automatically give the student matriculation for entrance into the universities.

Throughout the six years "science" is essentially a required course. In essence, this means that the majority of students have to take an average of 1,200 teaching periods of science during their six-year course. Some can take more, others less, as will be seen later.

To begin with let me discuss the first four-year science course. The basis for this is given briefly in my introduction to Science for high school students (hereafter referred to as SHS), and readers of this explanation are advised to read the Introduction to SHS.

The four-year science course covered by SHS is, one might say, "science with a difference" : it is not a General Science course, and it is not the conventional science course which splits the individual disciplines into separate compartments. It is an integrated course of science in which the subjects of astronomy, physics, chemistry, biology and geology are treated as a whole.

Of course, integration means different things to different people and our definition of it can best be appreciated from an examination of SHS. The main fact is that the course is so designed that the student does not, for example, think of energy in biological, physical and chemical systems as being different : it is one and the same thing in each of these systems.

All students taking the four-year course in New South Wales schools are split into three "streams" - the Ordinary-level course, the Credit-level course and the Advanced-level course. In practice, of course, only students who have taken the Credit or Advanced-levels can proceed on to the Higher School Certificate course, that is, to the last two years of the six-year course. In other words, students taking the Ordinary course would not usually go beyond the four years. Their formal secondary-school education thus ends at this stage.

The Foundation textbook Science for high school students and its companion Teachers' Manual was written initially to cover all three levels - Ordinary, Credit and Advanced. This is one of the reasons for its large size. Another reason is that we realized that there were few, if any, teachers in Australia (or anywhere else in the world) who could teach the course as a whole. Therefore, the textbook was written not only with the pupil in mind, but the teacher as well. We felt that there should be no compromise of standards, and there is a considerable amount of material in SHS which goes even beyond the Advanced-level course. The book was deliberately meant to tax even the very best student in our country, and it was also deliberately written in such a manner as to discourage any student from trying to "cram" or memorise the material in it. With such a vast amount of material, any such thought would quickly be dispelled ! To repeat, this was quite deliberate on our part, but it did give us a rather large volume.

SHS has 1,040 double-column pages, 835 illustrations and some 650,000 words of text. In single-volume form it weighs about $4\frac{1}{2}$ lb. Because of this weight the book is also available in two volumes, each of about 500-odd pages. It was our hope that all schools would finally swing over to the use of the two-volume format but, much to our amazement, our distribution figures have remained static with about 50 per cent of schools still using the single-volume, 1,040-page format. We do not understand this.

Since only about 60 per cent of the material in SHS is used by students following the Ordinary-level course it appeared sensible to produce the new version known as Abridged science for high school students, in which essentially the Credit and Advanced material contained in SHS is omitted. Abridged science for high school students will be ready for use by students before the start of the next Australian school-year in January 1966. It will appear in one format only - namely in two volumes, each volume containing about 300 pages. This is a very reasonable size, considering that four years of science must be covered, entailing an allocation of 750 periods. The book will also feature a summary at the end of each chapter.

During the coming years SHS and its companion Teachers' Manual will from time to time be amended and revised. For this purpose we have a permanent Revision Committee in existence, but necessary changes will be introduced so gradually that any one textbook will never be "outdated" during its many years of school use.

One point should be emphasised : we have deliberately written SHS and its abridged version in an easy and breezy manner. We believe that science is not a "dead" subject, although many scientists and authors seem to try and make it appear so. We have tried to make it exciting and easy to read, interesting and yet scientifically factual. At the end of the four-year course students are examined at either the Ordinary, Credit or Advanced levels.

It is interesting to note that many of the SHS textbook group of authors and editors were members of the Syllabus Committee which wrote the syllabus for the science course. We all felt that a syllabus by itself is almost a meaningless document, interpreted differently by different people. Our interpretation is given in SHS and is thus the interpretation of many of the syllabus authors themselves.

Let us now look at the fifth and sixth years : our first fifth-year course starts in January 1966, the new six-year scheme having come into operation in 1962. Students may again take science at a number of levels.

It is likely that there will be about 10 per cent of the students (those who will not proceed to a university) who will take what is known as a Third-level course. This will essentially be the Advanced-level course given in SHS... with a few additions. Textbook-wise we feel, therefore, that we have little or no role to play here.

Then there is the Second-level course, which is split into two : a short course consisting of six periods of science per week during each of the fifth and sixth years : and there is also a Second-level full course consisting of nine hours of science per week during each of the fifth and sixth years. These courses will in most instances be required - by the professional faculties - for entrance into the universities.

Finally, there is the First-level course. This consists of eleven periods of science per week during each of the fifth and sixth years. This course consists essentially of additional reading which the student is expected to do himself and (with the help of the teacher if need be) to study further certain selected topics aimed beyond the Second-level full course.

During the fifth and sixth years students following either the First or Second-level course must take Chemistry and Physics : they must further take either Biology or Geology. We do not expect more than a small fraction of students to take Geology in their fifth and sixth years, and consequently we have not prepared a textbook in this subject. For the fifth and sixth years we have therefore prepared the following texts, known as Senior science for high school students - Part 1 : Physics ; Part 2 : Chemistry ; Part 3 : Biology.

The total six-year course thus consists of Science for high school students and Senior science for high school students, Parts 1, 2 and 3, and all these books completely interlock with one another. I use the word "interlock" purposely, rather than "integrate" although this may seem to be splitting hairs. We thus end up with a six-year science text "package", completely interlocked and interlinked. There is simply nothing like it elsewhere in the world, giving New South Wales a real lead in this field of education.

Senior science for high school students, Parts 1, 2 and 3, will be out in December of this year. In addition, a companion Teachers' Manual will also be published at the same time. For all this work we have had and still have the co-operation of the best secondary school science teachers in the State and representatives from the teachers' colleges and the universities.

The contents of the Senior textbooks are really quite exciting and much of the material presented, for example, in the Physics part has never appeared before in such a fashion. Senior science for high school students takes off where the Credit-level of SHS finishes. In other words, as a matter of policy, we overlap with the Advanced material of SHS.

Lastly, the Foundation textbook groups will not be disbanded, but will continue to exist as far as we can see into the future, to carry out amendments and adaptations as the need arises. We are determined to keep the Foundation books as modern as the science of to-morrow. It is interesting to note that in Australia textbooks are not only being used by the students and teachers, but there are also enormous sales to parents, who are making a real and amazing effort to catch up with their young sons and daughters. This is by no means a small problem.

SCIENCE FOR HIGH SCHOOL STUDENTS, by the Nuclear Research Foundation School Certificate integrated Science Textbook Group of Authors and Editors, under the chairmanship of Professor H. Messel, published by the Nuclear Research Foundation within the University of Sydney, pilot edition 1963, first edition 1964, vol. I, 498 p., vol. II, 462 p.

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Four parts of this new textbook are reproduced in the following pages (Olbers' paradox ; Kinetic theory of gases ; The origin of magnetism ; Matter waves).

Olbers' Paradox. In 1826 a German astronomer, Olbers, found that the simple fact that the sky is dark at night was really very difficult to understand. He wrote a scientific article which, in fact, posed the question " Why is the night sky dark ? " Do not dismiss this as a trivial question and answer that the sun does not appear at night. There is much more to this than meets the eye. Olbers performed a simple calculation which seemed to show conclusively that the sky should be anything but dark at night. Since a paradox may be considered to be some conclusion which appears obvious and very much what one would expect, but yet is contrary to what is observed, Olbers' conclusion came to be known as Olbers' Paradox.

Olbers simply tried to calculate the amount of light that must be reaching us from all the distant stars and galaxies of the universe. He assumed that on the average the universe is uniform—that is, no matter how far one goes, the *average* distance between galaxies and their *average* brightness will be the same. He then used what is known as the inverse square law for the way in which the intensity of radiation of light being received from a source falls as the distance from the light source increases.

The radiation emitted from the source shown in Figure 1.9, for example, spreads out to cover area A at a distance of what we call one unit from the source. At twice this distance the same amount of radiation covers four times the area; at three times the distance the same amount of radiation covers nine times the area. The area over which the same

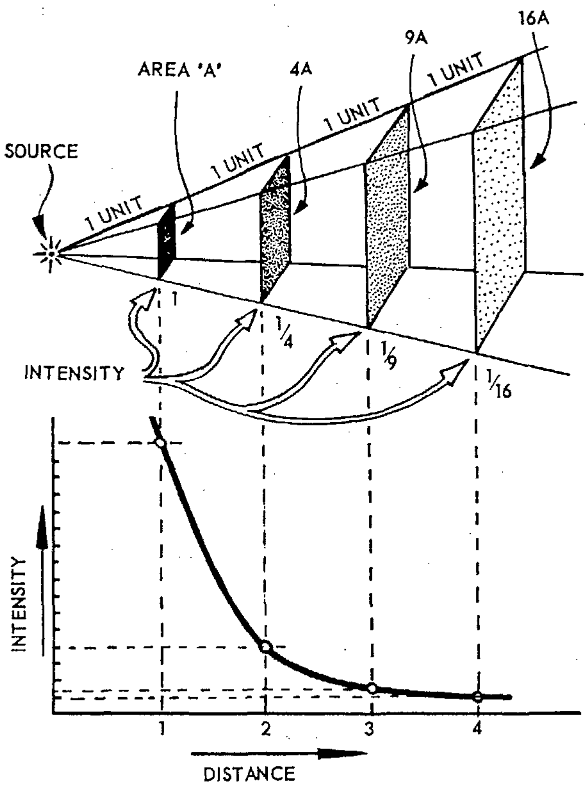

Figure 1.9 Intensity is inversely proportional to the square of the distance from the source

amount of radiation spreads increases as the square of the distance from the source. Hence, the intensity of radiation falling on any small area of constant size must decrease the further this area is from the source; in fact it decreases as the square of the distance from the source.

The first step of Olbers' calculation, therefore, was to observe that the further away a galaxy is from us, the less the intensity of its light reaching us. The radiation from a galaxy, say a hundred million light years away from us, would be one-quarter as intense at the earth as the radiation from a galaxy of equal brightness fifty million light years away.

Now, however, comes the second point of Olbers' argument. Let us look again at Figure 1.9, but this time imagine that the earth is located at the point indicated by " source ", and that we are concerned with all the light reaching us from the cone of rays shown. It is quite true that any one galaxy two units away will have one-quarter as much effect as a galaxy one unit away. On the other hand, there will be precisely four times as many galaxies at the two unit distance whose rays could be coming in within the chosen angles. Thus the total effect of all galaxies at the two unit distance must add up to be the same as the total effect of all galaxies at the one unit distance. The same is true for all other distances. When Olbers added up all the light that must be coming in from any direction, he found that his answer would just keep increasing forever if the universe were considered to go on indefinitely in size. The first answer that Olbers obtained, therefore, was that if the universe were infinite, the intensity of radiation reaching the earth should itself be infinite.

It is clear that there is one effect by which this enormously large answer should be reduced. Galaxies and other matter nearer to us may partially block out the light from more distant galaxies. However, detailed calculations show that even when these effects are included, the whole night sky would still be a blaze of light of the same intensity *as the sun's surface itself.*

The second way out of the paradox is the possibility that the universe does not go on forever but has limits; a similar and related explanation is that the universe started a certain number of years ago so that we would not yet be receiving radiation from the most distant galaxies. Present-day observations, however, already extend to distances of the order of 10^{10} light years, and if no other effects entered, our night sky would almost certainly not be dark. In fact, so much energy in the form of radiation would be reaching us from space that, even if the universe stopped at the limits reached by present-day observations, life could well not be possible on earth.

The darkness of the night sky is due simply to the expansion of the universe. Distant galaxies are rushing away from us, and the further away they are, the faster is their speed. The Doppler effect discussed earlier reduces the frequency of the radiation reaching us from such distant galaxies and, as we shall see in Chapter 19, this reduces the energy of the radiation. Calculations show that it is this reduction in energy due to the expansion of the universe which makes the conclusions of Olbers invalid, and the darkness of our night sky is now well understood.

The point about this story, however, is that here we see one way in which conditions on earth are completely dependent on what is going on in the far distant reaches of the universe 10^{10} light years away, and even much further. Thus the type of suggestion made by Mach, that perhaps inertial forces owe their origin to some effect—some field of influence—originating from the universe at large, and thus that mass itself is determined in this way, may not be so fanciful.

If Mach's suggestion is correct, it may mean that the masses of all objects may be gradually changing as the universe expands. At least this would be expected on the evolutionary theory of the universe, although it would not be true if the " steady state " theory were correct. If masses are actually changing, however, the rate of passage of time itself would be changing. Any time scale based, for example, on the period of motion of a planet in orbit, would be actually changing for this period is related to its mass. Moreover, such a time scale would be changing in a different way from an atomic time scale, so that what is called *dynamical time* and *atomic time* may even not be keeping in step. This is, of course, mere speculation; science can, however, not rule out the possibility that masses may be actually changing and that one cannot automatically think of " a uniform flow of time ".

4.1 KINETIC THEORY OF GASES

Consider a gas inside a container of some sort. Each of the particles is flying around with an average speed which is somehow related to the temperature of the gas; the higher the temperature the faster the average speed of each of the particles.

When a particle hits the side of the container it rebounds without losing energy—that is, it suffers what is called an elastic collision. As explained in previous chapters, in order to have its momentum changed in such a rebound there must have been a force acting on the particle, and in turn by Newton's third law the particle must have exerted a force *on* the wall. It is the sum total of all such forces from the continuous rebounding of particles against the sides of a container that determines the pressure on these sides and thus the pressure of the gas. We can now calculate what this pressure is, on the basis of a number of assumptions. Note what these assumptions are and where they come in, as you go through the argument which follows; they constitute our model or hypothesis.

Let us consider a gas enclosed in a container of volume V and suppose that altogether there are N particles each of mass m. For the moment we will ignore collisions between the particles themselves and simply assume that each particle has a speed v. For the purpose of this calculation let us also consider a spherical container because it makes things a little easier; we could, of course, take any shaped container but the results derived would always be the same irrespective of the shape of the container and the spherical shape is the simplest to use.

We will look to start with at a single collision of one of the particles with the wall. If the direction of the particle before impact makes an angle θ with the normal to the wall it will rebound also at an angle of θ to the normal—just as in the case of light for which " the angle of incidence is equal to the angle of reflection ". This is illustrated in Figure 4.2.

The next important point to know is that in such an elastic rebound the speed v cannot be changed, because the kinetic energy of the particle, that is $\frac{1}{2}mv^2$, must be the same before and after the collision.

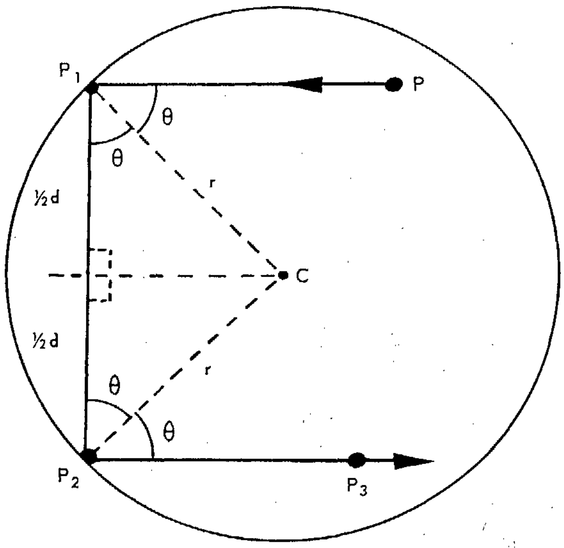

Figure 4.2 Kinetic theory of gases. The particle P rebounds from the walls of its container just as light rays would; $P \rightarrow P_1 \rightarrow P_2 \rightarrow P_3$. The angle of incidence θ equals the angle of reflection. P_1C and P_2C are normal to the walls The distance d between P_1 and P_2 is given by $d = 2r \cos \theta$ because $\frac{1}{2}d = r \cos \theta$

The change in momentum at right angles to the wall is $2mv \cos \theta$, and there is no change in the component of momentum tangentially along the wall. Hence the wall experiences a force outwards at right angles to it whose impulse—see Chapter 3 of the present volume and SHS Chapter 33—is $2mv \cos \theta$. The scattered particle will now move on until it strikes the wall again, and the diagram shows that once again its angle of incidence will be θ. The distance d it travels before the next rebound is given by

$$d = 2r \cos \theta \qquad \ldots . 4.1$$

where r is the radius of the container. This particle will therefore strike the wall a certain number of times each second which can be easily calculated. The speed of the particle is always v so that the number of rebounds per second is $v/d = v/(2r \cos \theta)$. Since each collision gives an impulse to the wall of $2mv \cos \theta$ the total impulse which the wall receives in one second from one particle is given by the formula

$$\text{impulse in one second} = 2mv \cos \theta \times v/(2r \cos \theta) = mv^2/r. \quad \ldots 4.2$$

It is to be seen that this is completely independent of the angle θ, so that this same impulse is given to the wall by each particle irrespective of its direction of motion. There are N particles altogether and hence the total impulse is one second from all the particles is

$$\text{total impulse/per second from all particles} = \mathrm{N}mv^2/r. \quad \ldots 4.3$$

We know however that impulse is force x time, and that when the time is one second the impulse is equal to the force itself.

Hence the total sum of the *magnitudes* of all the outward forces on the wall is given by Equation 4.3, but the pressure P is force per unit area, so that to find the pressure we must simply divide Equation 4.3 by the total area of the container wall $4\pi r^2$. Thus we find

$$\text{pressure P} = \mathrm{N}mv^2/4\pi r^3 \qquad \ldots . 4.4$$

Alternatively, we may write this in terms of the volume V of the container, since $V = 4\pi r^3/3$. Thus we obtain the equation

$$PV = 1/3\ Nmv^2 \quad \ldots\ldots 4.5$$

This is a very important equation for gases, but before we discuss it in detail we can readily make it more general. You may say for example that within a gas, the particles certainly will not all have the same speed. Suppose particle N, for example, has speed v_N.

Then instead of Equation 4.3 we would have that the total impulse per second from all the particles on the wall, which is the sum of all the outward forces on the wall, is

$$\text{sum of magnitudes of outward forces} = m\ \{v_1^2 + v_2^2 + \ldots + v_N^2\}/r \quad \ldots (\text{N terms}) \ldots\ldots 4.6$$

Instead of writing out this cumbersome expression it is much more convenient to use a quantity $\overline{v^2}$ which is the average of all the terms v_1^2, v_2^2 up to v_N^2 such that

$$N\overline{v^2} = v_1^2 + v_2^2 \ldots\ldots v_N^2 \quad \ldots\ldots 4.7$$

The quantity $\overline{v^2}$ is called the **mean square speed** of all the particles. Thus when the particles have different speeds Equation 4.5 becomes simply

$$PV = 1/3\ Nm\ \overline{v^2} \quad \ldots\ldots 4.8$$

It is interesting that the total kinetic energy of all the moving particles in the container—call it E_k—is

$$\begin{aligned} E_k &= \tfrac{1}{2}m\ (v_1^2 + v_2^2 \ldots\ldots v_N^2) \\ &= \tfrac{1}{2}\ Nm\ \overline{v^2} \quad \ldots\ldots 4.9 \end{aligned}$$

so that Equation 4.8 may be written

$$PV = 2/3\ E_k \quad \ldots\ldots 4.10$$

Thus the product of the pressure of the gas and the volume of the container is simply 2/3 of the total kinetic energy of the gas particles within the container. It may now readily be seen that Equations 4.8 and 4.10 must still be true even when we allow the particles to collide with each other because all such collisions are *elastic* collisions for which the sum of the kinetic energies of the two particles involved remains the same. Thus the total kinetic energy of all the particles within the container is independent of whether they are colliding with each other or not, and it is only the total kinetic energy that appears in the above equations.

It can also be shown that exactly the same result is obtained whatever the shape of the container. However, it should be noted again, that the derivation of Equation 4.8 depends critically upon a number of assumptions—these assumptions constitute the so called *ideal gas model.* In our derivation we assumed that the gas is composed of discrete chemically non-interacting molecules which collide perfectly elastically. We further assumed that the volume occupied by the molecules was negligible compared to the volume containing them. Obviously, these assumptions can only be approximations to the true state of affairs where the particles do interact due to intermolecular forces and where they do have finite volumes. There are thus deviations from the ideal gas law which can be detected experimentally. We shall not pursue this matter further in the present case.

We can now inspect Equation 4.8 more closely and see what it means in terms of some of the properties of gases that we can measure.

Boltzmann's constant and absolute temperature. As we have discussed earlier in this chapter, the temperature of a gas is related to how fast its particles are flying about and that if the temperature remains constant so must the average speed of the particles. In particular if the temperature remains constant the total kinetic energy E_k must remain constant. Thus if the temperature is kept the same, Equation 4.8 may be written

$$PV = \text{constant for constant temperature.}$$

This however is simply a law discovered experimentally by Robert Boyle in 1650—see SS Chemistry, Chapter 1 and SHS Chapter 23.

More detailed experiments on the properties of gases, in which the temperature also is allowed to vary, yield the so-called *gas law*—see SS Chemistry, Chapter 1—which may be expressed in the form

$$PV = NkT \qquad \ldots .\ 4.11$$

Here once again N is the number of particles in the gas and T is the temperature in *degrees Absolute or Kelvin.*

The constant k in Equation 4.11 is called the Boltzmann constant and has the value

$$k = 1{\cdot}37 \times 10^{-23} \text{ joules per degree} \qquad \ldots .\ 4.12$$

Equation 4.11 is the gas law which is obtained *experimentally.* By comparison with our Equation 4.8 we can make a most important deduction. The experimental result expressing the product PV in terms of NkT can only be reconciled with theory if we set the right hand side of Equation 4.8 equal to the right hand side of Equation 4.11. We can now see precisely what is meant by the temperature of a gas. If the Absolute temperature of a gas is T then

$$1/3\, m\, \overline{v^2} = kT$$

or

$$\tfrac{1}{2} m\overline{v^2} = 3/2\, kT \qquad \ldots .\ 4.13$$

Thus the Absolute temperature of a gas is directly proportional to the average kinetic energy of each particle. In particular the average kinetic energy of each particle is equal to 3/2 kT. The Boltzmann constant k has become a very well known constant in physics; it is the constant that directly relates the average kinetic energy of each gas particle to the temperature of the gas. Note the units of k, namely joules per degree, given in Equation 4.12 are evident from Equation 4.13, since the left hand side is an energy in joules and T on the right hand side is in degrees Kelvin.

You may now readily see how the Absolute zero temperature arises. It is the temperature at which the kinetic energy of the particles of the gas is zero, so that all the particles have become completely stationary. If E_k is zero the quantity 3/2 kT must be zero, and this can only mean that T must be zero.

In this section we have seen an interplay between what may be termed theoretical physics and experimental physics. Although the present case represents a very simple example, this interplay is typical of the way in which modern physics advances. On the one hand we have a result which has been obtained by performing experiments with gases; this is the gas law of Equation 4.11. On the other hand we can sit down with a piece of paper and, using the laws of mechanics and our ideas or hypotheses of how gases are made up of fast moving particles, simply calculate the result obtained in Equation 4.8. Recall, however, that these ideas, hypotheses or models were themselves developed as a result of many years of experimental work and its consequent interpretation. The comparison of the two equations gives us a clear understanding of what is meant by the term temperature of a gas, and of what is meant by the heat content of a gas; clearly the heat content of a gas is simply the total kinetic energy of all the moving particles within it.

If you study Chapter 5, you will realise this statement regarding the heat content of a gas is over-simplified. It is certainly true for the type of gas which we have considered in which the particles are small units such as atoms—that is, if the gas is a monatomic gas. When the particles consist of molecules made up of two or more atoms the molecule itself can be spinning or turning as it moves along. When energy is added to the gas in this case some of the energy is used up in making the molecules spin and tumble more rapidly rather than increasing the velocity, and this energy does not affect the temperature of the gas.

It is the kinetic energy of movement of the molecules as a whole which determines the temperature of a gas. The speed v in our calculation above thus relates to the speed of the centre of mass of the molecule. The total heat energy in this case has two contributions:—

- *there is the total kinetic energy of the centre of mass movement of all the particles plus*
- *some rotational kinetic energy due to the particles themselves spinning and tumbling.*

14.6 THE ORIGIN OF MAGNETISM

The finite speed of electromagnetic radiation has many consequences Not the least of these is the origin of those forces which have been *called* magnetic forces. In this section we shall see how magnetic forces come about and learn that they are really electrical in nature.

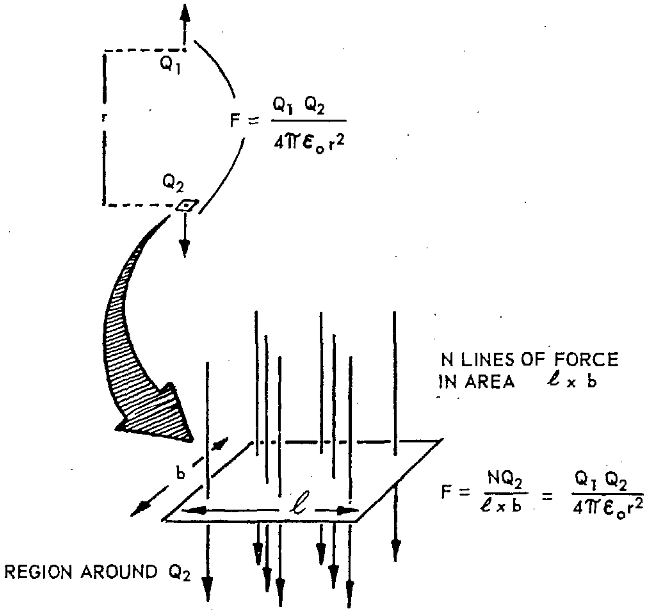

Figure 14.8 The electric field intensity, in the region around Q_2 is the number of lines of force in unit area

Figure 14.8 shows two stationary electrical charges Q_1 and Q_2, separated by a distance r. The Coulomb force between them, F, is given by—see Chapter 6—

$$F = (1/4\pi\varepsilon_0)\, Q_1Q_2/r^2 \qquad \ldots.\ 14.14$$

This is the force that Q_1 exerts on Q_2 and that Q_2 exerts on Q_1.

As the diagram shows and as discussed in Chapter 6, the electric field intensity in the neighbourhood of either charge—say Q_2—can be represented by the number of lines of force per unit area passing through the region about Q_2—that is N/*lb*.

Now consider what happens as charge Q_2 moves with uniform relative speed v, past Q_1 in the direction of l. Charge Q_2 will still experience an electric force depending on the number of lines of force per unit area. However, the motion of the charge brings about a contraction of length so that the lines of force are effectively crowded into a smaller area. The number of lines of force per unit area is therefore larger and the force experienced by the moving charge is *greater* than if the relative speed were zero.

Applying the Lorentz-Fitzgerald contraction to the length we find that the length becomess l' where

$$l' = l\sqrt{1 - (v^2/c^2)}$$

Since b is not affected by the motion, the area lb becomes A′, given by

$$A' = l\sqrt{1 - (v^2/c^2)} \times b.$$

Hence the force F′ experienced by Q_2 in motion is

$$\begin{aligned} F' &= NQ_2/\{lb\sqrt{1 - (v^2/c^2)}\} \\ &= (NQ_2/lb)\{1/\sqrt{1 - (v^2/c^2)}\} \\ &= (1/4\pi\varepsilon_0)\,(Q_1Q_2/r^2)\,\{1/\sqrt{1 - (v^2/c^2)}\} \qquad \ldots.\ 14.15 \end{aligned}$$

which is greater than the Coulomb force by the factor $1/\sqrt{1 - v^2/c^2}$. Clearly since it is the relative velocity v which enters, we can equally well look upon charge Q_1 as the one which moves past Q_2. Thus Equation 14.15 gives the force of Q_1 on Q_2 and of Q_2 on Q_1. They are equal and opposite in direction and are both increased by the same factor.

Equation 14.15 is the fundamental equation giving the force between two moving charges. We can use it for example to calculate the force between two charges which at the instant under consideration moving parallel to each other with velocities v_1 and v_2 respectively. We will consider this case below and then use it to calculate the force between two wires each carrying electric currents.

In order to now use Equation 14.15 we must express the uniform relative velocity v of the two charges in terms of v_1 and v_2. If Q_1 is moving *relative* to Q_2 with speed v then v represents the difference between v_1 and v_2. Therefore v_2 *added* to v must equal Q_1's speed, v_1.

Hence, by the addition of velocities—Equation 14.12—we have

$$v_1 = (v_1 + v_2)/\{1 + (vv_2/c^2)\}$$

and solving for v

$$\begin{aligned} v_1 + v_1\,(vv_2/c^2) &= v + v_2 \\ v\{1 - (v_1v_2/c^2)\} &= v_1 - v_2 \\ v &= (v_1 - v_2)/\{1 - (v_1v_2/c^2)\} \qquad \ldots.\ 14.16 \end{aligned}$$

We must next express the factor $1 - v^2/c^2$ in terms of v_1 and v_2. We have

$$\begin{aligned} 1 - v^2/c^2 &= 1 - \frac{(v_1 - v_2)^2}{c^2\{1 - (v_1v_2/c^2)\}^2} \\ &= \frac{c^2\{1 - (v_1v_2/c^2)\}^2 - (v_1 - v_2)^2}{c^2\{1 - (v_1v_2/c^2)\}^2} \\ &= \frac{c^2\{1 - (2v_1v_2/c^2) + (v_1^2v_2^2/c^4)\} - (v_1 - v_2)^2}{c^2\{1 - (v_1v_2/c^2)\}^2} \\ &= \frac{c^2 - 2v_1v_2 + (v_1^2v_2^2/c^2) - v_1^2 + 2v_1v_2 - v_2^2}{c^2\{1 - (v_1v_2/c^2)\}^2} \\ &= \frac{c^2\{1 - (v_1^2/c^2) - (v_2^2/c^2) + (v_1^2v_2^2/c^4)\}}{c^2\{1 - (v_1v_2/c^2)\}^2} \end{aligned}$$

The factor c^2 in both numerator and denominator now cancel. Moreover you may check that

$$1 - (v_1^2/c^2) - (v_2^2/c^2) + (v_1^2v_2^2/c^4) = \{1 - (v_1^2/c^2)\}\{1 - (v_2^2/c^2)\}$$

Hence we finally have that

$$1 - (v^2/c^2) = \{1 - (v_1^2/c^2)\}\{1 - (v_2^2/c^2)\}/\{1 - (v_1v_2/c^2)\}^2.$$

The force between the two moving charges, expressed in terms of v_1 and v_2, is found by substituting the above value for $1 - v^2/c^2$ into Equation 14.15, thus

$$\mathbf{F}' = (1/4\pi\varepsilon_o)(Q_1Q_2/r^2)\{1 - (v_1v_2/c^2)\}/\sqrt{\{1 - (v_1^2/c^2)\}\{1 - (v_2^2/c^2)\}} \quad \ldots\ldots\ 14.17$$

This expression may now be simplified. As mentioned in Chapter 8, typical speeds of electrons in conductors when electric currents are flowing are only of the order of 10^{-2} m/s, whereas c is 3×10^8m/s. Whenever the speeds v_1 and v_2 refer to moving electrons forming electric currents, therefore, such factors as v_1^2/c^2, v_2^2/c^2 and v_1v_2/c^2 are extremely small—being of the order of magnitude of about 10^{-21}.

Now whenever v_1^2/c^2 is small—and even if it is 1/10—it is a very good approximation to write—see Chapter 13.

$$1/\sqrt{1 - (v_1^2/c^2)} = 1 + (\tfrac{1}{2}v_1^2/c^2).$$

When v_1^2/c^2 is of order 10^{-21} this expression is accurate to 1 part in 10^{21}—more than accurate enough for our purposes. The same replacement can be made for the factor involving v_2^2/c^2 in the denominator of Equation 14.17.

Thus to a very fine approximation, we may rewrite Equation 14.17 in the simplified form

$$F' = (1/4\pi\varepsilon_o)(Q_1Q_2/r^2)\{1 - (v_1v_2/c^2)\}\{1 + (\tfrac{1}{2}v_1^2/c^2)\}\{1 + (\tfrac{1}{2}v_2^2/c^2)\}$$

Even this expression may, however, be simplified further. If the expressions in the brackets are multiplied out the first term is 1; then there are the small terms $+ \frac{1}{2}v_1^2/c^2$, $+ \frac{1}{2}v_2^2/c^2$ and $- v_1v_2/c^2$ which are already so small as to be of order of magnitude 10^{-21}. Further terms involve such products as $(1/4)\ v_1^2v_2^2/c^4$ which are much smaller again—of order of magnitude 10^{-42}—and can be completely neglected.

You may think that even the first group of terms after the 1 could be neglected, being only of order of magnitude 10^{-21} compared to the first term of unity. However as we shall see *these are the terms responsible for the entire phenomenon of magnetism.* Any other terms after these, however, would simply represent tiny corrections to the equations of magnetism.

On multiplying out the factors of Equation 14.18 in this manner therefore, we obtain the result

$$F' = (1/4\pi\varepsilon_o)(Q_1Q_2/r^2)\{1 - (v_1v_2/c^2) + (\tfrac{1}{2}v_1^2/c^2) + (\tfrac{1}{2}v_2^2/c^2)\} \quad \ldots . \; 14.19$$

Note that in Equation 14.19 the quantity

$$(v_1^2/2c^2) + (v_2^2/2c^2) - (2v_1v_2/c^2)$$

is some small positive quantity ΔZ, since $(v_1^2 + v_2^2)/2c^2$ is always greater than $2v_1v_2/c^2$. Thus Equation 14.19 may—on using Equation 14.14—be written

$$F' = (1/4\pi\varepsilon_o)(Q_1Q_2/r^2)(1 + \Delta Z)$$
$$= F + Q_1Q_2\Delta Z/4\pi\varepsilon_o r^2$$

This brings out a most important feature about the forces between uniformly moving charges. Equation 14.15 already showed that the force experienced by moving charges is greater than if they were at rest, since $1/\sqrt{1 - (v^2/c^2)}$ is always greater than one. Our present results shows further that moving charges not only experience the Coulomb force F, but an additional force $Q_1Q_2\Delta Z/4\pi\varepsilon_o r^2$ as well. *This force contains what is usually called the magnetic force and is simply the result of the uniform motion of charged particles.*

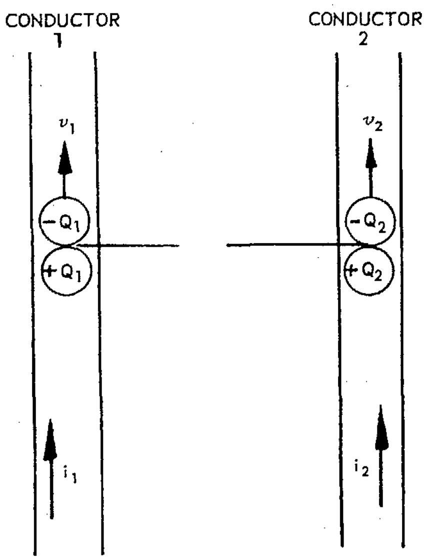

Figure 14.9 The electric currents I_1 and I_2 are due to the drift of the electrons $-Q_1$ and $-Q_2$ at speeds v_1 and v_2

Now consider two long straight conductors carrying currents I_1 and I_2 in the same direction. The currents are caused by the slow drift of electrons moving at speeds v_1 and v_2. The movement of the electrons—shown in Figure 14.9 as $-Q_1$ and $-Q_2$—automatically is associated with stationary charges of $+Q_1$ and $+Q_2$. We shall use Equation 14.19 to determine the individual forces between each pair of charges. We shall then take into consideration the total number of individual charges and obtain the resultant force between the conductors.

(i) Force between *stationary* charges $+Q_1$ and $+Q_2$.

Here both v_1 and v_2 are zero and hence

$F(i) = +(1/4\pi\varepsilon_o)(Q_1Q_2/r^2)$ . . . . the plus sign indicates repulsion.

(ii) Force between $-Q_1$ in motion—speed v_1— and $+Q_2$ at rest, that is $v_2 = 0$.

Here we must use Equation 14.19 leaving in v_1 but putting $v_2 = 0$. We find

$F(ii) = -(1/4\pi\varepsilon_o)(Q_1Q_2/r^2)\{1 + (\frac{1}{2}v_1^2/c^2)\}$ .... the minus sign indicates attraction.

(iii) Force between $-Q_2$ in motion—speed v_2— and $+Q_1$ at rest, that is $v_1 = 0$.

Here we must use Equation 14.19 leaving in v_2 but putting $v_1 = 0$. We find

$$F(iii) = -(1/4\pi\varepsilon_o)(Q_1Q_2/r^2)\{1 + (\tfrac{1}{2}v_2^2/c^2)\}.$$

(iv) Force between $-Q_1$ and $-Q_2$ *both in motion* with speeds v_1 and v_2 respectively. Here Equation 14.19 applies directly, and we have

$$F(iv) = +(1/4\pi\varepsilon_o)(Q_1Q_2/r^2)\{1 - (v_1v_2/c^2) + (\tfrac{1}{2}v_1^2/c^2) + (\tfrac{1}{2}v_2^2/c^2)\}.$$

The total force F between those sections of the conductors which contain simply the charges $+Q_1$, $-Q_1$ and $+Q_2$, $-Q_2$, is the sum of F(i), F(ii), F(iii) and F(iv), taking into account attractive and repulsive forces. Thus

$$\begin{aligned} F &= (1/4\pi\varepsilon_0)(Q_1Q_2/r^2)\,[1 - \{1 + (\tfrac{1}{2}v_1^2/c^2)\} - \{1 + (\tfrac{1}{2}v_2^2/c^2)\} + \\ &\qquad \{1 - (v_1v_2/c^2) + (\tfrac{1}{2}v_1^2/c^2) + (\tfrac{1}{2}v_2^2/c^2)\}] \\ &= -(1/4\pi\varepsilon_0)(Q_1Q_2/r^2)(v_1v_2/c^2) \qquad \ldots\ldots 14.20 \end{aligned}$$

The resultant force is thus one of *attraction* for currents in the same direction.

If instead of considering single moving charges Q_1 and Q_2 we consider some number N_1 and N_2 of each type, as in the case two short sections of thin wires, then the total force between these two current elements distant r apart is still given by Equation 14.20 but with Q_1 replaced by N_1Q_1 and Q_2 by N_2Q_2. Thus we would have

$$F = -(N_1Q_1v_1)(N_2Q_2v_2)/4\pi\varepsilon_0c^2r^2 \qquad \ldots\ldots 14.21$$

It should be noted that this expression only holds accurately for *short thin* current elements; otherwise the distance r would vary between the charges and the equation for the force would require amendment.

Suppose that in conductor 1 there are n_1 charges of Q_1 per metre and n_2 charges of Q_2 per metre in conductor 2. Now current is the rate of flow of charge, and if I_1 and I_2 are the currents in the two wires we have from Equation 7.1—see Chapter 7—that

$$I_1 = n_1Q_1v_1$$

and

$$I_2 = n_2Q_2v_2. \qquad \ldots\ldots 14.22$$

The total number of charges of each sign in a short length Δl_1 of wire 1 is then $n_1\Delta l_1$, and in a short length Δl_2 of wire 2 is $n_2\Delta l_2$. Thus the force between these two current elements is given directly from Equation 14.21, with $N_1 = n_1\Delta l_1$ and $N_2 = n_2\Delta l_2$. Further, on substituting for $n_1Q_1v_1$ and $n_2Q_2v_2$ from Equation 14.22 we finally find that the force between the current elements is *attractive*, and has a magnitude say ΔF given by

$$\Delta F = (1/4\pi\varepsilon_0c^2)(I_1\Delta l_1)(I_2\Delta l_2)/r^2 \qquad \ldots\ldots 14.23$$

Now you may recall that in the above we considered, to start with, the two charges Q_1 and Q_2 such that the line joining them was at right angles to their motion. By precisely the same methods it can be shown that if the angle between the line joining them and the direction of the currents be θ, the force between the two current elements $(I_1\Delta l_1)$ and $(I_2\Delta l_2)$ is attractive for currents in the same direction, and of magnitude

$$\Delta F = (1/4\pi\varepsilon_0c^2)(I_1\Delta l_1)(I_2\Delta l_2)\sin\theta/r^2 \qquad \ldots\ldots 14.24$$

This is precisely the basic law of magnetism expressed in Equation 8.6 *of Chapter* 8. From it all the effects of any one electrical current on another can be deduced, as seen in Chapter 8. The only difference is that the magnetic constant μ_0 is now identified as being equal to $1/(\varepsilon_0 c^2)$. Thus we have

$$\mu_0 = 1/(\varepsilon_0 c^2).$$

This equation connects a constant of *magnetism*—μ_0—with one of electricity—ε_0. The thing that connects them is the square of the *speed of light.* This is surely one of the most profound results of modern physics—magnetism, electricity and light are all fundamentally related.

Actually in 1864 Clerk Maxwell noticed that a comparison between the fundamental laws of electricity and magnetism seemed to involve the speed of light. It was for this reason that Maxwell suggested that all electrical influences must propagate at the speed of light. This led him to the conclusion that if two charges are moving, their effect on each other at any one instant would not be given precisely by Coulomb's law. Maxwell realised that each charge would be feeling the effects due to the other at some short time previously, and he conjectured that such differences from Coulomb's law were probably responsible for the whole field of magnetism.

This very remarkable conjecture by Maxwell also led him to the belief that light itself must be of electro-magnetic character.

Naturally however, Maxwell could not derive the basic formula represented by Equation 14.15 for the true expression for the force between moving charges, expressed in terms of their relative velocity. It is this equation which forms the basis of the quantitative understanding of magnetic phenomena, and its derivation had to await the theory of relativity.

MATTER WAVES

The interference properties of waves discussed in the previous chapter are of great importance in many branches of physics. Perhaps the most spectacular application of wave properties, however, is to the understanding of the behaviour of atomic particles.

In this chapter we will continue the story of the atom which was commenced in Chapter 19 and see how the understanding of the Bohr theory of the hydrogen atom was obtained in a very surprising manner: it is not only light which has the peculiar property of consisting of wave-particles, *but particles themselves—such as electrons—must be considered as wave-packets.*

21.1 THE HYPOTHESIS OF DE BROGLIE

In 1924, eleven years after Niels Bohr proposed his theory of the hydrogen atom, a young French theoretical physicist, Louis de Broglie, put forward a startling theory. In essence de Broglie simply posed the following question: if light, which we know to be a wave motion, also has a particle character, why should not objects which we think of as particles have a wave character?

de Broglie then suggested that perhaps an electron is really a wave-packet of some kind, and that what had been observed previously were simply the particle characteristics of electrons. He pointed out that a wave-packet, such as illustrated in Figure 19.4, could well be " bunched up " enough so that its possible wave-character need not have been detected.

The next step in this line of thought was clearly to consider what the wavelength in the electron wave-packet could be. de Broglie took the case of light as a guide. As we saw in Chapter 19 the energy E of a wave-packet of light and the frequency n are connected by the Planck condition $nh = \mathrm{E}$.

The wavelength λ is connected with the frequency by the equation $c = n\lambda$, where c is the speed of light. Hence

$$\lambda = c/n = hc/\mathrm{E} \qquad \ldots\ldots 21.1$$

de Broglie now re-wrote Equation 21.1 in the form

$$\lambda = h/(\mathrm{E}/c) \qquad \ldots\ldots 21.2$$

because this was a convenient stepping stone for making a guess as to the possible wavelength for an electron wave-packet. He noted that the mass of a photon of energy E is given by E/c^2 and its momentum by E/c, as shown in Chapter 19. Hence the wavelength for a photon wave-packet—Equation 21.2—may be written

$$\lambda = h/\text{momentum} \qquad \ldots\ldots 21.3$$

where the momentum is that of the photon.

At this point de Broglie put forward the hypothesis that Equation 21.3 should also apply for his suggested wave-packets for particles. If a moving electron of mass m_e has speed v, its momentum is $m_e v$. Thus de Broglie suggested that it should be represented by a wave-packet of wave-length λ given by

$$\lambda = h/m_e v \qquad \ldots\ldots 21.4$$

This suggestion by de Broglie inspired the German physicist, Erwin Schrodinger, to apply the concept of electron waves to the hydrogen atom. Schrodinger's dramatic publication of the results of this investigation was made in 1926.

21.2 THE SCHRODINGER THEORY

Although Schrodinger's calculations involved far more complex mathematics than is suitable for this course, his results can be quite easily understood.

Schrodinger imagined an electron wave-packet " in orbit " around a proton in the hydrogen atom. He realised however that in this case any such wave-packet could not remain as such, but must be spread out in the form of a *standing wave* around the orbit.

If you have a taut wire, for example, and give it a pluck at one point, you initially disturb it in the vicinity of that point. However a standing wave is set up in the wire, and the wavelength must be such that there are nodes at each end where no vibration can occur.

Similarly you might imagine a circular hoop of elastic material. If this is given a sharp blow at one point, it would initially be distorted at and near that point. It would soon settle down however to having standing waves around the hoop, of quite definite wavelengths.

Examples of the types of standing waves that would be set up are shown in Figure 21.1.

These standing waves all have one important property. *Their wavelength fits a whole number of times into the circumference of the hoop.*

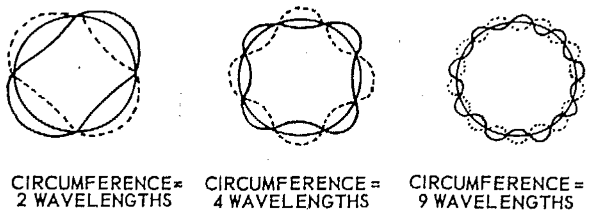

Figure 21.1 Three possible standing waves in an elastic circular hoop

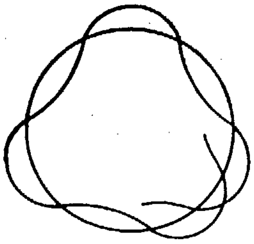

Figure 21.2 Unless a whole number of wavelengths fit into the circular hoop, destructive interference causes the vibrations to die out rapidly

Why is this so? The reason is that any vibration with a different wave-length would be one such as shown in Figure 21.2.

But in this case one part of the wave would be interfering with another and causing *destructive interference*—see Chapter 20. Before very long such a vibration would die out. It might appear at first sight that on being struck the hoop knew the frequency of the standing wave in advance? This cannot be so. The explanation is that the initial complex disturbance is made up of a large number of pure waves of different wavelengths. However, only that particular wave which satisfies the whole number wavelength rule will persist.

Schrodinger realised that the situation would be precisely the same if he imagined an electron wave around a proton in the hydrogen atom. The electron wave must be looked on as a standing wave around the orbit, *with the wavelength fitting a whole number of times in the circumference of the orbit.*

Thus the only stable orbits for electron waves would be ones which fulfilled this condition. Now from Chapter 19 we know that for an electron moving in uniform circular motion of radius r around a proton its speed v—see Equations 19.1 and 19.2—is

$$v = e\sqrt{1/4\pi\varepsilon_0 m_e r} \qquad \ldots\ldots 21.5$$

The de Broglie wavelength λ for such an electron is given by Equation 21.4 as

$$\begin{aligned}\lambda &= h/m_e v = (h/m_e e)\sqrt{4\pi\varepsilon_0 m_e r}\\ &= (h/e)\sqrt{4\pi\varepsilon_0 r/m_e} \qquad \ldots\ldots 21.6\end{aligned}$$

By the Schrodinger condition, however, this must fit a whole number, say j, times into the circumference $2\pi r$ of the orbit in order that the orbit be stable. This condition is therefore

$$(jh/e)\sqrt{4\pi\varepsilon_0 r/m_e} = 2\pi r$$

If we square both sides of this equation, we obtain the result

$$(j^2h^2/e^2)\ (4\pi\varepsilon_0 r/m_e) = 4\pi^2 r^2$$

and hence

$$r = j^2h^2\varepsilon_0/\pi m_e e^2 \qquad \ldots .\ 21.7$$

This is precisely the condition—see Equations 19.6 and 19.20—*which Niels Bohr had to assume when he put forward his theory in* 1913. Schrodinger derived it directly from de Broglie's suggestion that particles should be considered as wave-packets.

Moreover it was realised that on this wave-picture there is an understandable reason for Planck's frequency rule when an atom emits a photon.

For each wave-orbit there is a given wavelength of the electron standing wave. Moreover, there is a corresponding frequency of oscillation of this wave, connected with the wavelength by the relationship $v = (\lambda \times \text{frequency})$. Here v is the electron speed corresponding to the orbit, and is to be considered the speed of the wave around the orbit. Since $\lambda = h/m_e v$ we see that

$$\therefore\ \text{frequency} = v/\lambda = m_e v^2/h \qquad \ldots .\ 21.8$$

Suppose, for example, that an electron has been excited to some wave orbit corresponding to $j = j_2$, say, and is in the process of dropping down to a lower orbit, say with $j = j_1$. During the course of this transition, we can think of both wave-patterns as occurring simultaneously, with the outer one being depleted to build up the inner one. Let us suppose that the frequencies associated with these wave-orbits are n_2 and n_1 respectively, according to Equation 21.8.

Now if such an event occurred with two standing waves producing sound, the note heard would involve the beat frequency between the two standing waves, $(n_1 - n_2)/2$—see Chapter 20.

Similarly the frequency associated with the photon being emitted is $(n_1 - n_2)/2$. This can be shown to yield precisely the Planck condition that the frequency n of the waves in a photon is connected with the energy of the photon by the relationship $E = nh$. Those of you who study Section 21.5 will see in more detail that this is the case.

21.3 DIFFRACTION OF PARTICLES

Schrodinger had been so dramatically successful, after the application of de Broglie's hypothesis to the hydrogen atom, that scientists immediately sought ways of verifying directly that a beam of electrons could be considered as a beam of wave-packets.

What effects are absolutely characteristic of waves rather than particles? Clearly effects to do with interference—see Chapter 20—can only occur with waves and not with particles.

Now one important development in science which had been realised in 1912 was that the short wavelength X-rays which had been discovered by Roentgen could be used for studying the regular lattice arrangement of the particles in a solid—see SS Chemistry, Chapter 4. If a beam of X-rays is allowed to fall on to a solid, each particle of the solid reflects some of the X-rays in all directions, and thereby acts as if it were a little source of X-rays. The combination of, for example, all the reflected X-rays from a solid therefore involves an interference or diffraction pattern—interference occurring between the rays reflected from each of the little lattice sites in the solid.

The study of the nature of such diffraction patterns had, by the time of the Schrodinger theory in 1926, developed into a standard method for determining the detailed lattice structure in all types of solid materials.

It was natural therefore that scientists should attempt the same type of experiments with electron beams. In 1927 Davisson and Germer in America, followed in 1928 by Thomson in England, reported that they had succeeded in producing such diffraction patterns using beams of cathode rays as their electron beams.

This provided direct experimental proof that electrons are indeed little wave-packets of some sort, and a whole field of investigation called electron diffraction arose as an additional method for the investigation of the structure of solid materials.

A modern use of the wave-character of electrons is made with an instrument called an electron miscroscope, in which the reflection of a beam of electron wave-packets can be photographed to give actual pictures of tiny structures. It was by this technique that the photograph in Figure 1.7 of SHS Chapter 1 was obtained; you may recall that this was a photograph of the molecules of a sample of protein.

Naturally the pattern of such an electron beam is not seen with the naked eye, but it can activate photographic emulsion and it is in this way that photographs can be obtained even of large molecules themselves.

It is now known that *all* fundamental particles are to be considered as little wave-packets of " matter-waves " with wavelength given by the de Broglie condition of Equation 21.4. As you saw in SS Chemistry, Chapter 10 and will see further in Chapter 24, one of the constituent particles of a nucleus is the neutron whose mass $m_n = 1846\ m_e$, that is nearly two thousand times greater than that of an electron. Because of this greater mass, the wavelengths associated with neutron wave-packets are very much shorter than for electrons. It is for this reason that neutron diffraction experiments are capable of probing into finer details of the structure of materials than electron diffraction experiments; the shorter the wavelengths associated with the beam the finer the details which can be explored.

You will now realise, therefore, that the detailed understanding of all atomic and nuclear structure depends on a study of waves. The electrons in atoms must be looked upon as an assembly of standing waves. Similarly the detailed understanding of the interior of nuclei themselves depends on the wave-properties of the particles of which they are made.

This is why the term wave-mechanics is employed in describing the mathematics which is used in science today for discussing atomic and nuclear structures.

Strictly speaking, therefore, all matter should be considered to be made up from wave-packets. However it is only on the tiny scale of the atom or of the nucleus that wave-mechanics is of importance. For the explanation of ordinary everyday phenomena, wave-mechanics is unnecessary; everything may be considered to be made up of particles, for which the ordinary laws of mechanics apply. Yet it must be realised that all properties of matter which depend on the structure of the individual atoms or molecules are governed by the wave-like character of the fundamental particles. It is in this way that the wave particles of matter completely determine the properties of the universe in which we live.

21.4 WAVE PICTURE OF ATOMS

At this stage we should briefly enquire how much our picture of atoms should be modified in the light of wave mechanics—a point which was taken up briefly in SS Chemistry, Chapter 10.

Consider, for example, the hydrogen atom. On the Rutherford-Bohr picture the electron was considered to be located at a point, and in a well-defined orbit around the central proton as indicated in Figure 21.3.

On the wave picture, however, the electron is spread out into a standing wave right around the orbit—see Figure 21.3. On the old picture we could imagine that, at a certain instant, the electron would be located at some point P as shown in Figure 21.3, and would be following a definite orbit.

According to wave-mechanics we can never say that the electron is definitely at one point or another. *At any instant it would be equally as likely to be found at any one point around the orbit as at any other.*

Similarly it does not have to lie precisely on the Bohr orbit and there would be some chance of finding the electron somewhat away from the orbit.

Thus wave-mechanics " smears out " any precise knowledge of the location of the electron, and the same is true of its velocity or momentum. Although on the average the electron follows the Bohr orbit, with the appropriate speed, the spread of the standing wave allows a certain probability that the speed can at times have other values too.

When an electron is not " trapped " in an atom, but is one member of a beam of electrons, its position can be located to within the size or spread of its wave-packet. Now a wave packet must contain at least several wave-lengths; hence when the electron is free and travelling in a beam it is possible to locate its position to within a few wave-lengths.

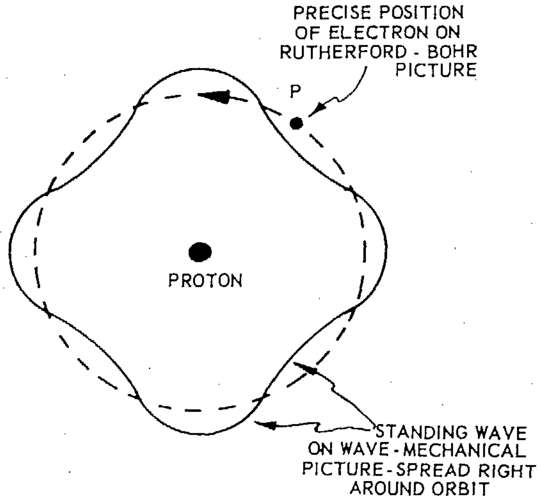

Figure 21.3 Illustration of the wave—mechanical " smearing " of the electron matter wave around an atomic orbit

As you see from Equation 21.4 the slower an electron is travelling the smaller its momentum and hence the larger its wavelength. Thus a low momentum electron cannot be located as accurately as a high momentum electron.

This wave-mechanical picture also applies to the many electrons of complex atoms, except that now there must be a whole host of standing waves—one for each electron. Moreover since electrons repel each other, the standing waves are affected by each other, and the mathematical complexity becomes extremely great.

Scientists have, however, performed a very large number of calculations for complex atoms using wave-mechanics, and in all cases in which the calculations have been accurately performed detailed agreement with experiment has been obtained. As we saw in SS Chemistry, Chapter 10, wave-mechanical descriptions of complex atoms give rise to the so-called shell structure of the electron clouds around the central nuclei, and thus give rise to an understanding as to why elements can be arranged in the form of the periodic table.

Where accurate calculations have proved possible, detailed agreement has also been achieved with the observed line spectra of elements. It is thus believed that the wave-mechanical picture is capable of giving agreement with all atomic and molecular phenomena. Wave mechanics has also been extensively used in the field of nuclear physics and in the detailed understanding of nuclear reactions and the structure of nuclei—see Chapters 23 and 24.

Naturally, however, if we draw on past experiences in science it is to be expected that the time will come when some newly discovered phenomenon will require an improvement to our picture or model which we use to describe nature. If this is to be the case with wave-mechanics it will almost surely come not from the field of chemistry—which involves the structure of atoms and molecules—nor from the field of nuclear physics—which involves the structure of nuclei. Wave mechanics has been very extensively applied and tested in these fields of science. If any such modification or refinement is to be found necessary it will probably arise from a field of study which is in its infancy—the study of the very interior structure of a " basic " particle such as the proton itself—see Chapter 24.

21.5 DERIVATION OF THE BOHR ASSUMPTIONS

Recall from Chapter 19, that the Bohr theory of the hydrogen atom relied on two basic assumptions. These could be expressed in the following form:

- that there are stable non-radiating orbits for which the electron's angular momentum is equal to $h/2\pi$ multiplied by a whole number j.
- that when an electron drops from one orbit to another the frequency n is connected with the energy E of the wave-packet by the relationship, first proposed by Planck, that $E = nh$.

We can now see in detail how these assumptions are two consequences of the wave-mechanical picture.

To start with, as we now know, any standing wave must have a wavelength λ which fits a whole number j times into the circumference $2\pi r$ of an orbit. Thus

$$j\lambda = 2\pi r$$

From the de Broglie condition—Equation 21.4—, however, we have $\lambda = h/m_e v$. Hence

$$jh/m_e v = 2\pi r$$

and so

$$m_e v r = jh/2\pi \qquad \ldots . \; 21.9$$

This is identical with Equation 19.18, and is precisely the first of the above-mentioned assumptions which Bohr found it necessary to make; it also yields as we have seen, Equation 19.20 and hence Equation 21.7.

Secondly, it was mentioned in Section 21.2 that if the electron is dropping from one wave orbit—j_2—to a lower wave-orbit—j_1—the two standing waves would be present simultaneously during the transition period. It might be expected therefore that the frequency associated with the photon being emitted be the frequency of the beat "note" $(n_1 - n_2)/2$. We will now see what this is.

The frequency of a given standing wave is given by Equation 21.8 as $m_e v^2/h$. From Equation 21.9 we may replace the quantity $m_e v^2$ by $j^2 h^2/4\pi^2 m_e r^2$ and use the value given by Equation 21.7 for r. We thus find that Equation 21.8 becomes

$$\text{frequency} = (m_e e^4/4h^3\varepsilon_o^2)\,(1/j^2) \quad \ldots\ldots 21.10$$

Thus as the electron drops from level j_2 to level j_1 the beat frequency $n = (n_1 - n_2)/2$ is

$$n = (n_1 - n_2)/2 = (m_e e^4/8h^3\varepsilon_o^2)\,(1/j_1^2 - 1/j_2^2) \quad \ldots\ldots 21.11$$

If $j_1 = k$ and j_2 is simply written as j this is identical to Equation 19.15 which yields the frequencies of all the spectral lines observed for hydrogen and accurately gives rise to the hydrogen constant—see Chapter 19.

Thus on the wave-mechanical picture the photon frequency follows as the beat frequency between the two electron standing waves. The fact that nh is equal to the energy difference between the two standing waves, and thus to the energy E of the photon, is clear. From Equation 19.14 or 19.15 we have that

$$E_{j_2} - E_{j_1} = (m_e e^4/8\varepsilon_o^2 h^2)\,(1/j_1^2 - 1/j_2^2)$$

and hence from Equation 21.10

$$E = E_{j_2} - E_{j_1} = nh \quad \ldots\ldots 21.12$$

THE NUCLEUS, annual review of the Nuclear Research Foundation within the University of Sydney and the School of Physics, 1965 (eleventh year), 64 p.

AUTRICHE / AUSTRIA

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(Editeur : Comite d'action des professeurs de physique des hautes écoles de formation générale de Vienne), rédacteur : Dr. Walter Kranzer, Stubenbastei 6-8, Wien I.

Sommaire du N° 11, avril 1966 (extraits)

- Weltraumprobleme und Schule (Les problèmes de l'espace et l'école)
- Die Bausteine der Materie (Les éléments de base de la construction de la matière)
- Die spezielle Relativitätstheorie als Unterrichtsthema (La théorie de la relativité) restreinte, comme sujet d'enseignement).

BELGIQUE / BELGIUM

Pour compléter la formation du corps enseignant scientifique, les Autorités belges organisent, entre autres, des stages réguliers : Gand(1), Namur(2), et des cours internationaux post-universitaires : Mons(3). A ces derniers cours sont invités de nombreux participants étrangers.

Voici quelques publications du Ministère de l'Education nationale et de la Culture, secrétariat général à la réforme de l'enseignement moyen, rue de la Loi 155, Bruxelles :

- Journées d'études, Studie Dagen, consacrées à l'enseignement de la physique au niveau de l'enseignement secondaire, 1961
- Physique du 20ème siècle, 4 cours internationaux post-universitaires de perfectionnement pour Docteurs et Licenciés en physique, 1962
- Documentation 20, Le système MKSA (1962)
- Documentation 24, Physique - Etude de l'oscillographe cathodique - Etude de l'électroscope de Wulf - Quelques expériences non classiques.

Pour assurer au corps enseignant l'usage d'un matériel ad hoc, a été fondé, vers 1949, le Centre technique de Gand(4), auquel ont été confiées, en particulier, les missions suivantes :

- Centraliser la documentation relative au matériel didactique des sciences de l'enseignement moyen
- Promouvoir l'étude et l'organisation des laboratoires de sciences
- Réparer les appareils défectueux
- Construire en série des appareils selon un prototype donné
- Construire en série des appareils d'expérience pour élèves
- Procéder à la confection de diapositives.

REFORME DE LA LICENCE EN SCIENCES PHYSIQUES, Prof. H. Sauvenier, Université de Liège.(5)

Dans toutes les sections universitaires, les professeurs et les étudiants déplorent la surcharge des programmes qui entraîne la surcharge des enseignants et des enseignés. Tout professeur tient, à juste titre, à tenir ses auditeurs au courant des derniers progrès de la Science. Il en résulte un accroissement annuel de la matière enseignée qui n'est pas toujours compensé par la suppression de certains chapitres moins à la page. Beaucoup d'étudiants, parmi les meilleurs, se plaignent de ne pas disposer d'assez de temps libre pour la

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1. 2. Pour information, s'adresser aux organisateurs respectifs, MM. J. Mielants et J. Lohisse. Inspecteurs de l'enseignement moyen, Ministère de l'Instruction publique, Bruxelles.
3. Pour information, s'adresser à M. J. J. van Hercke, Inspecteur, Secrétariat général de la réforme de l'enseignement secondaire, Ministère de l'Education nationale et de la Culture, Bruxelles.
4. Voir J. Lohisse, Problème d'actualité, Journées d'études, 1961, p.7
5. Extrait du "Bulletin de l'Association des licenciés et docteurs en sciences physiques diplomés de l'Université de Liège".

lecture, les réflexions personnelles ou les contacts humains avec leurs camarades des autres disciplines.

Le Conseil d'Administration a invité la Faculté des Sciences à lui faire des propositions d'aménagement de cours et d'horaires en vue de la réforme de la licence en sciences physiques. Après de nombreuses heures de discussion, le jury de cette section a mis sur pied un projet qui a reçu l'approbation de la Faculté et du Conseil d'Administration et entrera en vigueur à la rentrée académique de 1965. Cette approbation entraîne l'abrogation tacite des arrêtés royaux et ministériels actuellement en vigueur.

Voici les grandes lignes de ce projet :

Première licence

Toutes les matières légales obligatoires seront enseignées en première licence ; Il en résulte que le cours de Chimie Physique passe en première licence. Toutefois le nombre d'heures de cours (Th) et surtout de travaux pratiques (Pr) subit une réduction notable. Le programme de première licence s'établit comme suit :

Titres des cours	Nombre d'heures			
	Th	Pr	au lieu de Th	Pr
Compléments de mathématiques (1ère partie	30	15	45	
Physique générale approfondie				
Optique physique, spectroscopie,	40	60	45	120
Electricité, électronique	40	50	45	90
Physique atomique et moléculaire	40	40	45	60
Physique nucléaire	30	15	15	30
Compléments de mécanique analytique	40	15	60	-
Calcul des probabilités et théorie des erreurs d'observation	20	15	30	15
Physique théorique et mathématique	75	30	75	-
Chimie physique	40	30	60	60

En plus de l'apparition du cours de Chimie Physique, on remarque la disparition du partim astrophysique qui devient un cours libre, des partim thermodynamique et optique cristalline.

Seconde licence

Mais la grande innovation consiste à ne rendre obligatoires, en 2ème licence, que trois cours, à savoir :

Compléments de mathématiques
Un cours à option
Epreuve approfondie

ces deux derniers étant légalement obligatoires.

Les autres cours sont choisis par l'étudiant suivant ses goûts personnels. Toutefois, afin de le guider, on lui suggère un certain nombre d'orientations qui le préparent à la spécialisation qu'il souhaite embrasser. Il s'agit de :

Physique théorique et mathématique
Physique nucléaire
Physique de l'état solide
Astrophysique et physique spatiale
  (A) tendence expérimentale
  (B) tendance théorique
Spectroscopie atomique et moléculaire
Enseignement secondaire.

Cette liste n'est qu'exemplaire et non limitative.

Après avoir décidé du sujet du mémoire et, partant, de son orientation, l'étudiant choisit, avec l'accord du professeur qui dirige le mémoire, un nombre de cours dont l'importance horaire, ajoutée aux trois cours obligatoires, atteint un minimum de 330 heures de cours et de travaux pratiques.

Dans la liste des orientations apparaît la rubrique "enseignement secondaire". Les statistiques montrent que plus de la moitié des physiciens font carrière dans l'enseignement secondaire. Il faut reconnaitre que, dans l'état actuel des choses, ils sont mal préparés à cette tâche. La nouvelle orientation permet de remédier à cette situation ; elle offre aux étudiants qui, dès la fin de la 1ère licence, ont décidé d'entrer dans l'enseignement secondaire, la possibilité d'acquérir une certaine expérience du métier de professeur. Le cours qui leur est destiné, intitulé "Physique générale , méthodologie de la physique", sera orienté de manière à permettre une révision approfondie des chapitres fondamentaux de la Physique, l'examen du mouvement des idées et des conceptions au cours de l'évolution de la Physique. Les étudiants feront eux-mêmes un certain nombre d'exposés et devront mettre au point des expériences de démonstrations de cours. Ceci ne constitue en aucune manière une duplication du cours de méthodologie spéciale qui reste dans le cadre de l'agrégation de l'enseignement secondaire du degré supérieur.

Voici la liste des cours théoriques (Th) et travaux pratiques (Pr) actuellement organisés dans le cadre des matières légales :

	Titres des cours	Nombre d'heures	
		Th	Pr
1 b	Compléments de mathématiques (2ème partie) I	30	15
1 c	Compléments de mathématiques (2ème partie) II	30	15
1 d	Compléments de mathématiques (partim : fonctions spéciales de la physique)	15	15
2 e	Astrophysique et physique spatiale	40	40
2 f	Radiocristallographie	30	60
2 g	Hydrodynamique et acoustique	15	-
2 h	Optique géométrique	15	-
2 i	Physique de l'état condensé	15	30
2 j	Physique nucléaire (compléments)	45	60
2 k	Méthodologie de la physique	60	75
2 l	Astrophysique théorique	20	10
2m	Compléments d'astrophysique théorique	20	30
2 n	Compléments de spectroscopie optique atomique et moléculaire	30	-
2 o	Optique et astrophysique instrumentale	30	-
2 p	Hydrodynamique physique	25	15
5 b	Physique théorique et mathématique (2ème partie)	45	30
5 c	Physique théorique et mathématique (compléments)	45	30
5 d	Physique théorique et mathématique (partim : état solide)	30	-
7 e	Physique industrielle	45	40
7 f	Physique biologique	22,30	30
7 g	Spectroscopie et astrophysique	30	60
7 h	Phénomènes radioactifs (partim : aspect expérimental	30	18
7 i	Phénomènes radioactifs (partim : aspect théorique	30	18
7 j	Mécanique statique	30	-
8 a	La physique expérimentale	30	-
8 b	La physique mathématique	30	-

La seconde épreuve comporte un examen sur :

a) le cours 1 b) ;

b) - pour les étudiants choisissant l'orientation Physique théorique et mathématique : les cours 1 c), 1 d), 5 b) et 5 c) ;
- pour les étudiants choisissant l'orientation Physique nucléaire : les cours 2 j) et 5 b) ;
- pour les étudiants choisissant l'orientation Physique de l'état solide : les cours 2 f), 2 i), 5 b) et 5 d) ;
- pour les étudiants choisissant l'orientation Spectroscopie : les cours 2 i), 2 h), 2 n) et 5 b) ;
- pour les étudiants choisissant l'orientation Astrophysique et physique spatiale :
  - tendance expérimentale : les cours 2 e), 2 l), 2 n) et 2 o) ;
  - tendance théorique : les cours 2 e), 2 l) et 2 m).

  En outre : - les cours 1 d) et 2 p) sont conseillés ;
  - les étudiants seront invités à choisir un autre cours théorique, tel que le 1 c), le 5 b), le 5 d) ou le 7 i) ;
- pour les étudiants choisissant l'orientation Enseignement secondaire : le cours 2 k) ;

c) une épreuve approfondie sur des matières 8 a) ou 8 b) ;

d) au moins un des cours à option 7 a) à 7 j), de manière à ce que l'importance horaire totale de cours et de travaux pratiques de la 2ème épreuve atteigne un minimum de 330 heures.

Cette réforme qui sera mise à l'essai pendant une période de deux ans donne à tous les étudiants de 1ère licence une formation commune, à ceux de 2ème licence un début de spécialisation, tout en réduisant d'une manière appréciable, surtout en 2ème licence, le nombre d'heures de cours et de travaux pratiques.

L'ENSEIGNEMENT PROGRAMMÉ DANS LES SCIENCES PHYSIQUES[1], L. D'Hainaut.

1. Ce qu'est l'enseignement programmé

L'instruction programmée est une technique pédagogique basée sur les études expérimentales conduites par J.B. Skinner dans le domaine des comportements d'apprentissage chez l'animal et chez l'homme (1) (2).

De ces études, il résulte que l'acquisition est d'autant plus rapide et la rétention d'autant meilleure que la matière à étudier est morcelée et que l'acte d'apprendre est vite récompensé. Skinner utilise le terme plus objectif de "renforcé" car il s'impose de ne traiter que l'observable et non des interprétations subjectives relatives à la pensée ou aux sentiments. Cette attitude scientifique introduite en psychologie par Watson confère évidemment une grande valeur aux résultats obtenus.

Dans l'enseignement programmé, on présente donc à l'étudiant un texte ou une bande magnétique portant de petites unités d'information - nous les appellerons des "mailles" (frames)[2] - suivies d'une question. Avant de passer à la maille suivante, l'étudiant doit répondre à cette question et est immédiatement informé de l'exactitude de sa réponse.

Quel que soit le niveau ou l'intelligence de l'étudiant, la proportion de mauvaises réponses ne doit pas excéder 5 à 10 %, car le but de la question n'est pas de contrôler la manière dont la matière a été acquise mais de renforcer cette acquisition c'est-à-dire, en termes courants, de donner à l'élève une satisfaction dont le rôle est essentiel dans le mécanisme de l'apprentissage (4).

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[1] Extrait de la revue: Association belge des professeurs de physique et de chimie, N°2, mai 1964, p. 69 à 78.

[2] Certains auteurs utilisent le mot item, d'autres le terme cadre ; nous leur préférons "maille" qui rend à la fois l'idée d'unité élémentaire et de liaison de structure (frame).

Il existe trois types principaux de programmes :

1. Les programmes linéaires[1] à réponse construite imaginée par Skinner : l'étudiant doit écrire ou dire la réponse (overt response ou réponse énoncée) ou même simplement la penser (covert response ou réponse sous-entendue). Dans ses programmes, Skinner insiste sur la nécessité d'écrire la réponse (3) mais des études récentes (13) ont montré qu'il n'était pas toujours indispensable d'énoncer la réponse, en particulier pour les élèves les mieux doués (13').

2. Les programmes linéaires à choix multiples imaginés en 1929 par Pressey(5) où on propose à l'étudiant plusieurs alternatives parmi lesquelles il doit choisir la bonne réponse.

3. Les programmes à aiguillages (branching programs) de Crowder (6) formés d'unités d'information plus longues et terminées par une question dont le but n'est plus de "renforcer" l'apprentissage mais de déterminer le niveau de connaissances ou d'acquisition ; selon que la réponse est bonne ou mauvaise, l'étudiant avance dans le programme ou est branché sur des parties comportant des explications complémentaires.

Les programmes linéaires sont souvent présentés sous forme de feuilles séparées qui peuvent être introduites dans une machine dont le rôle est de simplifier au maximum la tâche de l'étudiant, d'empêcher les retours en arrière et d'éviter ainsi la tricherie ou la perte de temps. L'usage de ces machines n'est cependant pas indispensable et des expériences menées par l'Université de Californie et les "Bell Laboratories" ont montré qu'on pouvait obtenir les mêmes résultats avec un texte qu'avec une machine (7)

Les programmes à aiguillages sont généralement présentés sous forme de "livres brouillés" (scrambled books) (8) (9).

2. L'usage conventionnel de l'enseignement programmé dans les sciences physiques.

Principes.

On pense généralement que l'enseignement automatisé - plus particulièrement sous la forme de programmes linéaires - est bien adapté à l'apprentissage de tâches mécaniques qui requièrent plus de routine que de compréhension globale. L'algèbre est d'ailleurs une des branches pour lesquelles on a écrit le plus de programmes.

Restreint à ce rôle secondaire, l'enseignement programmé est accepté par la plupart de ceux qui s'en sont préoccupés. Cette conception est d'autant plus facilement admise par le personnel enseignant qu'elle soulage le professeur des tâches fastidieuses sans le remplacer dans l'aspect essentiel de son rôle.

On admet aussi généralement que la pédagogie cybernétique s'applique bien à des disciplines qui traitent de faits matériels et de concepts tirés de faits matériels ou qui s'y appliquent directement.

Remarquons cependant bien que ces limitations sont le fruit de l'opinion des partisans les moins chauds de l'enseignement programmé mais qu'elles ne reposent sur aucun fait expérimental, ni même - à ma connaissance - sur aucune théorie pédagogique structurée et cohérente. Les enthousiastes de l'instruction programmée n'acceptent pas ces restrictions et il existe plus d'un programme - en particulier le cours d'analyse du comportement de Holland et Skinner - qui témoignent en leur faveur.

Application à l'enseignement des sciences physiques.

Les sciences physiques concernent essentiellement le domaine des faits matériels où l'accord sur l'opportunité de l'enseignement programmé est assez général et un grand nombre d'éditeurs n'ont pas hésité à publier des programmes consacrés à des chapitres de physique et de chimie mais il existe peu de programmes d'ensemble (21).

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[1] C'est-à-dire qui font lire à tous les étudiants toutes les mailles l'une après l'autre dans le même ordre.

En chimie, l'étude des formules, des équations et des exercices numériques est surtout une question de routine qui exige une trop grande proportion du temps si chichement imparti au cours et c'est dans ce domaine que les élèves faibles ou retardés éprouvent le plus de difficultés : l'enseignement programmé trouverait là un champ d'application idéal mais à l'heure actuelle, il n'existe qu'un texte programmé (en anglais) traitant spécifiquement de ces matières (10).

L'enseignement rationnel de la chimie moderne repose sur des faits matériels et expérimentaux inaccessibles à la classe : la structure interne des atomes. Ici encore, l'instruction programmée doit permettre une assimilation plus rapide et plus profonde de la matière ; il existe dans ce domaine quelques programmes (11) dont un est de niveau très élémentaire (12). On est même parvenu à enseigner avec succès les concepts et les représentations de la théorie cinétique des gaz à des enfants de niveau primaire (13).

En physique, la plupart des programmes traitent de la mécanique ou des théories apparentées, probablement parce que les exemples et les faits cités peuvent être brièvement décrits et concernent des phénomènes familiers. Nous verrons toutefois que cette limitation n'est pas nécessaire et qu'il est possible d'intégrer l'enseignement programmé dans la méthode expérimentale.

A côté des programmes scolaires de physique, il existe de nombreux textes programmés d'électricité et d'électronique destinés à l'enseignement technique et surtout à la formation et au perfectionnement du personnel des industries (14) : c'est peut-être dans ce domaine que l'instruction programmée a le mieux prouvé son utilité et son efficacité.

3. Valeur de l'enseignement programmé.

Quand on parle d'instruction programmée, il ne faut jamais oublier que tout ce que nous en savons ne résulte pas des vues abstraites de pédagogues ou de philosophes mais découle immédiatement de faits expérimentaux, même et en particulier la théorie psychologique qui explique et supporte ce mode d'enseignement. Celle-ci ne fait jamais appel à d'autres termes que ceux qui concernent le comportement observable et s'interdit toute introspection ou toute interprétation des faits. Les programmes eux-mêmes sont mis au point empiriquement, maille par maille avec des élèves et testés sur de nombreux groupes d'étudiants (15).

Il me paraît donc aussi mal venu d'exprimer à priori des doutes sur son efficacité que de considérer la relation fondamentale de la mécanique comme une affaire d'opinion. Par contre, la valeur de cette pédagogie cybernétique est ouverte à la discussion sur le plan plus philosophique que scientifique de la formation harmonieuse de l'individu.

L'instruction programmée est un mode de conditionnement et certains esprits en seront choqués mais, en réalité, ce qui les heurte le plus, ce n'est pas le fait qu'elle soit un conditionnement mais plutôt qu'elle ne s'en cache pas et que la théorie dont elle est issue étudie spécifiquement les conditionnements (16). Quand un professeur souligne inlassablement d'un trait rouge (agent de renforcement négatif ou dans le langage subjectif, punition) le second double "l" du mot "parallèlle" ne conditionne-t-il pas l'élève fautif à l'orthographe correcte ? La seule différence est que personne n'y pense et qu'au lieu de conditionner par la récompense, on conditionne par la punition : c'est moins efficace et plus désagréable.

Personne ne nie plus l'avantage de la méthode socratique et de la pédagogie active bien que celles-ci n'aient jamais fait l'objet d'une étude expérimentale scientifique. L'enseignement programmé qui substitue aussi une forme de dialogue au monologue n'est autre qu'une variante de ces méthodes applicables pour toutes les questions posées à tous les élèves d'une classe.

Le reproche le plus fondé qu'on puisse formuler à l'égard de l'enseignement automatisé est qu'il ne permet guère à l'élève de s'exprimer par des phrases dans la branche enseignée. Toutefois il facilite l'acquisition d'un vocabulaire précis et il peut être complété par les séances de discussion et de travail de groupe que proposent les plus modernes des pédagogues (17).

4. L'enseignement programmé et la pédagogie de la redécouverte.

La pédagogie de la redécouverte, dans sa conception idéale, est l'expression la plus complète des méthodes actives dans l'enseignement des sciences : l'élève amené à retrouver lui-même les faits qu'il doit apprendre applique naturellement et intuitivement la méthode scientifique, comprend et retient mieux les faits qu'il a découverts lui-même. Cette meilleure assimilation résulte, partiellement au moins, de la satisfaction qu'éprouve l'élève à trouver la solution du problème qui lui était posé.

C'est précisément sur la valeur éducative de la récompense qu'est basé l'enseignement programmé et on pourrait croire qu'il n'est pas fondamentalement différent de la pédagogie de la redécouverte. Cette similitude n'est qu'apparente.

D'abord, l'attribution, dans la pédagogie classique, d'une valeur éducative à la satisfaction de la redécouverte résulte de la convergence d'une conviction d'origine introspective, de théories psychologiques et de constatations de faits particuliers mais elle n'est pas la conséquence immédiate de l'expérimentation objective sur les comportements d'apprentissage. Or cette étude scientifique objective montre que le renforcement (récompense) est effectivement un facteur essentiel d'apprentissage mais que "l'atomisation" de la matière à enseigner en est un autre que la pédagogie de la redécouverte néglige entièrement car le morcellement des difficultés qu'implique toute pédagogie n'a rien de commun avec leur émiettement tel qu'il est pratiqué dans les cours programmés.

La pédagogie de la redécouverte conduit l'élève dans une recherche mais elle l'abandonne au moment le plus difficile : celui où il doit combiner les différents éléments d'information qu'il a découverts et tirer la conclusion ou la synthèse qui le mèneront au bout de son raisonnement. La valeur éducative de cet hiatus est contestable : il donne sans doute à l'élève qui le surmonte une récompense par le sentiment d'accomplissement que procure la difficulté vaincue mais, comme le souligne B. Resnick (19), rien ne prouve que la puissance de renforcement de cette satisfaction est supérieure à l'efficacité, démontrée expérimentalement, d'un grand nombre de petits renforcements acquis pas à pas dans la progression du raisonnement.

Il ne faut d'ailleurs pas oublier que la méthode de la redécouverte est le fruit d'études qui ont porté principalement sur la pédagogie de l'enfant. Dans ce domaine, non seulement les matières scientifiques enseignées exigent un effort de synthèse plus réduit et ne laissent donc guère d'hiatus au moment de la conclusion mais les élèves ont une soif d'apprendre gargantuesque et omnivalente qu'on ne retrouve plus sous une forme aussi pure même chez les plus motivés et les plus doués des adolescents.

D'autre part, la satisfaction d'accomplissement et l'apprentissage par la redécouverte n'existent que si l'étudiant franchit l'obstacle qu'on lui oppose : en cas d'insuccès bien des élèves se décourageront et les plus faibles apprendront peut-être à tolérer leurs erreurs. Le meilleur moyen d'avoir la certitude que la majorité des élèves surmonteront la difficulté est encore de les guider pas à pas avec des questions conçues et testées de manière que tous puissent y répondre : on en revient à la conception d'un enseignement programmé.

Enfin, il est peu douteux que, dans la réalité des classes surpeuplées, des programmes surchargés et des horaires de sciences réduits, quels que soient les qualités et les efforts du professeur, la méthode de la redécouverte ne peut pas être pleinement appliquée ni entièrement profiter à tous les élèves pendant toutes les leçons.

Il ne faudrait cependant pas conclure que la pédagogie de la redécouverte n'est pas entièrement adaptée à l'enseignement des sciences. Elle est incontestablement la méthode la plus intelligente et c'est dans le domaine scientifique qu'elle trouve peut-être le champ d'application le plus valable mais ce n'est pas une panacée : elle ne s'applique pas indistinctement à tout et elle a parfois besoin d'être complétée particulièrement pour être profitable aux moins doués car rien ne démontre qu'elle enseigne par elle-même le processus de découverte. Comme le dit Polya - cité par Couffignal (20) - "il faut apprendre à démontrer mais aussi apprendre à deviner".

5. L'enseignement programmé et la méthode expérimentale

L'instruction programmée est, à première vue, un enseignement dépourvu d'expériences et elle pourrait paraître, de ce fait, condamnable sans appel dans le domaine des sciences physiques.

Un examen plus approfondi nous montrera, au contraire, que l'enseignement programmé, loin de s'opposer à la méthode expérimentale, la complète, la prolonge et renforce son efficacité.

Il faut d'abord noter que toutes les matières enseignées ne résultent pas d'expériences réalisées en classe (théorie atomique, problèmes, formules chimiques) et que, jusqu'à présent, la plupart des cours programmés ont précisément traité de ces points, ou, tout au plus, de matières qui font appel à des faits d'observation plutôt qu'à des expériences. Dans cet ordre d'idées, l'enseignement programmé a aussi utilisé la description écrite d'expériences simples mais difficilement réalisables en classe, telles que les expériences d'apprentissage sur les animaux (3).

Toutefois, limiter l'utilisation de la pédagogie cybernétique en sciences à ce type d'enseignement serait ramener son rôle à celui d'un accessoire intéressant peut-être, mais à portée trop restreinte.

Le rôle de l'instruction programmée dans l'enseignement des sciences physiques doit être de servir d'instrument d'analyse d'expériences réalisées par les élèves ou par le professeur et de guider les étudiants au moment où ils doivent tirer des conclusions, de les amener <u>sans exception</u> à la synthèse, parfois difficile, des éléments d'information que l'expérience et son analyse leur ont fournis. La pédagogie programmée est même, à mon sens, le seul moyen de faire profiter <u>pleinement</u> tous les élèves d'une classe d'une expérience qu'ils exécutent ou que le professeur effectue devant eux. C'est seulement ainsi que <u>chaque élève</u> pourra tirer toutes les implications et toutes les conséquences des faits qu'il a observés et pourra les emboîter exactement dans une synthèse harmonieuse.

L'application, dans cet esprit, de l'enseignement programmé en sciences fait l'objet d'une expérience conduite avec des élèves du cycle inférieur : il s'agit de rechercher, grâce à quelques expériences bien choisies et un programme bien mis au point quelles matières on peut avantageusement enseigner en chimie élémentaire à de jeunes élèves et en combien de temps on peut leur faire acquérir ces connaissances. Les résultats de ces expériences feront l'objet d'un prochain article.

6. Conclusion.

L'instruction programmée n'a pas la prétention d'être une méthode universelle mais son efficacité a été démontrée dans plus d'un cas particulier et la grande extension qu'elle prend en ce moment aux Etats-Unis laisse supposer qu'elle s'imposera en Europe et qu'elle ne restera pas confinée à l'enseignement des faits matériels.

Un des inconvénients de la pédagogie cybernétique réside dans la grande difficulté de l'élaboration des programmes. Le travail préparatoire exige une grande rigueur dans le choix des matières et une précision inhabituelle dans la définition des buts à atteindre ; la préparation des mailles requiert patience, minutie et ingéniosité ; on a bien tenté de trouver des méthodes générales de construction des mailles (15) mais ces méthodes n'apparaissent pas nettement supérieures à la pratique empirique. La réalisation d'un programme exige des contrôles sur des étudiants au fur et à mesure de l'avancement des mailles, en fin de chapitre et en fin de cours. A ces difficultés d'élaboration s'ajoutent des difficultés d'édition et l'impossibilité de traduire et peut-être d'adapter valablement un programme d'une langue à l'autre.

Ces circonstances expliquent sans doute pourquoi, à l'heure actuelle, il n'existe aucun programme important en français alors qu'aux Etats-Unis, plus de trois cents programmes sont édités sur des sujets qui vont de l'hébreu à la sténographie en passant par la théorie des groupes et des champs.

Comme je l'ai dit plus haut, c'est la preuve expérimentale qui confère à l'instruction programmée sa valeur. En exprimant ma conviction sur l'utilité de ce mode d'enseignement dans les sciences physiques, j'ai seulement voulu montrer qu'il s'agissait d'une opinion aussi plausible que la conviction contraire et que le problème méritait une étude ; c'est maintenant aux faits expérimentaux de le trancher.

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LA TÉLÉVISION EN CIRCUIT FERMÉ APPLIQUÉE A L'ENSEIGNEMENT(1), H. Brasseur

La télévision en circuit fermé peut être définie comme un système de télévision dans lequel le dispositif émetteur et le dispositif récepteur sont régis par les mêmes personnes.

En général, l'émission, même si elle est publique comme c'est le cas aujourd'hui, ne s'adresse qu'à un nombre limité de personnes.

D'autre part, la caméra de prises de vues est le plus souvent reliée au dispositif récepteur par un câble coaxial de longueur variable suivant les installations.

Les applications de la télévision en circuit fermé sont extrêmement nombreuses et servent à l'observation dans les cas où l'examen direct est soit dangereux, soit trop peu visible, soit incommode.

Citons, à titre exemplatif, les installations de télévision en circuit fermé pour la surveillance au voisinage d'un réacteur nucléaire, pour la surveillance des enfants en bas âge dans leur chambre, pour l'observation de la circulation aux grands carrefours des villes, pour la surveillance des clients dans un grand magasin, etc...

Il est naturel que l'enseignement s'empare de ce moyen audiovisuel par excellence.

A côté d'émissions publiques à circuit ouvert sous forme de télévision éducative (émissions littéraires, scientifiques, documentaires), on a organisé déjà en de nombreux endroits la télévision en circuit fermé pour l'enseignement proprement dit.

Citons, à ce propos, les installations de TV en couleurs qui existent dans un certain nombre d'Universités européennes et dont le but est de montrer en gros plan à de nombreux spectateurs les détails d'une intervention chirurgicale.

Plus modestement, peut-être, la biologie et la physique peuvent tirer parti de la télévision en circuit fermé.

Quelles sont les conditions d'une utilisation rationnelle de la TV en circuit fermé à usage didactique ?

Elle s'impose particulièrement dans les cas suivants :

1. Les détails de la démonstration à faire sont trop petits pour être vus à l'oeil nu par un grand nombre d'auditeurs et trop incommodes pour pouvoir être projetés.
   Tel est le cas pour l'image à observer sur un oscilloscope cathodique. L'écran de l'oscilloscope est généralement de petites dimensions et l'image ne peut pas être reprojetée sur écran.

2. Les détails de la démonstration sont trop peu lumineux.
   Il est patent que l'énorme perte de lumière qui accompagne une expérience sur la diffraction ou les interférences exclut la possibilité de vision par un grand nombre d'élèves. Aussi y a-t-il intérêt dans ces cas à utiliser une installation de TV en circuit fermé.

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1. Extrait de la revue: Association belge des professeurs de physique et de chimie, N°1, févr. 1964, p. 29 à 30.

De même, les projections microscopiques de démonstrations avec effets cinématiques sont justiciables de l'observation sur écran de télévision. Un bon exemple se trouve dans l'examen du mouvement brownien.

Trois remarques s'imposent :

1) On serait tenté, comme d'autres l'ont été antérieurement, de proposer le remplacement d'un examen en gros plan sur l'écran de télévision par la projection d'une diapositive de la micrographie. On ne saurait à notre sens insister suffisamment sur le caractère didactique d'une démonstration expérimentale. Une diapositive, quelle que soit sa perfection, est détachée du contexte expérimental et donne toujours un peu l'impression d'un manque de vie ou de réel. Le récepteur de télévision est sans difficulté associé à la démonstration expérimentale de sorte que celle-ci garde toute son efficacité didactique.

2) La même objection peut être élevée contre le film cinématographique. Il est évident qu'un élève curieux appréciera de voir transposer sur l'écran de télévision le résultat agrandi d'une démonstration qu'il voit réalisée sur la chaire mais dont il ne pourrait pas apprécier les détails à distance.

3) Du point de vue pédagogique, l'utilisation de plusieurs récepteurs de TV me paraît, sinon indésirable, au moins non souhaitable. Aussi y a-t-il intérêt à prévoir la projection sur un écran unique placé au-dessus du professeur.

Des installations de ce genre, bien qu'assez chères, sont loin d'être d'un prix prohibitif.

DIAPOSITIVES EN COULEURS, Bruxelles, publication de l'IVAC(1), 691 Chaussée de Mons, Bruxelles 7, 1966, 269 p.

Extraits.

Physique

Serie NM/1 - Magnetisme et aimantation

1. Explication du magnétisme par la structure de l'atome
2. Cristal de fer
3. Substances antiferromagnétiques
4. Ferrites
5. Aimantation du fer doux (schéma)
6. Aimantation de l'acier (schéma)
7. Influence d'un noyau de fer doux sur l'intensité du champ magnétique d'un solénoïde (schéma)
8. Cycles d'hystérésis (schéma)
9. Domaines de Weiss dans une matière ferromagnétique (modèle)
10. Joints entre les domaines de Weiss (modèle)
11. Comment on peut rendre visibles les domaines de Weiss (I)
12. Idem (II)

Série AT/1 - Appareils détecteurs de particules chargées

1. Décharge d'un électroscope
2. Utilisation de l'électroscope pour l'examen du rayonnement ionisant de substances radioactives
3. Chambre d'ionisation
4. Portrait de P. Curie (1859-1906)
5. Appareillage utilisé par les Curie

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1. International Visual Aids Center.

6. Quartz piezo-électrique de P. Curie
7. Chambre d'ionisation reliée à un amplificateur
8. Scintillateur
9. Portrait de C.T.R. Wilson (1869)
10. Premier principe de la chambre de Wilson
11. Deuxième principe de la chambre de Wilson
12. Schemas du fonctionnement de la chambre de Wilson
13. Réplique de la chambre de Wilson originale
14. Photos de rayonnements vus à la chambre de Wilson
15. Chambre continue à diffusion
16. Compteur Geiger-Müller
17. G.M. originaux de E. Fermi
18. Plaque (photographique) nucléaire
19. Paquet d'émulsions nucléaires
20. Chambre à bulles (1952)
21. Maquette d'une grande chambre à bulles (hydrogène liquide)
22. Traces d'un positon vu à la chambre à bulles

Série AT/2 - Particules élémentaires

1. Tableau des particules élémentaires
2. Portrait de M. Faraday (1791-1867)
3. L'électrolyse
4. Portrait de W. Crookes (1832-1919)
5. Portrait de J. Perrin (1870-1941)
6. Portrait de J.J. Thomson
7. Appareil de J.J. Thomson
8. Portrait de R.A. Millikan (1868-1952)
9. Détermination de e (méthode de Millikan)
10. Expérience de O. Stern et W. Gerlach
11. Deux électrons à spins orientés antiparallèlement
12. Deux électrons à spins orientés parallèlement (fer)
13. Portrait de W. Pauli (1900-1959)
14. Structure d'un atome d'hélium
15. Structure d'un atome de lithium
16. Structure d'un atome de néon
17. Structure d'une molécule d'hydrogène
18. Portrait de L. de Broglie (1892)
19. Démonstration de la diffraction et de l'interférence d'électrons
20. Diagramme de diffraction des électrons
21. Modèle d'un atome avec électron à caractère ondulatoire
22. Découverte des rayons canaux (E. Goldstein, 1886). Déterminations de e/m des ions
23. Expérience de Joliot-Curie (1932)
24. Portrait de J. Chadwick (1891)
25. Découverte du neutron par Chadwick (1932)
26. Découverte du positon par Anderson (1932)
27. Formation de positons dans le noyau de l'atome

Série AT/3 - Machines accélératrices de particules chargées

1. Maquette du laboratoire de Cockroft et Walton (1932)
2. Générateur en cascade de Greinacher (1921)
3. Schéma d'un générateur en cascade
4. Maquette d'un générateur en cascade
5. Schéma d'un générateur de Van de Graaff
6. Accélérateur de Van de Graaff
7. Maquette d'un générateur et accélérateur de Van de Graaff

8. Schéma d'un accélérateur de Van de Graaff
9. Schéma d'un accélérateur
10. Schéma d'un accélérateur linéaire
11. Klystron destiné à un accélérateur linéaire
12. Coupe d'un accélérateur linéaire
13. Portrait de E.O. Lawrence (1901)
14. Principe et schéma du cyclotron
15. Maquette d'un cyclotron (coupe)
16. Le synchro-cyclotron de Philips (1)
17. Idem (II, Autre face)
18. Deux aimants de l'Eurotron
19. Maquette de l'Eurotron (accélérateur de protons)
20. Maquette de l'accélérateur de protons à Harwell
21. Schéma et principe du bêtatron

Série AT/4 - Modèles d'atomes

1. Portrait de J. Dalton (1788-1844)
2. L'atome de Dalton (1803)
3. L'atome de J.J. Thomson (1904)
4. Portrait de E. Rutherford (1871-1931)
5. Expérience de Rutherford
6. Explication de l'expérience de Rutherford
7. L'atome selon Rutherford
8. L'atome planétaire
9. Portrait de M. Planck (1858-1947)
10. Principe de la cellule photoélectrique
11. Portrait de Einstein (1879-1955)
12. Portrait de N. Bohr (1885)
13. Atome excité ($E_1 - E_2 = h\nu$)
14. Niveaux d'énergie d'un atome de sodium excité et d'un ion de sodium
15. Portrait de J. Franck (1882)
16. Portrait de G. Hertz (1887)
17. Expérience de Franck et Hertz (1913)
18. Modèle d'un atome d'uranium
19. Modèle animé d'un atome d'hydrogène
20. Modèle animé d'un atome de lithium
21. Modèle animé d'un atome d'oxygène
22. Structure de l'atome avant et après 1932 (Chadwick)
23. Les nucléons. Structure du noyau de l'atome
24. L'atome de Sommerfeld (1924) (I)
25. Idem (II)
26. L'atome de Schrödinger (1926)

Série AT/5 - La radioactivité

1. Portrait de E. Becquerel (1859-1908)
2. Expérience de E. Becquerel
3. Laboratoire de P. et M. Curie
4. Feuillet d'un carnet de notes de M. Curie
5. Portrait de P. et M. Curie
6. Ecrans de plomb utilisés par Becquerel (1901)
7. Epreuve photographique obtenue dans ce matériel
8. Influence de champs magnétiques et électriques sur les rayons radioactifs
9. Mesure de la vitesse de désintégration
10. Loi de Soddy et Fajans
11. Famille de l'uranium

12. Famille du thorium
13. Famille de l'actinium
14. Famille du neptunium
15. Portrait de F. Joliot (1900-1958)
16. Portrait de I. Joliot-Curie (1897-1956)
17. La radioactivité artificielle
18. Proportions entre le nombre de protons et de neutrons
19. Idem, graphique
20. Instabilité du noyau
21. Idem
22. Le neutrino

Série AT/6 - Isotopes

1. Portrait de D. Mendelejeff (1834-1907)
2. Système périodique des éléments
3. Portrait de H.G.J. Moseley (1887-1915)
4. Loi de Moseley (1913)
5. Portrait de F.W. Aston (1877-1945)
6. Schéma du spectrographe de masse
7. Réplique du troisième spectrographe de masse d'Aston (1937)
8. Coupe d'un spectrographe de masse
9. Isotopes du chlore
10. Place de l'argon et du potassium dans le système périodique
11. Isotopes stables de l'hydrogène
12. Isotopes stables du lithium
13. Béryllium
14. Eléments non radioactifs ayant peu ou beaucoup d'isotopes
15. Séparation électromagnétique
16. Séparation par diffusion
17. Séparation par ultracentrifugation
18. Séparation par thermodiffusion
19. Expérience de séparation par thermodiffusion
20. Préparation d'eau lourde par distillation
21. Préparation d'eau lourde par l'électrolyse de l'eau
22. Séparation par échange atomique
23. Idem appliqué à la séparation d'eau lourde

Série AT/7 - Energie et réactions nucléaires

1. Première transmutation d'un élément (N⟶O)
2. Transmutation N⟶O révélée dans une chambre de Wilson
3. Portrait de P.M.S. Blackett (1897)
4. Portrait de J.D. Cockroft (1897)
5. Transmutation du lithium
6. Portrait de E. Fermi (1901-1954)
7. Matériel de Fermi
8. Portrait d'O. Hahn (1879)
9. Table de laboratoire avec le matériel de Hahn
11. Portrait de L. Meitner (1878)
11. Désintégration d'un atome d'uranium
12. Réaction en chaîne
13. La masse et l'énergie
14. Graphique : énergie nucléaire par fusion et par fission

Série AT/8 - Bombe atomique - Réacteurs

1. La première bombe atomique

2. Eléments fissiles
3. Le plutonium
4. Le thorium 232
5. Modérateur
6. Réflecteur
7. Blocs de graphite et barre de cadmium
8 à 22. Vues du montage de la pile atomique EL 3 à Saclay

ASSOCIATION BELGE DES PROFESSEURS DE PHYSIQUE ET DE CHIMIE (ABPPC), revue trimestrielle ; rédaction : Albert Dessart, 2 avenue Frère Orban, Mons - Tel. (065) 33931.

ANOTHER APPROACH TO THE FIRST-YEAR PHYSICS LABORATORY COURSE (1)

by R. C. Murty, Department of Physics, University of Western Ontario, London, Canada

A different approach to the first-year physics laboratory course, consisting of open laboratory sessions and practical examinations, is described. The responsibility for the student's development is left much more in his own hands than is customary. The underlying philosophy of the course and its organization is discussed.

I. Introduction

In recent years there has been considerable discussion on the role and nature of laboratory work in physics (1-8). Friedmann (9) claims that "it seems reasonably well established that a first-year laboratory course should be along predetermined paths and an open-ended laboratory as described by Michels (10) is only suitable after the student has become acquainted with traditional laboratory procedures". Chambers (11) suggests "a thorough course of lectures and examples classes before starting any practical work at all", while Conway, Mendoza, and Read (12) suggest the seminar method of teaching experimental physics.

Another approach which is described below has been introduced in 1962 and seems to be successful in stimulating a new attitude on the part of the students because it leaves the responsibility for the student's development much more in his hands than is customary.

II. Organization of the laboratory

The academic year is divided into four six-week sessions. During the first four weeks of each six-week session, students perform a set of experiments listed in the laboratory manual. The experiments cover mechanics, properties of matter, heat and wave motion. Each laboratory period includes a lecture or recitation which may last up to an hour. The lectures usually cover such topics as errors, graphs, method of dimensions, experimental techniques, and the theory of some of the more difficult experiments such as "wave motion" or "Stefan's law". These lectures are not held regularly and the students are encouraged to consult books and discuss the experiments with the demonstrators or use this period for private study.

In the laboratory, the emphasis is mainly on the study of the relationship between quantities rather than the evaluation of a physical constant. Within the general framework of the experiment, the students are allowed comparative freedom to perform the experiments in their own way. The demonstrators keep the students under observation and offer help only when a student is repeatedly making mistakes. Then, the demonstrator tries to make the student aware of his mistakes by the use of leading questions. The later part of the laboratory period is utilized in discussing the results with the demonstrators. Students are advised, but not required, to keep a data book and frequently to write a report on an experiment of their choice. In the discussion of all the experiments, percentage errors are stressed while probable errors receive only brief mention.

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1. Reprinted from: American Journal of Physics, vol. 33, No 3, p. 205, March 1965.

The fifth week of each six-week session is set aside for an open laboratory. During this period the students are free either to repeat an experiment in order to improve the accuracy of their previous results or to attempt modifications. Occasionally, certain experiments which are not included in their laboratory manual are on display and some of these are demonstrated to the students while others are left to be performed by the students themselves. Attendance at the laboratory period of the first five weeks in each six-week session is not compulsory. It is noticeable that attendance falls off when the students first realize that no record is being kept but improves rapidly in the second six-week session.

The final week of each six-week session is set aside for a practical examination. Our aim in designing the examination has been to test neither the student's memory nor his ability to repeat an experiment. Rather, it is designed to test his understanding of the methods and principles involved and his ability to apply them to new situations. Each student works alone during the examination and is expected to write up the experiment as a report. The examination questions are similar to those of the Advanced and Scholarship Levels of the General Certificate of Education in the United Kingdom. Typical questions are :

> "Suspend the given mass from the end of the helical spring and find the period. Repeat with other masses. Use the simple pendulum and find the 'lengths of the pendulum' corresponding to the various periods obtained with the helical spring. From a graph of mass attached to the spring versus length of the pendulum find the force constant and the mass of the helical spring."
>
> "An unknown mass, a bucket of water and Young's modulus apparatus are provided. Find the specific gravity of the unknown mass."

Our instruction manual is written with this new approach in mind. As a result, it differs considerably from conventional manuals. Descriptions of apparatus are kept to a minimum and only very general instructions about procedure are given. The value of graphs is stressed and wherever possible students are advised to plot their measurements to obtain linear graphs. Some "theory" questions are included at the end of each experiment. The manual also contains a chapter on errors, graphs, significant figures, and the writing of reports. A major aim of the manual is to emphasize to the student that the responsibility for his development rests with him. The manual serves more as a guide rather than a key to experimental work.

Most, if not all of the students who enter universities in Ontario have had little or no laboratory experience in physics. All have seen the experiments demonstrated by their teachers but few have handled the apparatus themselves. In addition, nearly half of them have not studied statics and trigonometry in high school. While such students are placed in a special lecture section (noncalculus section), they have the same laboratory course as the others. The students taking the noncalculus physics course are generally planning to study medicine. The others make their choice of specialization at the end of the first year and may enter any of the sciences. Because of the differences in background and aspirations of the students, the experiments are generally of an elementary nature but a few are more advanced (e.g., angular momentum, Stefan's law).

A member of the faculty is in charge of the laboratory. The daily working of the laboratory is left to graduate student demonstrators. Each demonstrator is in charge of an experiment involving 18 to 20 students. Regular meetings between faculty and demonstrators are held to discuss the aims of the laboratory and how best to achieve them.

III. Concluding Remarks

We must inevitably ask ourselves whether the aims mentioned earlier are achieved by this new approach and whether the students benefit more from it than from a conventional laboratory course. The results so far are encouraging. For example, in a test experiment where they are asked to determine the relationship between the protruding length (B) of a meter rule and the depression (A) produced when a weight is hung at the end of the meter rule (the other end being fixed), most of the students assumed a simple power law relationship

$A = kB^n$. Many students plotted graphs of A versus B, A versus B^2 and B^3 and even A versus 1/B. Few students plotted a graph of log A versus log B and obtained the relationship. Fewer still asked for the log-log paper before plotting their measurements !

Perhaps more valuable though less tangible results can be cited. Since attendance is not compulsory, the students feel that laboratory work is no longer a chore but something to be enjoyed. The open-laboratory periods and the tests enable the students to perform at least some experiments alone rather than in pairs. Many students do spend the first hour of each laboratory period on private study. Because of the open laboratory and comparative freedom during the periods of regular experiments, students have a chance to explore new avenues and have more time to discuss the experiments among themselves and with the demonstrators. Conversations with the students reveal that there is actual enthusiasm for this type of laboratory course and they seem to grasp at least the spirit of experimental work and its relation to theory.

Notes :

1. Phys. Today 15, No.3, 28 (1962)
2. H. Kruglak, Am. J. Phys. 26, 31 (1958)
3. H. Kruglak, Am. J. Phys. 28, 791 (1960)
4. L. Nedelsky, Am. J. Phys. 26, 51 (1958)
5. W.E. Hazen, A.G. Dockrill, M. Lapointe, and L. Thurston, Am. J. Phys. 27, 174 (1959)
6. H.V. Neher, Am. J. Phys. 30, 186 (1962)
7. I.E. Dayton, Am. J. Phys. 30, 218 (1962)
8. H.V. Beck, Contemp. Phys. 4, 206 (1963)
9. G. Friedmann, Am. J. Phys. 31, 693 (1963)
10. W.C. Michels, Am. J. Phys. 30, 172 (1962)
11. R.G. Chambers, Bull. Inst. Phys. 14, 330 (1963)
12. R.G. Conway, E. Mendoza, and F.H. Read, Bull. Inst. Phys. 14, 181 (1963)

FILMS IN MAGI-CARTRIDGES (1)

Dynamic Productions, P.O.Box 564, Montreal 3, Quebec

Mechanics

- Door Bell Timer
- Newton Law - Mass Constant
- Force Constant
- Impulse - Momentum
- Conservation of Momentum
- Free Fall

National Film Board of Canada, P.O. Box 6100, Montreal 3, Quebec

Physics

- Instantaneous Speed I
- Instantaneous Speed II
- Instantaneous Speed III
- Idea of Speed I
- Idea of Speed II
- Idea of Speed III
- Uniform Motion (In a Straight Line)
- Average Speed
- Measurement of Time I
- Measurement of Time II
- Measurement of Time III
- Displacement
- Uniformly Accelerated Motion
- High Speed Measurement
- Free Fall
- Types of Movement

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1. See : Source Directory Educational Single-Concept Films available in Magi-Cartridges, third edition, March 1966, Technicolor Corporation, Box 517, Costa Mesa California U.S.A.

DANEMARK / DENMARK

A NEW INSTITUTE FOR MATHEMATICS, PHYSICS AND CHEMISTRY

by Prof. Søren Sikjaer

In the autumn of 1966 an Institute of Mathematics, Physics and Chemistry will be inaugurated as part of the Royal Danish College of Education. Actually, it consists of three independent institutes, each of them having its responsible chief. They have, however, a library (space for 30.000 volumes), a large lecture room and a coffee room in common. At the disposal of each of the institutes there will be lecture rooms and laboratories of different kinds. The total floorage will be 6000 m^2 and the price for the building alone 10 million kroner, to which must be added some millions for the equipment.

The Royal Danish College of Education has the privileges of a university, for instance the right of conferring the doctor's degree. Our teachers have the same titles, the same salaries and the same rights and duties as the university teachers. At the new institutes the teachers of the primary schools and the junior department of the secondary schools will receive a special training, comprising courses from the most elementary to the university level. The characteristic feature of these studies will be their pedagogical purpose. As regards the most extensive studies we aim at a synthesis between a profound knowledge of the subject and a real understanding of the scientific method with great capability of teaching and knowledge of methodology, didactics and psychology.

At these institutes there will also be carried on research work, of which the most characteristic will be a special educational research, for instance the transformation of subjects of the modern physics to the level of the school, For the experimental part of the physical-educational research there will be a large laboratory equipped with all imaginable facilities, and in addition there will be a workshop, where mechanics among other things will be able to construct new apparatuses for the use of schools. Also an exclusively scientific research work will be carried on, so that the transformation of material for the school will be performed by people who are themselves working actively at the scientific problems.

It will be of vital importance to the institutes to have international contacts, and we hope that we will manage to have guests from abroad who will stay at one of the institutes and for some length of time take part in the work.

ON SCIENCE EDUCATION IN THE UNITED STATES(1), by Dr Donald F. Hornig, Princeton University.

Even at the elementary level, I think our emphasis will shift toward the inductive science the researcher knows, the effort to allow students to learn to observe for themselves the facts of nature and to reason from them, to set up experiments to aid their reasoning and to test their conclusions. I have always been struck by the dichotomy between the scientist, who sees science as an active, creative problem-solving activity, and the student, who has conventionally seen it as a dogmatic, tightly organized body of often unexciting fact.

When the frontiers of science are receding so quickly, and when the theoretical outlook of many branches of science is undergoing frequent and abrupt changes, we must work constantly to educate teachers who understand science more profoundly, and to keep the teachers of science at all levels abreast of the changes. The National Science Foundation now sponsors the following :

- Summer Institutes for Secondary School Teachers of Science
- Summer Institutes for College Teachers of Science
- Summer Institutes for Elementary School Personnel
- Academic Year and In-Service Institutes for Secondary and Elementary School Teachers
  and
- Research Participation Programs for Teachers.

These programs are essential and must expand.

I should like to propose that at all levels of scientific education teachers should be given time to conduct their own experimentation. I do not have in mind formal research efforts - although for some school teachers this would be magnificent. I have in mind experimental work to satisfy curiosity about matters relating to their teaching, to the improvement and deeper understanding of their laboratory experiments, and to a constant search for new ways to present their experiments most effectively. I would propose that at all levels of schooling teachers should do such experimentation in concert with students, so that the better students can go beyond formal laboratory work at the earliest possible stage. Each teacher ought to be involved actively and creatively in scientific activity. Active participation raises the questions that make programs of study pertinent.

We can look forward to exciting years. Science curricula will be rewritten at all levels and will be addressed not only to the college-bound but to everyone. We will find ways to introduce science and make it exciting to every student who must grow up in our changing world.

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1. From an ESI/quarterly report, 1965, published by Educational Services Incorporated, Watertown, Massachusetts 02172.

TRAINING OPPORTUNITIES FOR SECONDARY SCHOOL TEACHERS OF SCIENCE AND MATHEMATICS, 1966 (1)

The National Science Foundation, an independent agency of the Federal Government, is concerned primarily with strengthening basic research and education in the sciences, including mathematics, engineering, and social sciences.

The Institute and Research Participation Programs of the National Science Foundation have as their prime objective the improvement of the quality of science and mathematics instruction in the Nation's classrooms. The programs are designed to enable teachers to obtain a more complete and up-to-date knowledge of new developments in their particular subject-matter fields. Most of these programs are directed toward secondary school science and mathematics teachers because of the teachers'vital role in the national effort to improve the understanding and mastery of science in the United States.

This brochure provides information concerning four programs supported by the National Science Foundation for the immediate benefit of secondary school teachers, the subsequent benefit of their students and, finally, the benefit of the Nation. These programs are : 1) Summer Institutes ; 2) Academic Year Institutes, 3) In-Service Institutes, and 4) Research Participation. During 1966 the Foundation expects to be able to provide opportunities to about 36,000 teachers for study in these various secondary school teacher programs.

The course of study in an institute is designed for a specific group of secondary school teachers and is restricted to a curriculum in biology, chemistry, earth science, mathematics, physics, anthropology, economics, psychology and sociology, or to some combination of those fields. The teacher entering one of these programs can expect to study as a member of a group of teachers having approximately similar backgrounds. Under the Research Participation Program, teachers may undertake a research project under the general guidance of an established scientist.

Another program of interest to teachers is the Cooperative College-School Science Program, which involves colleges and local school systems in collaborative efforts for local science education improvement. These training opportunities are locally oriented and only teachers from the particular school system may participate. In general, projects are designed to improve the subject-matter capability of the teachers within a given school system in order to implement effectively the aims of that school system.

Summer Institutes for Secondary School Teachers of Science and Mathematics (2)

Summer Institutes provide courses which vary widely in scope, but which are especially designed for science and mathematics teachers. Some institutes are planned for teachers with comparatively good backgrounds, others for teachers with average backgrounds, and still others for teachers who have little or no background in the subject matter. The institutes are intended to strengthen the teachers' mastery of the subject matter they teach ; the subject matter is emphasized rather than methods of teaching.

Academic Year Institutes for Science and Mathematics Teachers (3)

Academic Year Institutes are designed for science and mathematics teachers for full-time study while on leave of absence from regular teaching duties. Programs are available for : (1) teachers interested in concentrating on a single discipline, such as mathematics, physical science, biology, or general science ;(2) teachers interested in studying several related disciplines ; or(3) teachers whose scientific backgrounds are in need of updating.

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1. From a leaflet E-65-C-17, published by National Science Foundation, Washington D.C 20550.

2. 3. For detailed information apply respectively for Publications Nos E-65-C-11 / E-65-C-9 / E-66-P-1 / E-65-D-9 of the National Science Foundation (1966)

Some institutes provide for an additional, optional, summer program to enable selected participants to complete the requirements for an advanced degree.

In-Service Institutes for Teachers of Science and Mathematics (1)

In-Service Institutes enable secondary school teachers of science and mathematics who are teaching full time to obtain supplemental instruction after school hours or on Saturdays. A typical institute meets once or twice a week for periods of two to four hours for a full academic year. These institutes enable teachers to obtain additional knowledge of subject matter, become acquainted with important new textual and laboratory materials, or take a sequence of courses, frequently in combination with related Summer Institutes.

Research Participation for High School Teachers (2)

This summer program enables teachers of science and mathematics to participate in research at colleges, universities, and research foundations by actually working on an individual basis in the laboratory or in the field with experienced scientific investigators. An applicant for this program should have a master's degree in scientific subject matter or an academic background including sufficient advanced courses to qualify for that degree. In some cases, the Research Participation for High School Teachers Program may offer the opportunity to conduct research required for a master's thesis. Institutions make their own decisions as to academic credits for research participation.

LENGTH OF INSTITUTES BY LEVEL AND PROGRAM, FISCAL YEAR 1965 (3)

Secondary Institutes

Type of Institute	Duration
Academic Year Institutes	One academic year plus optional related summer program
Summer Institutes	Average 7 weeks. Range 4-12 weeks
Research Participation	8 or more weeks in the summer with limited number of academic year extensions
In-Service Institutes	One academic year of part-time study
Conferences	Average 15 days
Special Projects	Variable

Elementary Institutes

Type of Institute	Duration
Summer Institutes	Average 6 weeks. Range 5-8 weeks
In-Service Institutes	One academic year of part-time study

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1. 2. For detailed information apply respectively for Publications Nos E-65-C-11 / E-65-C-9 / E-66-P-1 / E-65-D-9 of the National Science Foundation (1966)

3. National Science Foundation, Washington, D.C. 20550. (3/30/66)

SUPPORT OF PHYSICS BY PROGRAM AND LEVEL FOR FISCAL YEAR 1965[1]

Institutes for Secondary School Teachers

Program	Number of Projects	Obligated Number of Participants	Gross Obligations
Academic Year Institutes	20	167	$ 830,900
Summer Institutes	126	2,594	3,185,670
Research Participation	15	37	86,930
In-Service Institutes	63	1,532	405,560
Special Projects	9	3,244	47,520
Conferences	1	90	23,000
Total	234	7,664	$ 4,579,580

Institutes for Elementary School Personnel

Program	Number of Projects	Obligated Number of Participants	Gross Obligations
Summer Institutes	6	135	$ 143,320
In-Service Institutes	1	30	5,710
Total	7	165	$ 149,030
Grand Total	241	7,829	$ 4,728,610

SUMMER INSTITUTES AND CONFERENCES FOR COLLEGE TEACHERS[2]

The Summer Institute and Conference Programs of the National Science Foundation were created in recognition of the important role of the teacher in developing our scientific manpower potential. These programs are designed by the sponsoring colleges and universities to strengthen the subject-matter competence of science, mathematics, and engineering teachers. Financial assistance from the National Science Foundation makes possible the attendance of many teachers who would otherwise need to supplement their income from summer occupations. Conferences deal with specialized topics during a period of less than four weeks while institutes are designed for a longer session of six to twelve weeks duration.

Part of Subject Areas of Institutes offered for Physics :

Argonne National Laboratory, 8 weeks, June 14-August 6: Modern Developments in Physics ; for teachers of physics. Dr. Rollin G. Taecker, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60440.

University of California at Berkeley, 6 weeks, June 28 - August 6 : New Introductory Physics ; for junior college Physics teachers of engineering and science students. (Director of Program, Prof. Alan M. Portis, Department of Physics). Write : Letters and Science Extension, 2223 Fulton Street, Berkeley, California 94720.

Fisk University, 6 weeks, July 5 - August 14 : Introductory College Physics with a PSSC Orientation ; for teachers of general or introductory college physics, Dr. Nelson Fuson, Department of Physics, Box 8, Fisk University, Nashville, Tennessee 37208.

The University of Michigan, 8 weeks, June 28 - August 18, New Teaching Materials in Elementary Physics ; for college teachers of physics. Dr. Richard H. Sands, Randall Laboratory of Physics, University of Michigan, Ann Arbor, Michigan 48104.

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1. National Science Foundation, Washington, D.C. 20550 (3/30/66)
2. From the National Science Foundation Publication No. SPE-64-C-10

<u>Michigan State University</u>, 4 weeks, June 14 - July 9 : Solid State, Low Temperature Physics ; for teachers of physics. (Co-Directors of Program : Prof. R.D. Spence, Prof.Frank J. Blatt, Department of Physics). Write : Solid State Physics Institute, Science and Mathematics Teaching Center, Michigan State University, East Lansing, Michigan 48823.

<u>Oak Ridge Institute of Nuclear Studies</u>, 8 weeks, June 14 - August 6 : Recent Developments in Physics ; for teachers of physics in small or liberal arts colleges. Dr. Ralph T. Overman, Chairman, Special Training Division, Oak Ridge Institute of Nuclear Studies, P.O.Box 117, Oak Ridge, Tennessee 37831.

<u>Ohio University</u>, 5 weeks, July 19 - August 21 : Advanced Undergraduate Physics Laboratories ; for teachers of college physics. Dr. Charles A. Randall, Department of Physics, Ohio University, Athena, Ohio, 45701.

<u>Texas A&M University</u>, 12 weeks, June 7 - August 27 : Elements of Modern Physics ; Electricity, Circuit Theory ; Vector Analysis and Associated Applied Mathematics ; for junior college and college teachers. Advanced Mechanics, Electromagnetism, and Thermodynamics ; for returnees for third summer. (Director of Program : Dr. J.G. Potter, Department of Physics). Write to : Prof. C.M. Loyd, Coordinator, NSF Programs P, Texas A&M University, College Station, Texas 77843.

SCIENCE COURSE IMPROVEMENT PROJECTS

<u>Physical Science Study Committee</u> (PSSC)

- <u>Physical Science Study Committee - Junior High Physical Science</u> (1), by Uri Haber-Schaim, Educational Services Incorporated, 164 Main Street, Watertown, Mass., 02172. (1963-)

The objective is to prepare a course in physical science for the ninth grade. The project is in the first stage of development ; seven chapters are in print in a preliminary version ; several more chapters will be ready for use in pilot schools during 1963-64. The major emphasis in the course is on the study of matter. Student laboratory work is of primary importance. To emphasize this, laboratory instructions are incorporated in the body of the text ; the results are not described. Since many junior high schools have little or no laboratory facilities, the equipment accompanying the written materials has been designed in such a way that the students can perform the experiments in ordinary classrooms. The course is intended to be suitable for use both as a terminal course in physical science and as preparation for the study of biology, chemistry and physics.

Further information may be received by writing to Educational Services Incorporated.

- <u>Physical Science Study Committee (PSSC) (Secondary, College)</u> (1), by Jerrold R. Zacharias, Department of Physics, Massachusetts Institute of Technology Cambridge, Mass., 02139. (Grantees : Massachusetts Institute of Technology, 1957-1959 ; Educational Services Incorporated, 164 Main Street, Watertown, Mass., 02172, 1960-) (1957-)

The PSSC physics program has developed a textbook ; a laboratory guide with new experiments ; simplified, low-cost apparatus in kit form ; 54 films which set the tone and standards for the course ; achievement tests ; an extensive library of paper-bound books written by distinguished authors on topics of science ; and teachers' guides which provide background material and make concrete suggestions for class and laboratory activities . All course materials are available from the commercial sources listed below.

The PSSC course consists of four closely inter-related parts. The first is a general introduction to the fundamental physical notions of time, space, and matter. This is followed

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1. Notices from: Science Course Improvement Projects. National Science Foundation, NSF 64-8, July 1964.

by a study of light, both optics and waves ; a study of motion from a dynamical point of view ; and a study of electricity and the physics of the atom. The course concentrates on fewer facts than are usually included in an elementary physics course. Considerable time is spent on the stories running through physics which tie together the facts with explanations. The laboratory is an important tool in learning the ideas and is on an equal level with the textbook, class discussions, and films as a means of learning and teaching. The text, laboratory guide, teachers'guide, and tests are being revised for publication in 1965.

The textbook, laboratory guide, and teachers'guide, D.C. Heath and Co., 285 Columbus Avenue, Boston, Mass., 02116.

Apparatus kits : available from several supply companies.

Films : rented and sold by Modern Learning Aids, 3 East 54th Street, New York, N.Y., 10022, which also distributes a teachers'guide to PSSC films.

Achievements tests (3 batteries : the original battery, an alternate battery, and a scrambled version of the original battery) : Cooperative Test Division, Educational Testing Service, Princetown, N.J., 08540.

Science Study Series, a library of paper-bound books for outside reading in fields related to the PSSC course : Doubleday and Co., Inc., 501 Franklin Avenue, Garden City, N.Y. 11530.

Further information : Educational Services Incorporated.

- Physical Science Study Committee - advanced topics (Secondary, College)(1)
  by Uri Haber-Schaim. Educational Services Incorporated, 164 Main Street, Watertown, Mass., 02172. (1962-1965)

The course materials consist of text, laboratory guide, films, apparatus kits, and teachers'guides which go beyond the material in the basic PSSC physics course. Available at present are the following : Chapter A-1, Angular Momentum; Chapter A-2, Relativistic Kinematics ; Chapter A-3, Speed, Mass and Energy ; Chapter A-4, Irreversible Processes ; Advanced Topics Laboratory Guide I; teachers'guides for A-1, A-2, and A-3 ; apparatus kits for the experiments ; and the films, Angular Momentum : A Vector Quantity, Time Dilation, and The Ultimate Speed. In various stages of development are the following : three additional chapters (one on statistical mechanics and two on quantum physics), Advanced Topics Laboratory Guide II, teachers' guide for Chapter A-4, and apparatus for several new experiments, including the Millikan experiment.

The new materials are suitable for use in advanced high school courses and in colleges using the PSSC text for freshman physics courses or to supplement the regular physics course materials.

Chapters and laboratory guide : Mr. Sturtevant Hobbs, D.C. Heath and Co., 285 Columbus Avenue, Boston, Mass., 02116.

Teachers'guides and films : Educational Services Incorporated.

Apparatus : Macalaster Scientific Corporation, Cambridge, Mass., 02139.

The PSSC course has been translated and all the material adapted for the needs of several countries as for example in Canada, Colombia, Italy, Scandinavia, Yugoslavia.

- Le cours du PSSC au Canada (2)

Au Canada, l'activité principale consiste à introduire la physique du PSSC notamment dans les provinces suivantes : Colombie britannique, Alberta, Saskatchevan, Ontario et Québec. En particulier, le Professeur Derek Liversey, du Département de physique de l'Université de Colombie britannique, Vancouver B.C., a préparé conjointement avec deux

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1. Notice from: Science Course Improvement Projects. National Science Foundation, NSF 64-8, July 1964.
2. D'après une lettre du 7 octobre 1965 de M. Paul Lorrain, Directeur du Département de physique, Faculté des Sciences, Montréal 3, Canada, à Mme Grivet (Unesco)

autres physiciens un petit ouvrage intitulé "A Laboratory Course in Physics" qui est une sorte de complément de la physique du PSSC. Il est édité au Canada chez Copp & Clark à Toronto. Cet ouvrage a le grand avantage d'intégrer à peu près parfaitement la théorie et l'expérience. Par contre, il est très incomplet puisqu'il évite à dessein à peu près toute la matière couverte par le volume du PSSC. (1)

- Curso de Física PSSC en Colombia (2)

Curso de física PSSC (20 de Julio al 28 de Agosto de 1965) - 49 profesores de enseñanza media siguieron un curso intensivo PSSC bajo la dirección de profesores especializados en este método. El éxito fue total y de gran repercusión. Dos de los mejores alumnos, los profesores Vargas y Pereira, se incorporaron en el Departamento de Física, de la Universidad del Valle.

Taller de Física - Hace tres meses, el Departamento de Física de la Universidad, montó un taller para fabricación de equipo PSSC. Cuenta con un carpintero, un mecánico, un ayudante y maquinaria adecuada.

Colegios Pilotos - El Departamento de Física de cada uno de estos colegios, está bajo la dirección del Departamento de Fisica, de la Universidad del Valle. Se decidió emplear el método PSSC, y en consecuencia el Departamento de Física de la Universidad, proporcionó equipos completos de Laboratorio PSSC para que sirvan de modelo. (1 equipo sirve para 4 alumnos,)

- Le cours du PSSC en Italie (3)

L'histoire de l'origine des cours pilotes en physique se rattache à un séminaire organisé en 1961 à Cambridge (U.K.) par l'OECE : on y a présenté aux délégués des pays membres tout le matériel élaboré par le PSSC pour un cours de physique des années terminales de l'enseignement secondaire. Le jugement sur ce matériel a été positif, et notre Ministère a décidé de l'essayer, dans une version italienne le plus possible fidèle, dans les établissements de l'instruction classique. Pour l'enseignement technique, les "observateurs" qui avaient participé en 1962 au premier stage d'été ont exprimé l'opinion que le matériel du PSSC pouvait être aussi bien essayé dans le premier cycle des Instituts Techniques, ou dans les trois années de l'Institut pour Géomètres. Ils ont en effet jugé que les difficultés dérivant du plus jeune âge des élèves auraient été compensées par les horaires un peu plus favorables.

C'est ainsi que la Direction Générale de l'enseignement technique fut amenée en 1964 à instituer une deuxième Commission Nationale pour les cours pilotes en physique dans les établissements techniques.

La nouveauté principale pour nos écoles du cours PSSC, et son plus grand mérite, est d'avoir donné une importance capitale aux travaux pratiques des élèves, à leurs observations et à leurs mesures, et d'en avoir fait le point de départ de toute connaissance dans le domaine de la physique. Cette méthode courageuse amenait à la nécessité d'un matériel didactique adapté, mais les expériences et les mesures imaginées et suggérées étaient d'une telle simplicité de montage, et employaient un matériel tellement bon marché que les efforts pour équiper toutes nos classes-pilotes n'ont pas paru insurmontables.

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1. Le manuel du PSSC a été traduit en français : Physique, PSSC, I, II, & III ; traduction : Serge Lapointe ; adaptation : Louis Ste Marie ; Edition Hachette, Canada 1962.
   N.B. Ce manuel a aussi été traduit en français sous la responsabilité de Jean-Paul Mathieu, chez Dunod (Paris), 1964. "La Physique" . Il en est de même du guide de laboratoire qui a été traduit sous le titre "Recueil d'expériences de physique".
2. Universidad del Valle, Departamento de Física, Cooperación con el Bachillerato, Boletin Informativo No 1, Noviembre 1965.
3. Extrait de "Les organisations des réformes des enseignements scientifiques dans les écoles secondaires d'Italie" par Prof. Dr. Maria Ferretti. Voir ref. sous Italie

En consacrant une considérable partie du temps aux travaux pratiques et à la discussion des problèmes, le cours du PSSC, tout en conduisant les élèves jusqu'à des connaissances assez récentes, ne contient pas des sujets traditionnels (tels que les machines simples, par exemple). Le développement de la matière suit même un ordre différent que d'habitude, pour des motifs qu'on a jugé raisonnables.

C'est ainsi qu'on a traduit en italien le plus fidèlement possible les livres pour les élèves (textes et manuel de laboratoire) et le guide pour les enseignants. La Commission Nationale s'est chargée de la responsabilité des révisions. Les petites monographies préparées par le PSSC pour donner aux élèves la possibilité d'approfondir librement quelques chapitres particuliers de la physique ont commencé aussi d'être traduites en 1964. Pour les films, nous avons eu la chance de pouvoir profiter de l'aide économique et technique d'une entreprise industrielle et nous pouvons disposer, depuis le début de 1964-65, d'une série assez nombreuse de versions italiennes. Les appareils pour les travaux pratiques ont été reproduits en nombre suffisant par les ateliers de l'Institut Technique Industriel Aldini Valeriani de Bologne, d'après les dessins originels que la maison américaine nous a gracieusement fournis.

La révolution introduite dans les établissements de l'instruction classique par les travaux pratiques a été acceptée courageusement par les enseignants et les proviseurs, et avec un vrai enthousiasme par les élèves. Après trois années, on juge les résultats de cet enseignement tout à fait positifs.

- PSSC course in Scandinavia

See chapter devoted to Sweden.

- PSSC course in Yugoslavia (1)

The results achieved by the pupils of pilot classes :

Besides the conventional evaluation through discussion and laboratory practice, the following elements were used in checking pupils'knowledge :

eight written school-works
five control written works
the standardized PSSC tests
homework
two special control written works

Regular written works in connection with the currently treated subject-matter were done during two school-hours. Every class had different problems to solve but equal in weight.

In control works the pupils were given short numerical exercises and one theoretical question from the currently treated subject-matter. The results shown by pupils indicate to what extent they have mastered the material. In this way the quality of acquired knowledge by text method was checked., Control written works lasted one school-hour only.

Final control works were intended for checking the ability of the pupils for independent study, and for determination of the general level of acquired knowledge. The results were quite satisfactory.

It was found that there is a considerably high correlation between the general knowledge in physics and test scores. That is the reason that the results of testing are good indication for successful treatment of the subject-matter. The results shown by the pupils of pilot classes are good, since their mean mark is 3.09.

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1. From a report of the Yugoslav National Commission for the realization of special project, STP-4/SP, Prof. Aleksandar Milojevic, president, and Mihajlo Platisa, secretary, of the National Commission for Physics, Belgrade, December, 1965.

It was impossible to make comparison between the results of pupils in pilot classes and those attending traditional courses, due to different conditions for the realization of physics teaching.

Massachusetts Institute of Technology (MIT)

- Science Teaching Center : College Physics(1), by Jerrold R. Zacharias, Department of Physics, Massachusetts Institute of Technology, Cambridge Mass., 02139. (1961-)

The Science Teaching Center is concerned with the first two years of college physics and is now preparing a new introductory course. This preparation involves : (1) selecting topics and preparing written materials in the form of lecture notes to help students gain early understanding of modern physics, specifically relativity and quantum physics ; (2) developing lecture demonstrations to support the new content ; (3) designing corridor demonstrations ; (4) producing student experiments, mainly in modern physics ; (5) assisting in the production of college level films.

For A Progress Report (July, 1963), which describes the project in more detail and lists available publications and films, and for other information about the project, write Mr. Malcolm K. Smith, Science Teaching Center, Room 6-208, Massachusetts Institute of Technology.

Teaching of the new introductory physics course prepared by the MIT Science Teaching Centre started in 1964/65 at Washington University, St. Louis, Missouri and at San Diego State College, as well as at the MIT. The text of a talk on the new course, given by Professor A.P. French to an Advanced Placement Conference at Case Institute, in Cleveland, Ohio, on 25 June 1964 is reproduced on the following pages.

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1. From : Science Course Improvement Projects. National Science Foundation, NSF 64-8, July 1964.

A NEW INTRODUCTORY PHYSICS COURSE AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY *

by A. P. French

DESPITE the air of definiteness that may be implied by the title of my talk, the remarks that I shall offer you this morning are in the nature of a progress report. I should like to tell you something about the results, and the future plans, arising out of the work that has been going on at the Science Teaching Center at M.I.T. over the past few years. One of our chief aims has been to take a fresh look at introductory physics at the college and university level. Our work at M.I.T. is of course by no means the only effort of this kind; there has been a surge of interest, in various places in this country, in the whole question of what should be present in the general course in physics, and how it should be presented. Before I get down to the specifics of our course at M.I.T., it might be worthwhile to spend a few moments considering the problem in general.

The task of any basic course in physics should presumably be to give an accurate and balanced picture of what the physical world is like. That is a tall order, to be sure, but I think there has been a growing conviction that the typical elementary course presented during the freshman and sophomore years falls lamentably short of this goal. One might suppose that it should be almost axiomatic that a physics course worth its name, even at the elementary level, should contain the really important notions that underlie our description and understanding of the world. As far as physics is concerned, there are two outstanding ideas that the twentieth century has contributed and which should surely be introduced at an early stage in any general course in physics. These are relativity on the one hand and quantum physics on the other. Both of them are so deeply imbedded in our understanding of nature, and our ability to describe it, that they should occupy a central position in any physics course. The world is not a classical Newtonian structure to which relativity and quantum behavior are added as an afterthought or as a reward to students for perseverance after a year or two of grind. Yet, until recently, that is the kind of footing on which relativity and quantum theory have been presented to students at the beginning levels in colleges and universities. Many of you no doubt have made the acquaintance of the lectures, now coming out in book form, that Richard Feynman gave at Caltech during 1961-63. In the preface to his lectures he observes that students coming out of high school "have heard a lot about how interesting and exciting physics is — the theory of relativity, quantum mechanics, and other modern ideas." He goes on: "By the end of our previous course, many would be discouraged because there were really very few grand, new and modern ideas presented to them. They were made to study inclined planes, electrostatics, and so forth, and after two years it was quite stultifying."

Of course one may sympathize with these opinions, and yet still have doubts about what should be the content of a beginning course at the university level. After all, so long as we do not probe too deeply, classical physics provides a wonderful description of much of our physical experience. Newtonian mechanics provides a thoroughly accurate account of any motion that we can see with our eyes. It is obviously

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* From ESI Quarterly Report Summer-Fall, 1964, published by Educational Services Inc., Watertown , Massachusetts 02172.

relevant to our description of nature, and we know that students need a lot of practice in using it before they are adept with it. But in limiting ourselves to a description of the physical world in these terms, we are preventing ourselves — and our students — from probing into many of the questions that ought to be of supreme interest, because we are condemning ourselves to an acceptance of gross matter as we happen to find it. Why is glass transparent? Why is sulfur yellow? Why is mercury a liquid? Why don't atoms collapse under the attraction of their positive and negative charges? I am not suggesting that a freshman course in physics can give satisfactory answers to all of these, but I do think we are cheating the student if we do not put him on the road to quantum mechanics and the atomic description of matter.

In these last remarks I have indicated one of the key features of the approach to physics that we have been developing at M.I.T. It is what we have chosen to call "the particulate view." We start from the assumption that a workable, meaningful description of the physical world can be made in terms of particles and their behavior. The question immediately arises — "What is a particle?" Ultimately, perhaps, only the fundamental particles — electrons, nucleons, and so forth — may qualify, but that, from our standpoint, is too restrictive. The dynamics of a star in a galaxy, or of a planet in the solar system, is as much the dynamics of a particle as is the motion of an electron in a cathode ray tube. (You might even say that it is more so, because wave-mechanical properties can be safely neglected.) Once we have developed a familiarity with the individual particles and their behavior as described by classical or quantum mechanics (whichever may be the more appropriate) we shall be ready to consider the motions and properties of aggregates of particles and of matter in bulk. One of the advantages that we see as coming out of this kind of approach is a breaking down, at least in part, of the customary barriers and compartments into which the subject of physics is conventionally divided. We have a splendid chance in fact to show how physics enables us to put together facts and ideas that might have seemed separate at one time, and to relate the microscopic and the macroscopic aspects of nature. Thus to take an obvious example, one of the triumphs of this century in astrophysics has been the emergence of a rather full understanding of how something as large as a star works through the operation of reactions occurring on the nuclear scale. To establish a connection between the largest and the smallest in this way is certainly one of the really exciting things in the whole world of intellectual experience, and there is no reason at all why this sort of thing shouldn't start right at the beginning of a college course. Moreover, by opening the student's eyes to such relationships one can continually impress on him that the scale of distance of the universe that he lives in has markings over a colossal range — from 10^{-15} meters to 10^9 light years — and that to narrow down one's attention to familiar terrestrial objects — from grains of sand (10^{-3} meters) to mountains (10^3 meters) — involves a drastic limitation of our field of interest, however convenient that may be in everyday life. But I have said quite enough about generalities; let me now turn to some of the details of the course as we have been teaching it to M.I.T. undergraduates.

Our course actually begins with the Millikan experiment. This has several advantages. It leads us at once to a fundamental granularity in nature, it provides us with a universal atomic constant, and it paves the way for a simple discussion of dynamical problems involving charged particles. We then turn at once to electrons. After presenting some of the evidence that electrons are constituents of all kinds of matter, we discuss the motions of electrons of low energies in electric fields. This gives us the chance to develop or review a certain amount of kinematics and Newtonian dynamics for motion in one and two dimensions. Moreover, we want to lose no time in introducing electronic devices as detectors for various other types of particles and processes. A student does not need to understand all the niceties of surface phenomena or gas discharges in order to appreciate the use of electron multipliers or Geiger counters as detectors.

Next we turn to atoms and molecules. Again the purpose is twofold. We want to give the students a feeling for the reality of atoms — particles with masses and sizes that can be measured in ways that he can readily understand. But we can also push our review of dynamics a little further; we can point to the evidence that individual atoms, just like baseballs, carry momentum and fall under gravity. Next we say something about ions and mass spectrometry. The student learns something about the measurement of atomic masses, but he also makes the acquaintance of the velocity-dependent magnetic force. Thus, by a few examples of genuine physical importance, he is introduced to several different types of forces and the motions that they produce. I should emphasize that this is not a part of our formal development of dynamics; it makes use of no more than a student might reasonably be expected to have learned in high school.

Our account of atomic particles ends with a brief discussion of nuclei. We consider these as particles having mass, electric charge, certain characteristic numbers of neutrons and protons, and certain rather well-defined sizes. It is not at all our intention at this stage to give a detailed descriptive account of atomic and nuclear physics; nor do we want to bring in the new fundamental particles that are the concern of high-energy physics. We do want to say something to indicate the scale and the structure of the atomic world, and we want to give the student a feeling for how one can learn about such matters by making suitable observations. Indeed, we have consciously taken as our text what Newton wrote in his preface to the *Principia:* ". . . for the whole burden of philosophy seems to consist in this — from the phenomena of motions to investigate the forces of nature, and then from these forces to demonstrate the other phenomena."

At this point we have thought it appropriate to insert a chapter called "Randomness." Here, we develop, explicitly and in some detail, the consequences of having a system made up of a finite number of particles. After introducing some of the elementary ideas of probability, we consider various examples of fluctuation phenomena — radioactive counting, Brownian motion, etc.

We now return to particles, but of a distinctive kind — photons. After presenting some of the evidence that photons are particles that can be counted, we demonstrate that this goes hand-in-hand with wave behavior. In order to talk usefully about the interference properties of photons, we must say something about waves and the interference of waves in general. We need not, however, call upon anything beyond the usual double-source interference problems. With the help of actual experiments (films) we can show how the maxima of the interference patterns are correlated with maxima of the probability for a photon to arrive at a given point on the detector. Thus the essentially statistical nature of atomic phenomena makes its appearance in this course. Having introduced the wave-particle duality for photons, we then point to the existence of this same duality for the particles — electrons, atoms, etc. — whose purely particulate nature we had accepted up to this point.

The remainder of this first part of the course consists of a rather brief survey of the larger types of particles, from molecules up to stars. The chief purpose of this is to introduce the scale of magnitudes involved, although the operation of different kinds of forces for different sizes of particles — nuclear forces for nuclei, electric forces for almost everything else, gravitational forces for very large objects — is something to be brought out at this stage.

Let me reiterate at this point that everything that I have described so far falls within one-third of the first semester of the course. If the purpose were to fill the student with detailed information about the particles in question, the time would be totally inadequate. However, as I have pointed out, this is not at all the purpose of the exercise. It is, if you like, almost an impressionistic approach. But it is far from being purely descriptive. The student begins to learn to tackle quantitative problems in dynamics, as well as handling order-of-magnitude calculations and approximations. And of course, as always, the consideration of randomness and probability calls for clear and logical thinking.

I have chosen to describe this first part of the course in rather considerable detail, despite its brevity, because it does much to define the spirit in which we have approached the whole program, and also because it is in many respects the most unconventional part of the enterprise.

In Part II of the course, which as we have taught it occupies the rest of the first semester, we turn to the classical mechanics of particles. We have sought to lay particular emphasis on the conservation laws for momentum and energy, and to solve problems with the help of these concepts, rather than through the direct use of F = ma. Free use is made of potential energy diagrams as a basis for analyzing motions of constant total mechanical energy. We develop the parabolic expansion of a potential about its minimum, and treat such problems as the vibration of an atom in a one-dimensional lattice. From one-dimensional problems we turn to two-dimensional problems and central forces. Again we make free use of the potential diagram, in this case with the centrifugal potential included. In these terms we treat the Kepler problem and Rutherford scattering. We limit ourselves throughout to what are effectively point particles; there is no discussion of rigid bodies. We do introduce angular momentum as an important conserved property for motion of a particle under a central force. Our study of one-dimensional motions in a potential, of course, includes the linear harmonic oscillator. We solve this in the first instance from the equation for conservation of energy, and we also discuss Newton's law as a differential equation applying to this problem. This and other dynamical problems show how one can begin developing a solution by numerical methods in cases where the exact analytic solution may be unknown to the student (or perhaps to anyone else).

In this discussion of dynamics, we are looking ahead to some of those features that will reappear in relativity and quantum mechanics. Emphasis on energy methods is one example of this. Two other examples are: the use of transformations between different frames of reference (pointing toward relativity) and an introduction to perturbation methods in simple dynamical problems with an eye on their future possible use in quantum mechanics.

Part III of our course — the first half of the second semester—is devoted to the subject of special relativity. Today, of course, we have access to a wealth of experimental information that did not exist in 1905 when Einstein made his theory. By pointing to some of this evidence — to the existence of a limiting speed for energetic electrons, the dynamical properties of photons, and the large time-dilation effects exhibited by mesons — the need for a non-Newtonian dynamics is made quite clear, but for the systematic development of relativistic mechanics we return to Einstein's postulates and their consequences. We discuss a number of applications of relativistic kinematics and relativistic dynamics including the calculation of threshold energies for the creation of particles in nuclear collisions. We take the formal analysis as far as the transformations of energy, momentum and force.

I think there are several good reasons for introducing relativity at this stage, even though we have not yet done with our development of classical mechanics. First, relativity is necessary to provide a correct description of the dynamics of a particle, for in working with electrons we quickly discover that Newtonian mechanics is not enough. Second, the great principles of special relativity — the equivalence of inertial frames and the relativity of simultaneity — are basic tenets of a physicist's creed. Third (perhaps a meretricious reason) the students love it, and if you say the word "relativity" you can be sure of their rapt attention. Fourth, although the ideas are grand and important, the mathematics is easy.

Next we come to Part IV — oscillations and waves. Our discussion of the harmonic oscillator in Part II of the course does not go beyond an analysis of the sinusoidal vibration of an undamped particle under a linear restoring force. Now we take up all the problems associated with forcing, resonance, and dissipative effects. The detailed shape of the response curve of a resonant system, the relation between line width and decay time, and the analysis of energy and power input for a forced oscillator, are all considered in some detail. The analysis is tied primarily to a mechanical system, but the appearance of resonance in all sorts of other physical systems is illustrated. This subject clearly requires the free use of differential equations. Most of our students have not yet had any significant contact with differential equations in mathematics. However, at this stage they have had at least one and one-half semesters' experience with calculus, and are able to recognize reasonable forms of solutions, and verify them by substitution.

Our next step — in keeping with our description of complicated systems as made up of individual particles — is to consider the problem of coupled oscillators. We begin with a system of two oscillators, which we solve for its normal modes, and show how any arbitrary motion of the system can be described in terms of superposition of these normal modes. Once again we are deliberately introducing ideas and approaches that are purely classical, but which will be of value when quantum mechanics is discussed.

We proceed next to the normal modes of a many-particle coupled system, and finally to a continuous medium as represented by a string. (Though, as we point out, not even a string is really continuous, and under sufficient enlargement would appear as a system of coupled particles with spacings of a few angstroms.)

Our emphasis now shifts to progressive waves. We point out how a normal mode of a stretched string, for example, can be described as a superposition of waves traveling in opposite directions, and in this way we are able to relate the wave velocity to what we have already learned about the coupled oscillations. By referring back to the coupled oscillations with a finite number of particles, we can introduce here the distinction between phase and group velocities. The remainder of this part of the course is devoted to mechanical waves in two and three dimensions. And thus ends the first year of our course.

At this point my account ceases to be a progress report and enters its planning phase. The second year of our course has not yet been formally taught to students, and many of its details remain to be sorted out. The broad picture, at least of our intentions, is however clear. The first semester of the second year will be devoted to electromagnetism. We shall expect to follow a fairly well-beaten path for the first half of this semester, assembling the facts of electrostatics, magnetostatics, and electric and magnetic induction. This will bring us to a statement of Maxwell's equations. Immediately following this (or perhaps interwoven with it, as appropriate) will be an exposition of electromagnetism from the viewpoint of relativity. In essence, what is done here is to start with Coulomb's law and the relativistic transformations, and analyze the interactions between point charges in various states of motion. Such a treatment brings out in all its glory the interconnection between electric and magnetic fields, and highlights the essentially relativistic character of electromagnetic theory (a feature that Einstein himself, of course, took as a starting point in 1905).

In the remainder of this third semester of our course, we shall go as far as we can in the discussion of electromagnetic radiation. Clearly our selection of topics here must be very limited, and we expect to restrict ourselves to plane-wave solutions of Maxwell's equations. Our main discussion of wave optics must, however, come here, and it would be highly desirable to analyze with some care the main features of interference and diffraction phenomena for microwaves and light.

The fourth semester of our course is reserved for an introduction to quantum physics. A presentation of the ideas of quantum mechanics in an elementary yet satisfactory way, during the students' sophomore year, presents a real challenge. Regular discussions of this problem were held throughout the Spring semester at M.I.T. this year, and two experimental seminars for sophomores were conducted so as to try out some possible approaches. No final decisions have been reached, but there is a balance of opinion in favor of beginning with the selection of discrete states of atoms in magnetic fields, rather than with the more usual elementary approach via de Broglie waves. The Schrödinger equation and its solutions will of course come along later, when its status and content can be better appreciated. Some discussion of systems containing identical particles is also regarded as being of the highest importance.

If time permits (which is pretty unlikely) we should like to end our two-year sequence with some discussions of the properties of bulk matter, on the basis of its being composed of huge numbers of particles. One of the points to be emphasized here would be that the statistical averages for such numbers of particles lead to collective properties such as pressure, temperature, elasticity, etc. It is here, if at all, that we shall be concerned with any kind of presentation of the ideas of thermodynamics. Traditionally, of course, heat and thermodynamics would come hard on the heels of the mechanics during the first year of our course. We have deliberately turned away from this possibility, feeling that the continuum approach to thermodynamics might be appropriately taught (and often, perhaps, better taught) in departments of chemical or mechanical engineering or chemistry.

This, then, is the structure of our course as we envisage it at present, although it remains to be seen how much material we can in fact get through during the second year. I could perhaps end here, but I don't propose to do so. A course is much more than just a syllabus, and I should like to say enough to convey something of the flavor that we have tried to give to our course, as well as sharing with you some of our ideas about the teaching of physics.

I myself feel very strongly that elementary physics teaching — and indeed undergraduate instruction generally — is altogether too much the slave of the textbook. And textbook instruction has acquired a life and character of its own. Physics as it is presented on the pages of many textbooks often bears surprisingly little resemblance to physics as it is actually practiced. What I mean by this, chiefly, is that the material is sterilized, abbreviated and codified so that one loses all sense of the actual process of discovery — the real experiments, the false starts, the inspired guesses, and all that goes into a living, developing science. A certain amount of streamlining is of course necessary and desirable, or the beginning student would be hopelessly lost. But one of the most valuable things we can do is to put the student in touch with the raw material of the subject — real data and original papers — so that it is not a desiccated scholastic discipline, but a human activity in which he is involved at first hand. In developing our material at the Science Teaching Center, we have tried hard to instill this approach. Let me give you a couple of examples of our "documentation" of our text material. My first example comes from our discussion of randomness. In Figure 1 you will see two graphs, both constructed from original data. One of them shows the result of a blood count: the distribution of blood cells on the identical squares of a hemacytometer slide. The other shows the results of an experiment by Rutherford, a study of the numbers of alpha particles arriving in equal intervals from a very weak radioactive source. The same laws of random distributions apply to both, and the student can make his own analyses of the data. He is not just learning the theory of random distributions, he is put in touch with the research laboratory. My second example concerns the Doppler effect. In Figure 2 you see a graph, taken from the research literature, which shows the received frequency of the radio signal emitted by the first Sputnik as it passed over the M.I.T. Lincoln Laboratory a few days after it was launched. From these data the student can draw his own conclusions about the altitude, as well as the speed, of the satellite. And we are trying to introduce such examples at various appropriate points throughout our text material. In the same spirit we have given frequent references to original papers that the student may profitably refer to. Every freshman can read and understand the first few pages of Einstein's first paper on relativity. When he has done so, he has not only

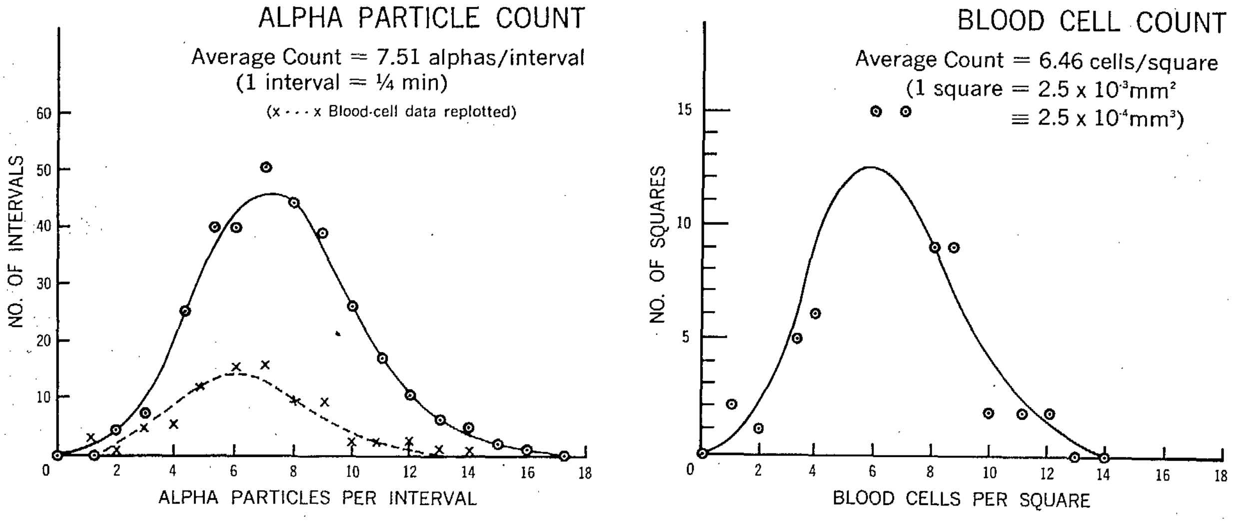

FIGURE 1

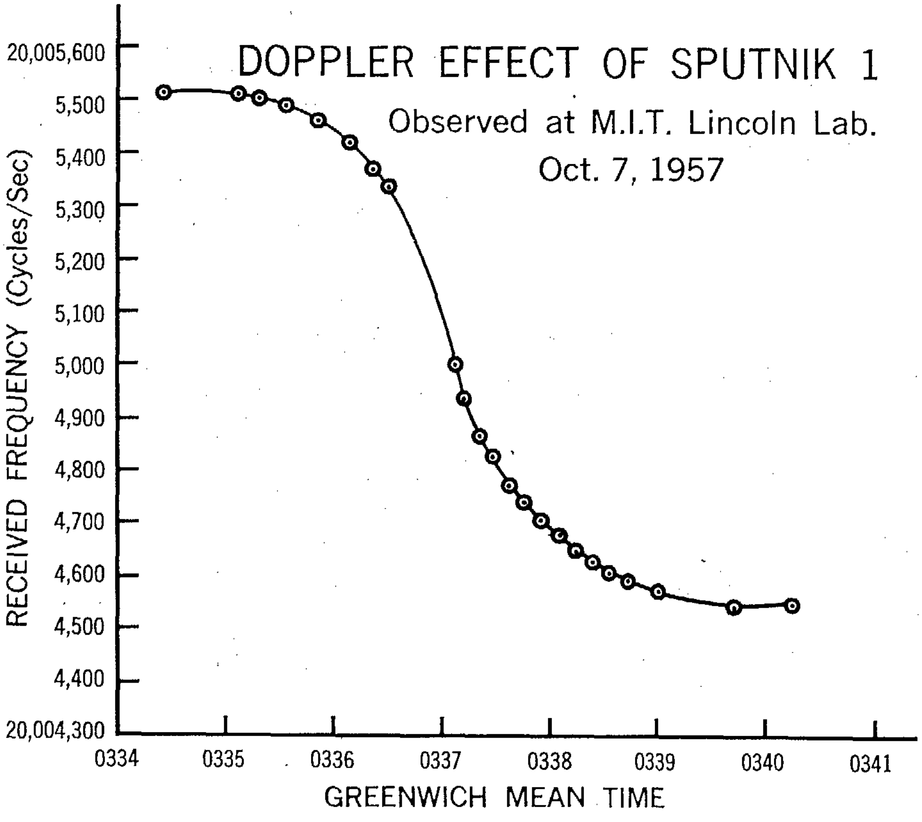

FIGURE 2

learned what are the postulates of special relativity, but he has also learned that Einstein's mind is not totally remote from his own. By proceeding along these lines the text can, I believe, be what it ought to be, namely a channel of communication between the student and the science, rather than being what it so often is—a barrier between the two.

This leads me to some still more general observations, with which I shall conclude my talk. The notion that a course in science is the study of a single textbook is very deeply imbedded in the educational system. I am far from alone in believing that this is a narrow and wrong point of view. The student cannot be blamed if he gets the idea that there is a well-defined and limited set of facts and principles to be learned, and that the textbook is the source of them. We need to break down this monolithic structure and diversify the student's experience. This means that he should read from many sources, and not from just one textbook, that he should do meaningful and relevant experiments in laboratory, and that his acquaintance with real phenomena should be enriched with the help of demonstrations and films. Every conscientious teacher knows this, and does his best to put it into practice. But the monolithic textbook, between hard covers, remains like a millstone around one's neck, making freedom of movement almost impossible. We at the Science Teaching Center at M.I.T. do not want to add one more millstone to the stockpile. And what we have in mind is that, instead of just another monolithic text, we should present the various parts of our course as a set of separate monographs. We would aim to produce more of them than could ever be covered in a two-year course anywhere. And then it would be open to the individual teacher to make his selection from the list, according to his own ideas and local circumstances. In this way, I hope, we could get away from anything in the nature of orthodoxy and settled traditions (new style). In other words, what I have tried to describe to you is *an* introductory course in physics, which will not, I hope, be ossified into *the* introductory course at M.I.T. or anywhere else.

HARVARD PROJECT PHYSICS [1]

Harvard Project Physics, a group of scientists and high-school teachers from all parts of the country, continues its efforts to develop over the next two and one-half years the instructional materials needed for a new kind of physics course designed mainly for secondary schools. The course is intended to appeal to a wide variety of students, from the science-oriented to the science-shy - and above all, to the large and growing fraction of students who are now taking no physics course at all in their senior high school years. Financial support is currently being provided by the Carnegie Corporation, the National Science Foundation, the United States Office of Education, and other agencies.

A Basic Course with Keyed Options. Departing from the traditional pattern of a more or less monolithic course package of fixed size, Project Physics is developing a course consisting of two parts : one is a relatively short, or at least manageable, basic course, consisting of the six units of the basic text, the associated laboratory and demonstrations, audio-visual materials (films, film loops, film strips, and transparency overlays), programmed instruction, examinations, and Teacher Guides. This basic course defines the minimum dimensions of activity for the school year. In addition, Project Physics is working on a large array of supplementary and complementary materials of all kinds, designed to be

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[1] From : Harvard Project Physics, Newsletter 3, Pierce Hall, 29 Oxford Street, Harvard University, Cambridge, Massachusetts 02138.

used in coordination with the basic course materials. With the aid of a Teacher Guide, the teacher can make selections from these optional materials to make the complete course.

An introductory course cannot cover all topics in physics. Through trial versions and long discussions, our staff physicists and teachers have agreed with a high degree of unanimity that the Project Physics' basic course contains those elements which should be included in an introductory physics course. Other topics will be available for use in the course in the form of optional materials. The options will be exercised by the teacher according to his individual training and preferences, his own developing ideas, and his students' ability and interests. The basic course has a complete structure and form of its own, however, and may well be the form in which the average teacher in an average class prefers to begin teaching the course.

This two-stage system is intended to help in dealing with the wide spectrum of our intended audience - students ranging from the bright pre-scientist to the potential drop-out - and with the variety of teachers in a wide range of academic situations. Every student should be able to complete the basic course, and then the majority of classes will still have from one to three months of school time remaining after the completion of the basic part of the course, depending on the extent to which the teacher uses the optional materials during the course and on the pace maintained by the class as a whole. Consequently, there is a large amount of flexibility to afford latitude for individual students, teachers, and school systems. In addition, we have tried to assure rapid building of confidence on the part of the teacher by avoiding unnecessary innovations ; it would not be realistic to demand that the general structure of the subject matter be radically removed from what teachers have been trained to handle.

If a teacher wishes to expand on a given topic in the basic course, he may select an article, reprint, or essay from the Reader, a special chapter, or a supplementary unit. As long as the basic course is made accessible to all students, it is left to the discretion of the teacher whether one or more additional selections are assigned for study by the entire class, whether different selections are assigned to individual students, or whether any additional selections specifically prepared by Project Physics are assigned at all.

<u>Basic and Optional Reading Materials.</u> Each of the six, separately bound units of the basic text has its own conceptual structure which holds its four chapters together as an integral unit. Each unit makes some connection to its neighbor by means of its prologue or epilogue, one outlining the important consideration that will be encountered in the chapters ahead, the other leading into the next unit while consolidating the work just studied. Below is the general table of contents for the old version of the basic text sent out to schools last September.

Unit One : Concepts of Motion
  Introduction
  Chapter 1 : All is Motion - All is Change
  Chapter 2 : Describing Acceleration - Galileo's Problem
  Chapter 3 : Analysing Complex Motions
  Chapter 4 : The Birth of Dynamics - Newton Explains Motion
  Epilogue
Unit Two : Motion in the Heavens
  Introduction
  Chapter 5 : Where is the Earth ? - The Answers of Greek Philosophers
  Chapter 6 : Does the Earth Move ? - The Works of Copernicus and Tycho
  Chapter 7 : A New Universe Appears - The Work of Kepler and Galileo
  Chapter 8 : The Unity of Earth and Sky - The Work of Newton and the New Astronomy
  Epilogue

Unit Three : Conservation and Chaos
    Introduction
    Chapter 9 : The Conservation of Mass and Momentum
    Chapter 10: The Conservation of Mechanical Energy
    Chapter 11: Heat : Substance or Energy ?
    Chapter 12: A Gas as a Mechanical System
    Epilogue
Unit Four : Waves and Fields
    Introduction
    Chapter 13: Waves
    Chapter 14: Light
    Chapter 15: Fields at Rest - Electricity and Magnetism
    Chapter 16: Fields in Motion - A Wave Theory of Light
    Epilogue
Unit Five : Models of the Atom
    Introduction
    Chapter 17: The Chemical Basis of Atomic Theory
    Chapter 18: Atoms, Electrons, Radiation, and Quanta
    Chapter 19: The Rutherford-Bohr Model of the Atom
    Chapter 20: Wave-Particle Dualism and the New Mechanics
    Epilogue
Unit Six : The Nucleus
    Introduction
    Chapter 21: Radioactivity
    Chapter 22: Isotopes
    Chapter 23: Nuclei and Particles
    Chapter 24: Nuclear Energy
    Epilogue

Concerning the status of our text, a passage in the current Newsletter of another curriculum development project (one not in physics, but in engineering) happens to apply equally well to our own Project : " ... The final text, which will appear some years from now, is expected to bear little resemblance, except in content, to this year's trial text. Although hopefully the coming revision will represent considerable progress, the text will be used on the same strictly limited basis during the 1966-1967 year."

A major problem in any basic text is, of course, to help the student focus on the main ideas and themes in the course. The Project is making every effort to keep out material that is not needed for the main story line, to avoid lengthy or unnecessary derivations, and to keep mathematics to a level consistent with a fair, but basic, presentation of the subject matter. Special attention is devoted to the control of the rate at which new concepts are introduced. During one phase in each unit, a series of new, interrelated ideas may be presented at a steady pace ; but this is followed by a period of consolidation during which the number of new concepts presented is small, and the older ones are organized. The principal scientific ideas or themes that appear throughout the six units are articulated in order to tie the units closer together.

Supplementary Units. Of the twenty supplementary units planned, several have now been commissioned. Dr. John Harris of the laboratory staff at Project Physics has been working on two supplementary units, one on electricity and magnetism centered around electrical circuits and devices, and one on the experimental approach to elementary particle physics, using bubble-chamber slides. Dr. William Shurcliff of Cambridge Electron Accelerator and Professor Irving Kaplan of the Massachusetts Institute of Technology, both associated with Project Physics, are collaborating on a unit about accelerators and reactors ; Professor Kaplan is also writing a supplementary unit on special relativity. Professor Leo Lavatelli of the University of Illinois has been commissioned to write a unit on Brownian motion, and Dr. Elizabeth Wood of the Bell Telephone Laboratories is working on a unit entitled Physics as Seen from the Air. Professor David Anderson of Oberlin College is writing a unit centering on several case studies in discovery in the physical sciences. Among the remaining supplementary units the Project plans to supply for the course, the subjects represented range from biophysics to physics and literature, from the physical optics of instruments to the interaction of physics and technology.

The course will also contain a book of optional readings. The Reader, now in first draft, will contain articles from scientific journals, reprints of research reports, and essays written especially to expand on a topic in the basic text. The readings will vary in quantity, content, and length, and serve both remedial and enrichment functions ; in each case their relationship to the basic course will be made clear. Professor Alfred M. Bork of Reed College has been in charge of gathering and editing materials for the Reader this year. Although still in a preliminary stage, the first trial draft of the Reader, which relates directly to the six units of the basic text, should be available for use in our trial classes by September 1966.

Caltech

- Feynman on Physics (1)

The recent publication of the first volume of Feynman on Physics(2) marks an epoch in the development of better physics courses in our colleges, universities, and technological institutes. This book is so different from anything previously available that the American Journal of Physics, the American Association of Physics Teachers, and the Commission on College Physics must give it special recognition.

The belief expressed by the three conferences that led to the creation of the Commission on College Physics was that courses and curricula would be improved with sufficient rapidity only if the most able of physicists participated in projects at a considerable number of institutions(3). It was recognized at the same time that such projects would achieve effectiveness only if the interactions among them would be strong - only if each became part of a national effort.

The first volume of Richard Feynman's lectures may be considered as a report on a project that started immediately after the conferences of 1959-60. As such, it promises to provide the type of interaction that these conferences envisaged. It seems probable that only a limited number of departments will have the necessary facilities or a sufficient proportion of well motivated students of high ability to duplicate the course exactly, yet this does not detract from the value of the book. That value lies in the gold mine of ingenuity, of deep understanding, and of brilliant presentation contained in the lectures. Every physicist of our acquaintance who read the book in its preliminary form found in it at least some chapters that not only captivated his interest, but also resulted in such a deepening of his understanding of some phases of physics that his courses would be significantly changed in the future. One sometimes hears of "a lawyers' lawyer" - perhaps we should define Feynman as an "instructors' instructor". The fact that the book does not contain problems may discourage its use as a text, but a book of problems is to be published.

Different sections of the book will have special appeal for particular physicists, but we can recommend a few for early reading. Probability (lecture 6) starting with very elementary considerations, leads through the normal distribution and the random walk to some discussion of the uncertainty principle. Space-Time (lecture 17) built on two earlier lectures on special relativity, gets into the four vector statement of conservation at an elementary level.

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1. An editorial from the American Journal of Physics, November 1963.
2. The Feynman Lectures on Physics, edited by Richard P. Feynman, Robert B. Leighton, and Matthew Sands (Addison-Wesley Publishing Company, Reading, Massachusetts, 1963)
3. For a report of these conferences, see Am. J. Phys. 28, 568 (1960)

Electromagnetic Radiation (lecture 28) contains few equations but presents a revealing qualitative discussion of retarded potentials. Symmetry in Physical Laws (lecture 52) is one of the clearest elementary expositions that we have seen.

As may be judged from these samples, the Feynman course has been designed to make clear from the beginning of elementary physics that we live in a relativistic, quantum mechanical world. It shares this in common with several of the other new courses that are being developed(1), as it does the emphasis on qualitative reasoning and the development of physical insight. This does not mean that any of the courses are less mathematical than traditional ones. If anything, they require higher level mathematics from the student, but they attempt to show that physical reasoning is not limited to analytical approaches and they often develop what mathematics is needed as part of the course, rather than to expect the student to bring it with him.

Detailed information concerning new science and mathematics curricula in U.S.A. will be found in the

> Third Report of the Information Clearinghouse on New Science and Mathematics Curricula, March 1965, compiled under the direction of J. David Lockard, a joint project of the American Association for the Advancement of Science and the Science Teaching Center, University of Maryland.

PHYSICS FOR THE INQUIRING MIND, the methods, nature and philosophy of physical science, Eric M. Rogers, Princeton, New Jersey, 1960, Princeton University Press, London : Oxford University Press, fifth printing 1963, xi + 778 pp.

Contents

- Part One : Matter, Motion, and Force
    - Gravity. A Field of Physics
    - Projectiles : Geometrical Addition : Vectors
    - Forces as Vectors
    - "It's Your Experiment" : Laboratory Work
    - Law and Order among Stress and Strain
    - Surface Tension : Drops and Molecules
    - Force and Motion : $F = M \cdot a$
    - Crashes and Collisions: Momentum
    - Fluid Flow
    - Vibrations and Waves
- Interlude
    - Appendix on Arithmetic
- Part Two : Astronomy : A History of Theory
    - Mankind and the Heavens
    - Facts and Early Progress
    - Greek Astronomy. Great Theories and Great Observations
    - Awakening Questions
    - Nicolaus Copernicus (1473-1543)
    - Tycho Brahe (1546-1601)
    - Johannes Kepler (1571-1630)
    - Galileo Galilei (1564-1642)
    - The Seventeenth Century
    - Circular Orbits and Acceleration

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1. Some of the other courses being developed are discussed briefly in Progress Report of the Commission on College Physics, Am. J. Phys. 30, 665 (1962)

  - Isaac Newton (1642-1727)
  - Universal Gravitation
  - Scientific Theories and Scientific Methods
- Part Three : Molecules and Energy
  - The Great Molecular Theory of Gases
  - Energy
  - Measuring Heat and Temperature
  - Power. A Chapter for Laboratory Work
  - The Principle of Conservation of Energy - Experimental Basis
  - Kinetic Theory of Gases : Fruitful Expansion
- Interlude
  - Mathematics and Relativity
- Part Four : Electricity and Magnetism
  - Electric Circuits in Laboratory
  - Electric Charges and Fields
  - Magnetism : Facts and Theory
  - Chemistry and Electrolysis
- Part Five : Atomic and Nuclear Physics
  - Electrons and Electron Fields
  - Magnetic Catapults : Driving Motors and Investigating Atoms
  - Analyzing Atoms
  - Radioactivity and the Tools of Nuclear Physics
  - Atoms : Experiment and Theory
  - Laboratory Work with Electrons : from Generators to Oscilloscopes
  - Atom Accelerators - The Big Machines
  - Nuclear Physics
  - More Theory and Experiment : Physics Today
- General Problems
- Index

Editor's comment

Although the table of contents reproduced above gives no indication of this, "Physics for the Inquiring Mind" is not a traditional work.

This book is designed mainly for the non-physicist seeking an introduction to the laws of physics which will provide him with full explanations. The author satisfies this need in detail. The numerous worked problems and the exercises suggested mark stages along the path mapped out by the author, who has brought his wide learning and many humorous illustrations to the service of this attractive presentation of physics.

In following the thoughts of Eric Rogers through the pages of this imposing volume, the reader is frequently taken back along the course of history and is confronted with many basic philosophical problems.

With "Physics for the Inquiring Mind", the first edition of which appeared in 1960, Eric Rogers has done pioneering work.

PHYSICS, second edition, by Physical Science Study Committee, Boston 1965, D.C. Heath and Company, reviewed by Noel C. Little, Everett J. Ford and Lester G. Paldy, pp. xvii + 686 (1)

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1. From : The Physics Teacher, Vol. 4, No 2, Feb. 66, p.89

The second edition holds to the philosophy of the first, i.e. to let the student find things out for himself. There is again the strong emphasis on fundamental principles, with mechanics, wave motion and electromagnetism playing the central role. Many topics usually dealt with are omitted, or at least given minor treatment. But one might ask, "Why mention Aristarchus but not Archimedes ?" Formal mathematics is kept to a minimum, yet perhaps a greater use of this language of the physicist might clarify the student's thoughts without leading him to rote substitution in formulas.

The major changes are most evident in the substantial rewriting of the chapters on the magnetic field, electromagnetic induction and waves. The section on optical instruments has been deleted. The introduction to vectors has been changed slightly, but the cumbersome chapter in the first edition dealing with the motion of charges in electric fields has been divided into two chapters ; into the second is segregated such circuit theory as is given. The description of the Millikan experiment has been modified to mesh with the new, inexpensive apparatus which has recently become available. The problem assignments have been revised, improved and extended and are much more realistically suited to the student's capabilities. Answers to short problems appear at the end of the book. Many of the suggestions from the "feed-back" of teachers using the text have been incorporated in the new edition.

Although the treatment is unique, there is a consistent motif behind it all. It can withstand the sharpest criticism of the scientific world.

The Berkeley Physics Laboratory*

A. M. Portis

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A brief description of the development and present state of the Berkeley Physics Laboratory is given. Thirty-six experiments in all are planned. Twenty-eight of these experiments have been used with student groups ranging in size from forty to six-hundred and fifty. The first twenty-eight experiments are described with particular emphasis on the electron deflection and microwave experiments, which are innovations of this laboratory.

INTRODUCTION

DURING the current term at Berkeley, 650 beginning engineering and science students are doing experiments that reflect the quality of current physics research.

Perhaps the first thing to say about this new laboratory program is that it was originally conceived in the summer of 1962 only as a stop-gap for a few dozen students. These students were to be exposed to the new material developed by the then-called College Physics Course Working Committee. In describing its intentions this group stated[1]:

> "The present anouncement concerns a working committee comprising several individual physicists who believe strongly in the need for an entirely new course which is a non-adiabatic advance over the present course . . . . Our intention is to present physics as far as possible as it is used in current research."

The present laboratory was originally developed defensively—we were concerned that if these three dozen students were placed in the conventional laboratory of Mechanics and Properties of Matter, Heat, Sound, Electricity, Magnetism, Light, "Modern Physics," we would have assuredly generated thirty-six confirmed theorists—and in their first year of college! It seemed that no laboratory at all was almost to be preferred to what was available, and that there was nothing to be lost by making a modest effort to set up a simple, inexpensive, and unmistakably modern laboratory. All of these students had completed a course in high-school physics together with a full laboratory. They were intrigued by modern science and anxious to do experiments that were fresh and interesting and fun.

We began by thinking about a laboratory that might parallel the projected volumes of the now-called Berkeley Physics Course:

I. Mechanics (including special relativity)
II. Electricity and Magnetism (based on special relativity)
III. Waves and Oscillations
IV. Quantum Physics
V. Statistical Physics

It became clear very early that a simple inexpensive laboratory could not hope to make it possible for the student to discover special relativity, the principal innovation of the course. Although we could easily design new kinds of toys which would elucidate various coordinate transformations, we would not be doing very much better than the conventional laboratory in "presenting physics as it is used in current research." We concluded that our mission must be to present experimental physics rather than to provide illustrations for lecture material, and that for a laboratory to be fresh and modern it must cut loose from the traditional ogranization—and from the lecture.

A number of the members of the Committee had been active in microwave development or had been exposed to one of the wartime radar training programs. It appeared at least feasible to develop a physics laboratory along these lines. But at the same time it must be unmistakably a physics laboratory—the taste in the selection of experiments must be that of a physicist and the experiments must be oriented toward discovery rather than toward technique.

We felt that the first third of the laboratory might emphasize timing measurements with the

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* Supported by the National Science Foundation through a grant to Educational Services Incorporated.

[1] Charles Kittel, Am. J. Phys. 30, 843 (1962).

Reprinted from: American Journal of Physics, vol. 32, No 6, June 1964, pp. 458-464.

TABLE I. Experiment titles for Part A.

BERKELEY PHYSICS LABORATORY
PART A

1. Acceleration and deflection of electrons
2. Magnetic deflection of electrons
3. Helical motion of electrons
4. Time of flight of electrons
5. Exponential relaxation
6. Damped oscillations
7. Frequency response
8. Resonance
9. Nonlinearity
10. Modulation
11. Negative resistance
12. Relaxation oscillations

TABLE II. Experiment titles for Part B.

BERKELEY PHYSICS LABORATORY
PART B

1. The transistor
2. Amplification and response
3. Negative feedback
4. Positive feedback and oscillation
5. Coupled oscillators
6. The delay line
7. Dispersion on a delay line
8. The distributed line
9. The microwave klystron
10. Microwave propagation
11. Microwave polarization
12. Microwave diffraction

TABLE III. Experiment titles for Part C.

BERKELEY PHYSICS LABORATORY
PART C

1. Radioactive decay
2. Statistics of random processes
3. Thermionic emission
4. Electron shot noise
5. Electron diffraction
6. Optical spectra
7. Optical pumping
8. Electron spin resonance
9. Photoelectric effect
10. Diffraction of light
11. Detection of photons
12. Photon interference

cathode-ray oscilloscope. Although we did not want to teach circuit electronics, we did want the students to feel comfortable about using a 'scope. We ultimately decided that by dealing in the first four experiments with electron dynamics, we could illustrate particle mechanics and develop a familiarity with the cathode-ray tube at the same time. The next four experiments dealt with transient and periodic response of linear systems, studied through electronic circuits. The final four experiments in Part A were to introduce Fourier analysis and to make the connection between periodic and transient phenomena. We have since concluded that Fourier analysis is too theoretical in its motivation for a first course and have instead elected to spend the final four experiments on nonlinear phenomena—a subject overlooked in most undergraduate physics curricula. The present list of experiments as they will appear in the laboratory manual for Part A are shown in Table I.[2]

Part B of the laboratory presented less of a problem. We wished to begin with power amplification and end with microwave optics. Our first decision had to be a choice between the vacuum triode and the transistor. Although students might understand the operation of the vacuum triode, they could hope to acquire at best a vague idea of the operation of the transistor. Even so, we decided to use the transistor; first, because the transistor is new and intriguing and is being increasingly used in current research while the vacuum triode is disappearing; second, because the transistor is more believably a three-port circuit element and by its very microscopic complexity forces one to a phenomenological analysis. In making the transition from power amplification to microwaves, we elected to take the phenomenological route: resonant circuits to coupled circuits to periodic structures to continuous lines to vacuum. The titles of the experiments as introduced in Part B are given in Table II.

In developing Part C we decided to deviate somewhat from the development of the course and to split classical and quantum statistics. We begin with the statistics of random events and end with photon detection. Intermediate is a section on quantum physics. At the time of this writing, only the first four experiments have actually been performed by our first group of students, who are now in their third term of the course. The anticipated titles for the Part C experiments are given in Table III.

With the spring term, 1964, the Berkeley Physics Course is being given to one third of the six-hundred and fifty beginning science and engineering students at Berkeley. The Laboratory is being taken by the full 650, having completely replaced the conventional laboratory. In the material that follows we describe a few of the

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[2] Part A of the laboratory will be available in the early Fall as *Berkeley Physics Laboratory, Part A* (McGraw-Hill Book Company, New York, 1964). Parts B and C of the laboratory will follow.

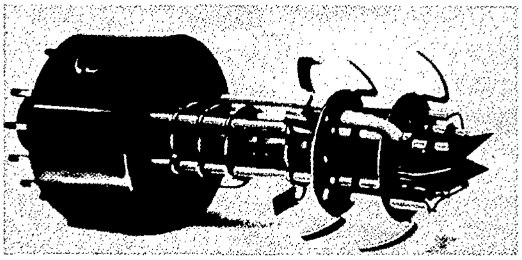

FIG. 1. Photograph of the electron gun and deflection assembly of the 3BP1 cathode-ray tube.

experiments which seem to best illustrate the possibilities of this kind of laboratory. In the final section we discuss our initial experience with the full-scale laboratory.

PART A

We show in Fig. 1 the electron gun and deflection assembly of the 3BP1 cathode-ray tube, which is presented in the first experiment. The first four experiments are an introduction to electron dynamics with no preliminaries. We assume either that the student has had some experience in electrical measurements in his high school physics course or that he can pick up the essentials of electrical measurement in a very short time in connection with the experiment. In Experiment A-1 the student applies accelerating and deflecting voltages to the cathode-ray tube and determines the deflection of the electron beam from the position of the spot on the face of the cathode-ray tube. What theoretical background he may need is presented by analogy with the acceleration and deflection of bodies in gravitational fields.

In Experiments A-2 and A-3 students study the deflection of electrons by magnetic fields. The experimental equipment used is shown in Fig. 2.[3] Experiment A-2, which is concerned with the deflection of an electron beam by a transverse magnetic field, leads into a determination of the direction and magnitude of the earth's magnetic field. Experiment A-3, which presents a simplified Busch Tube[4] determination of e/m, offers a precision of a few percent. Experiment A-4, which is a time of flight experiment, not unlike that of Wiechert,[5] makes possible a determination of e/m from a timing measurement.

With the completion of the first four experiments, students have some familiarity with voltages and currents, with electron deflection and with timing measurements. In Experiment A-5 we introduce the use of the cathode-ray oscilloscope in the observation of charge decay. Although most students have not previously been exposed to charge relaxation, they have studied radioactive decay and know that the source intensity drops exponentially with the time. For theoretical background it is a simple matter to demonstrate the analogy between radioactive decay and charge decay. In Experiment A-6 the oscilloscope is used in the observation of damped oscillations. Four oscilloscope traces showing underdamped, critically damped, and overdamped response are given in Fig. 3. In connection with both Experiments A-5 and A-6 mechanical systens are available in the laboratory so that students may observe for themselves the analogy between the response of the electrical and the mechanical systems. One must be careful that these experiments do not simply become experiments in analog computing. Many physicists who think primarily in terms of mechanical systems are reluctant to recognize that electrical systems are as "physical" as mechanical systems. The laboratory attempts to take the view that the simple harmonic oscillator is an idealization. One finds different kinds of realizations of the harmonic oscillator in all of physics. The mass on a spring and the LC circuit are simply two different kinds of realizations. Admittedly we can make more intimate physical contact with the mechanical one. However, if we wish to vary

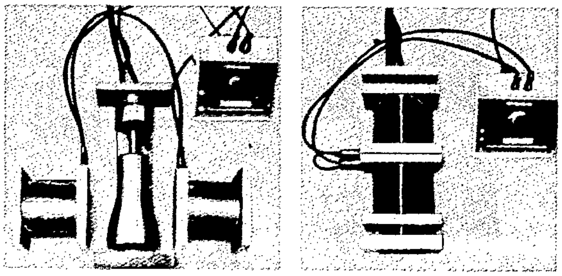

FIG. 2. Photographs of the experimental equipment used for Experiments A-2 and A-3. See Ref. 3.

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[3] The solenoids and tube base were specially fabricated for this laboratory and are available from Modern and Classical Instruments, 1446 Second Street, Livermore, California.

[4] H. Busch, Physik. Z. 23, 438 (1922).

[5] E. Wiechert, Ann. Physik und Chemie 69, 739 (1899).

parameters and observe the character of the response easily and precisely, the kind of data shown in Fig. 3 is without equal in a beginning laboratory. Experiments A-7 and A-8 reexamine the systems of A-5 and A-6, but this time in terms of their response to a sinusoidal voltage (or driving force).

With this discussion of the first eight experiments, it is clear that this series of laboratory experiments requires that all students perform the experiments in the same order. Such a procedure is not possible in most introductory laboratories, where each experiment requires an entirely different piece of equipment. In many such laboratories experiments must be performed in sets of four. One group of students perform them as 1, 2, 3, 4, but another group of students may have to perform them as 2, 3, 4, 1, etc. By designing four experiments around a single set of equipment with only inexpensive subsidiary components distinguishing the experiments, we are easily able to have all students perform the experiments in order. Thus we can have experiments which depend on each other both logically and pedagogically, and it is possible to have a laboratory which stands on its own.

The final four experiments of Part A introduce nonlinear systems. We begin in A-9 with the tungsten filament, where the variation in its temperature introduces a nonlinear relation between voltage and current. The semiconductor diode is presented as a device which is not only nonlinear but is also rectifying. In Experiment A-10 we use a diode network to produce modulation, and we study the response of the LC circuit to a modulated signal. In Experiment A-11 we introduce negative resistance, with the glow lamp and the tunnel diode as examples of devices which show a negative resistance characteristic over part of their operating range. In the final experiment we assemble and study the relaxation oscillator—a device which depends on a negative resistance characteristic for its behavior.

In all of the experiments an attempt is made to create the atmosphere of the research laboratory. We try as much as possible to avoid "canned" experiments. A minimum of equipment has been developed specially for the laboratory. We have tried to use standard instruments and standard components requiring no special modification.

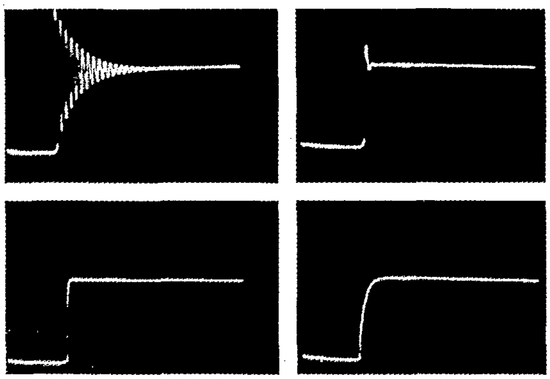

FIG. 3. Photographs of the cathode-ray tube trace showing damped oscillations of an LCR circuit for various values of damping. The lower-left figure illustrates critical damping. The photographs were made on Polaroid film.

We have developed a simple circuit board, using eyelets and rubber tubing which avoids soldering, but even such a board would not be out of place in an actual research laboratory. In addition, the laboratory manual attempts to stimulate the student's interest with background information, suggestions, and questions. We are determined to avoid the usual THEORY, APPARATUS, PROCEDURE, DATA, CALCULATIONS, QUESTIONS structure of most laboratory manuals. We regard the Physical Sciences Study Committee Laboratory Guide[6] as a model of what a laboratory manual should be and have tried to follow its approach.

PART B

The first four experiments of Part B employ the transistor as a power amplifying device. Our concern is not with the design of amplifiers, but rather with the transistor as a realization of an active system. In this we are primarily interested in the transient response of the device and in the effect of feedback on its transient response. Although the techniques of the laboratory continue to be electronic, we insist that the questions we ask be those that would be of greatest interest to a research physicist. Although the physicist must be concerned at times with the periodic response of a system, the transient response is primary to his understanding and is presented that way in this laboratory. There is

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[6] *Laboratory Guide for Physics*, Physical Science Study Committee (D. C. Heath and Company, Boston, Massachusetts, 1960).

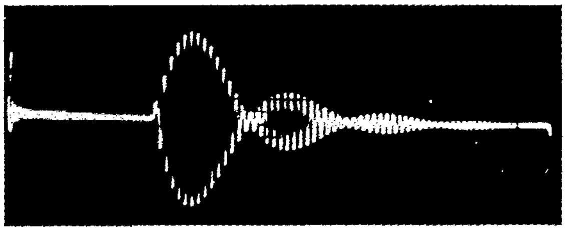

FIG. 4. Photograph showing the oscillations in one of a pair of coupled circuits. The oscillations in the other circuit of the pair reach a maximum at the nodes of this circuit.

the additional advantage in this approach that students seem to be able to "understand" transients more easily than they "understand" periodic response.

The second group of four experiments of Part B covers the distance from coupled oscillators to distributed lines. In Experiment B-6 the emphasis is on the transient response of a coupled system, as is shown in Fig. 4. In the laboratory, models of the Wilberforce Pendulum[7] as well as other kinds of coupled oscillators are available. In addition, a number of 8 mm film cartridges, currently available,[8] may be used to show the behavior of coupled mechanical oscillators. In Experiment B-6 our emphasis is again on transients—the propagation and reflection of pulses on a periodic line.

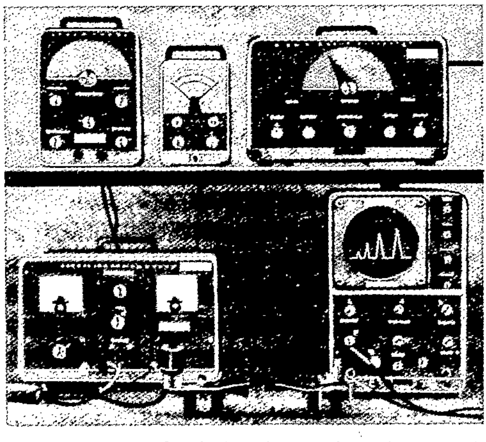

FIG. 5. Photograph of the electronic units used in this laboratory with a microwave transmitting and receiving horn in the foreground. The cathode-ray tube shows the electronic modes of the 723A/B klystron.

The final four experiments of Part B use the microwave klystron as a source of short wavelength radio frequency waves with which we can study propagation phenomena. In Fig. 5 we show in the foreground the microwave components used in this series of experiments.[9] The microwave klystron is frequency modulated by the sawtooth sweep of the oscilloscope. In this way the oscilloscope may be used as a monitor of received microwave power. Where a medium is sharply dispersive, the presentation of the full electronic mode on the oscilloscope does offer a real advantage. Otherwise disk-seal microwave triodes could be used as an alternative to klystrons.[10] The remaining equipment pictured in Fig. 5 comprises the full electronic bench used for most of Parts A and B.

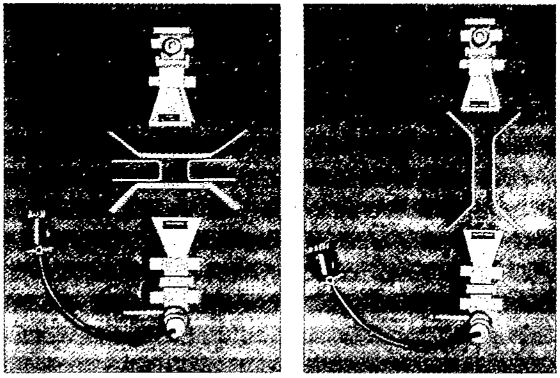

FIG. 6. Photograph of the microwave arrangements for Experiment B-10. On the left is shown a microwave cavity. The baffles on the right are used in the detection of microwave cutoff.

In Fig. 6 we show the arrangement used in Experiment B-9 for the investigation of microwave propagation. The left side of the figure shows a microwave cavity, formed from two pieces of eighth-inch hardwood cloth and a pair of aluminum side baffles. Microwave cutoff may be investigated with the arrangement shown in the right half of the figure, where a pair of long aluminum baffles are used. Students observe that when the baffles are less than a half wavelength apart there is no microwave propagation.

In Fig. 7 we show a pair of baffles, oriented at 45°, which are used to produce elliptical or circular polarization of microwaves. By placing the

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[7] Available from Modern and Classical Instruments. See Ref. 3.

[8] These films were produced by Dr. Franklin Miller Jr., Kenyon College, Gambier, Ohio, and are available through he Ealing Corporation, Cambridge, Massachusetts 02140.

[9] Available from Microwave Components, Inc., Doylestown, Pa.

[10] C. L. Andrews, The Physics Teacher **2**, 55 (1964).

detecting horn on a pair of rollers, as shown in Fig. 8, one can analyze the transmitted microwave signal. By bringing the baffles closer and closer one is able to form first a quarter-wave plate, then a half-wave plate, etc.

In Fig. 9 we show the arrangement used in Experiment B-12 for the observation of microwave diffraction. Students may easily vary the slit width and slit separation by having a number of small triangles available. As a complement to the microwave experiments, it may be desirable to demonstrate optical diffraction or possibly to show some of the films that are available on the subject.[7]

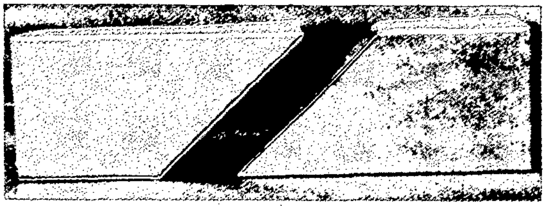

FIG. 7. Photograph of the 45° baffles used in the production of circularly polarized microwaves.

PART C

Part C of the laboratory begins with classical statistics, using a radioactive source as a generator of random events. By operating a small self-quenched Geiger tube from the high-voltage supply of the oscilloscope and using the vacuum tube voltmeter as a rate meter, we are able to avoid the introduction of additional electronic equipment of limited versatility. In order to give students additional experience with random events we provide them with paper tapes of radioactive events as run off on a fast chart recorder. These tapes, together with random-number tables, provide a rich source of experimental data. In Experiments C-3 and C-4 we investigate electron emission and the fluctuations in an electron stream.

In Experiment C-5 it is planned to use a cathode-ray tube with an internal target in the study of electron diffraction.[11] We expect to provide students with photographs of x-ray diffraction photographs so that they may compare the two kinds of spectra.

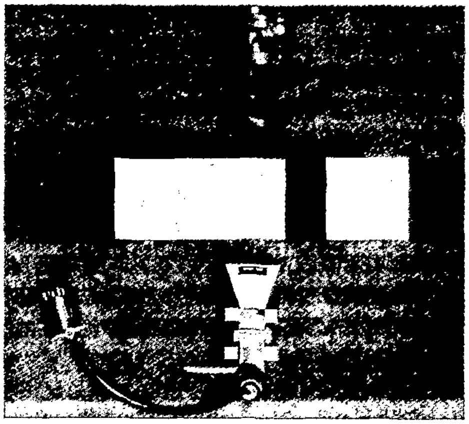

FIG. 8. Photograph of the circular polarizer showing the detector on a set of rollers.

In Experiments C-6 to C-9 we hope to investigate the optical properties of an alkali vapor, and to use optical absorption as a monitor of electron spin resonance.

In the final four experiments of the laboratory, C-9 to C-12, we plan to introduce the photomultiplier and to use it in the study of "photon physics."

CONCLUSION

Our first group of students has by now worked its way through the first third of Part C. A second group has completed a modified Part A and is one third of the way through Part B. A full six hundred and fifty students have completed the first third of Part A. In all we are very pleased with the favorable response that the

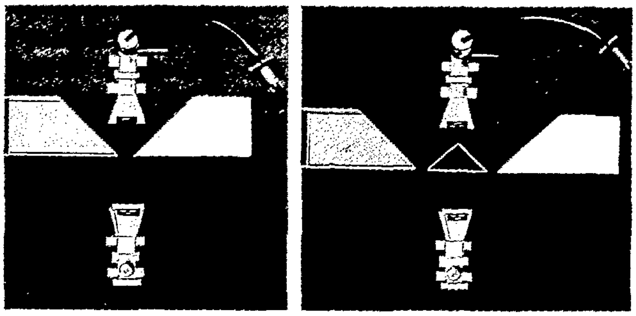

FIG. 9. Photograph of the arrangement for single and double slit diffraction. In use the detector is placed at a substantially greater distance from the slits than shown here.

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[11] This tube was developed with the cooperation of the General Electric Company by Harry F. Meiners and Stanley A. Williams. It is distributed by the Welch Scientific Company, 7300 North Linder Avenue, Skokie, Illinois.

laboratory has had. Our first two groups were volunteers and we were not surprised that they were enthusiastic about the laboratory. But that we are finding a strongly enthusiastic response to the laboratory from the present large group of students and teaching assistants leaves us pleasantly surprised. Where we had been afraid that the massive amounts of electronic equipment would frighten students, we have not found this to be the case. We have found instead that the students are reluctant to leave the laboratory, the teaching assistants are willing to remain in the laboratory with the students, and even the faculty come into the laboratory from time to time. Much of this may be because the laboratory is new. But an introductory laboratory must *stay* new to perform its role in the training of science and engineering students. Faculty time must be made available for the supervision and continued development of undergraduate laboratories.

The author has had a great deal of help and encouragement from the members of the Berkeley Physics Course Committee, from his colleagues, from those teaching assistants who have been associated with the course, and from the beginning groups of students who have endured a great deal at our hands. The members of the Course Committee have agreed not to thank each other in print. I would like, therefore, to begin by acknowledging the encouragement and support of Professor B. J. Moyer, Chairman of the Department of Physics. Without his support at critical times the laboratory would have disappeared with our beginning students. Professor Ronald Ross has supervised the expansion of Part A and the dozen teaching assistants whose services are required. Professor Arthur Kip stands ready to offer similar services for Part B and Professor Sumner Davis for Part C. I would like to especially thank William Holzer, a physics graduate student and teaching assistant, who has devoted himself to the development and teaching of the laboratory from the beginning, often at considerable personal sacrifice.

In conclusion I would like to pay special tribute to the Commission on College Physics and to its retiring Chairman, Professor Walter C. Michels. This Laboratory has felt itself fortunate to have come to maturity under the paternal eye of the Commission and of its Chairman. Without the community of concerned physicists, which the Commission on College Physics represents, the Berkeley Physics Course and Laboratory would never have been conceived.

BERKELEY PHYSICS COURSE
Vol. I. Mechanics, C.Kittel, W.D.Knight, M.A.Ruderman. New York. McGraw Hill, 1966
18 p. + 479
Vol. II. Electricity and Magnetism, Purcell, 1966, 18 p. + 459.

Preface to Volume I

The subject of this volume of the Berkeley Physics Course is elementary mechanics. Our approach is not radical, but differs perhaps from many textbooks in several aspects :

1. The consequences of the special theory of relativity are developed in detail. The central results here are essential to the development of electricity and magnetism in Vol.II.

2. We have emphasized the motion of charged particles in electric and magnetic fields. This area is rich in simple and important applications, and it relates immediately to the early experiments in the Berkeley Physics Laboratory.

3. We have tried to present elementary mechanics so that paths are seen leading to other parts of physics, to astronomy, to geophysics, and (as far as we could) to chemistry and biophysics. Many astronomical problems and examples are included.

4. We have tried to approach problems as most physicists would approach them, thereby hoping to develop early in the student a facility in some of the unwritten methods of scientific research and reasoning. We have emphasized order-of-magnitude estimates and dimensional analysis.

5. We have provided (in the form of advanced topics at the ends of the chapters) important relevant material for the superior student.

The first version of this volume, written by M.A.Ruderman, was used by an experimental class at Berkeley in the spring of 1963. It was then revised by C. Kittel with the assistance of W.D.Knight. We benefited from criticism by Philip Morrison, Edward M. Purcell, A.C.Helmholz, Alan M.Portis, Eyvind H. Wichmann, David Korff, Bernard Friedman, Alan Kaufman, W.A.Nierenberg, and others. The many drawings which are such a vital part of the volume were created by Eugene D.Commins and were drawn in final form by Felix Cooper. The second version was used at Berkeley and at Maryland by experimental classes in the fall of 1963, and a revision of the second version was used by regular classes of 230 students at Berkeley and 45 students at the University of Texas in the spring of 1964. The enthusiastic student response was enormously encouraging to the exhausted authors. The revised second version was extensively revised again in the summer of 1964.

Preface to Volume II

The subject of this volume of the Berkeley Physics Course is electricity and magnetism. The sequence of topics, in rough outline, is not unusual : electrostatics ; steady currents ; magnetic field ; electromagnetic induction ; electric and magnetic polarization in matter. However, our approach is different from the traditional one. The difference is most conspicuous in Chaps. 5 and 6 where, building on the work of Vol.I, we treat the electric and magnetic fields of moving charges as manifestations of relativity and the invariance of electric charge. This approach focuses attention on some fundamental questions, such as : charge conservation, charge invariance, the meaning of field. The only formal apparatus of special relativity that is really necessary is the Lorentz transformation of coordinates and the velocity-addition formula. It is essential, though, that the student bring to this part of the course some of the ideas and attitudes Vol.I sought to develop - among them a readiness to look at things from different frames of reference, an appreciation of invariance, and a respect for symmetry arguments. We make much use also, in Vol.II, of arguments based on superposition.

Our approach to electric and magnetic phenomena in matter is primarily "microscopic", with emphasis on the nature of atomic and molecular dipoles, both electric and magnetic. Electric conduction, also, is described microscopically in the terms of a Drude-Lorentz model. Naturally some questions have to be left open until the student takes up quantum physics in Vol. IV. But we freely talk in a matter-of-fact way about molecules and atoms as electrical structures with size, shape, and stiffness, about electron orbits, and spin. We try to treat carefully a question that is sometimes avoided and sometimes beclouded in introductory texts, the meaning of the macroscopic fields E and B inside a material.

In Vol. II, the student's mathematical equipment is extended by adding some tools of the vector calculus-gradient, divergence, curl, and the Laplacian. These concepts are developed as needed in the early chapters.

In its preliminary versions, Vol. II has been used in several classes at the University of California. It has benefited from criticism by many people connected with the Berkeley Course, especially from contributions by E.D. Commins and F.S. Crawford, Jr., who taught the first classes to use the text. They and their students discovered numerous places where clarification, or something more drastic, was needed ; many of the revisions were based on their suggestions. Students'criticisms of the last preliminary version were collected by Robert Goren, who also helped to organize the problems. Valuable criticism has come also from J.D. Gavenda, who used the preliminary version at the University of Texas, and from E.F. Taylor, of Wesleyan University. Ideas were contributed by Alan Kaufman at an early stage of the writing. A. Felzer worked through most of the first draft as our first "test student".

The development of this approach to electricity and magnetism was encouraged, not only by our original Course Committee, but by colleagues active in a rather parallel development of new course material at the Massachusetts Institute of Technology. Among the latter, J.R. Tessman, of the M.I.T. Science Teaching Center and Tufts University, was especially helpful and influential in the early formulation of the strategy. He has used the preliminary version in class, at M.I.T., and his critical reading of the entire text has resulted in many further changes and corrections.

Publication of the preliminary version, with its successive revisions, was supervised by Mrs. Mary R. Maloney. Mrs Lila Lowell typed most of the manuscript. The illustrations were put into final form by Felix Cooper.

The author of this volume remains deeply grateful to his friends in Berkeley, and most of all to Charles Kittel, for the stimulation and constant encouragement that have made the long task enjoyable.

THE FEYNMAN LECTURES ON PHYSICS, I, II & III , Richard Feynman, Robert B. Leighton, Matthew Sands. Reading, Massachusetts, 1965, Addison-Wesley Publishing Company, Inc., respectively 12 + 514 p., 12 + 548 p., 10 + 358 p.

See the review of Vol. I under "Caltech" (page 136)

FUNDAMENTAL PHYSICS, by Jay Orear. Copyright 1961 by John Wiley & Sons Inc. Fifth Printing February 1965. Library of Congress Catalog No 61-5666. 381 p., 303 illustrations

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Answers to odd-numbered problems

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PROGRAMMED MANUAL FOR STUDENTS OF FUNDAMENTAL PHYSICS, by Jay Orear, Associate Professor of Physics in Cornell University. Copyright 1962 by John Wiley & Sons Inc. Produced by Educational Aids Publishing Corp., Carle Place N.Y. Third printing May 1965, VI + 314 p.

The Preface and Chapter 12, "Quantum Theory", of the Programmed Manual are reproduced below.

Preface

This programmed Manual makes use of some of the latest developments in the rapidly growing field of programmed instruction (teaching machines). This Programmed Manual has several advantages over conventional workbooks and over other types of teaching machines. Some of these advantages are:

1. Immediately after working a step of a problem or exercise, the correct answer is given; however, the answer is not available before working that part of the problem (taking a peek ahead will leave a permanent mark). This provides the immediate reinforcement which psychologists value so highly.
2. Each student can work at his own pace and level of difficulty. Slower-paced, easier material is automatically provided when a student runs into difficulty; while deeper and more challenging material is occasionally provided for only the advanced and more talented students. Each student follows his own individualized path through the material. The path automatically adjusts itself to meet the student's needs.
3. In this workbook students never get lost or stuck when trying to solve deep problems involving long chains of reasoning. Hence it is possible for students to work problems of greater difficulty than they could handle in conventional workbooks. A person should be able to do a reasonable job of mastering physics all on his own just by working through this Programmed Manual while studying its accompanying textbook.*
4. Unlike other programmed books, this Programmed Manual is cheatproof in the sense that it is impossible for a student to "take a peek" without leaving a telltale mark. Copying is discouraged by the requirement that no two paths should be the same. Guessing leads to too many wrong responses, inconsistency in the responses, and a longer path (extra work for the guesser).
5. Preceding steps and their answers are often displayed on the same page and can be referred to in working the next step. This is a valuable feature for the programming of science and math. Most other teaching machines are incapable of this. Nearly all other programmed books and teaching machines attempt to be self-contained with the consequence that there is no convenient means provided for the student to refer back to earlier material. In science and math the current subject matter usually depends closely on earlier material and a means should be provided for ready display of earlier material in a concise, logical order. The means provided here for display and reference is the accompanying textbook—here it is the textbook rather than the program that is self-contained.

This entire program, except for a few changes, was tested in a preliminary edition in 1961-1962 on a class of 400 at Cornell University and also at several other schools. A large amount of this material had also been tested the previous year. One test in the Spring semester of 1962 involved a group of students who had volunteered not to attend any classes, except for exams. This group, using just the text and Programmed Manual, did as well on the exams as the regular students who attended 5 hours of classes per week. This result indicates that it is possible to master college physics (except for the labs) by using just the Programmed Manual and its accompanying textbook.

Instructions

Each question is to be answered by moistening the answer of your choice. If your selection is correct it will turn green. If it is incorrect, it will turn red. For best results we recommend touching a pencil eraser to the tongue (these are non-toxic water colors), although a fountain pen filled with water, a small brush, or even a wet pencil may be used.

If a red response is obtained, rework the problem and then select one of the other choices. Keep trying until the correct answer (green) is obtained. Often several questions will be grouped together in a single box or frame. Each frame is followed by an instruction telling where to go next. Quite often the order of the frames will be deliberately scrambled. Do not work the frames in numerical order unless the instructions say to do so.

Some of the frames involve what is called branching. In that case the instruction at the bottom of the frame would read:

If red go to 4-3 ; if green go to 2-5.

This instruction means that if you initially missed the question (got any red response at all), then you must proceed to frame 4-3 (page 4, frame 3); or if all your initial selections in the frame were correct (no red marks anywhere in the frame) go instead to frame 2-5 (page 2, frame 5). In branching, each student follows his own sequence of frames which should be most suited to his particular needs. For example, in the Chapter 2 program there are 4096 different possible paths that could be followed. If each of these paths occurs with comparable probability, then there is only about one chance in 4000 that your completed lesson for Chapter 2 and that of one of your friends should look the same. Certainly no two completed workbooks should be filled out in exactly the same way.

Most of the questions are made sufficiently easy so that an average student can usually get the correct answer (although there are occasional questions which nearly everyone is expected to miss). If you find yourself consistently getting more red responses than green, something is wrong. Too many reds probably mean that you are going too fast and are substituting guesswork for thinking. NEVER GUESS, WORK OUT EVERY PROBLEM CAREFULLY BEFORE MAKING YOUR SELECTION.

The program in this manual is designed strictly for self-study. Hence the advantages of this Programmed Manual will be lost and your time wasted if you work it together with one or more students.

Name ____________________

Date ____________________

Chapter 12

Quantum theory

1-1 Rutherford determined the mass of the atomic nucleus by the $\boxed{\text{number ; energy}}$ of $\boxed{\text{alpha particles ; electrons}}$ that were scattered backwards. The scattering mechanism is the $\boxed{\text{gravitational ; electrostatic ; magnetic ; nuclear}}$ force.

Go to 1-2.

1-2 *(from 1-1)* Consider a box of cross sectional area A . The box contains 3 apples each with a cross sectional area σ . The total cross sectional area presented by the apples is $\boxed{A \;;\; \sigma \;;\; 3\sigma}$. An arrow aimed at the box would have a chance of $\boxed{\frac{3\sigma}{A} \;;\; 3\sigma A \;;\; \frac{\sigma}{A}}$ of hitting an apple. If N_a arrows are shot into the box, the number hitting apples would be $N_a(3\sigma/A)$ $\boxed{\text{true ; false}}$.

Go to 2-1.

2-1 *(from 1-2)*

In the next two frames we will see how the charge of the nucleus is determined by counting the number of scattered alpha particles.

Suppose each nucleus has a cross sectional area of σ cm^2. Suppose one alpha particle is shot at a metal foil of cross sectional area A containing N nuclei. The chance of hitting one of the nuclei would be the ratio of the cross sectional areas or $\boxed{\frac{\sigma}{A} \; ; \; \frac{N\sigma}{A} \; ; \; \frac{A}{\sigma}}$. If the total number of alpha particles shot at the foil is N_a , the number of scattered alphas would be N_a times $\boxed{\frac{\sigma}{A} \; ; \; \frac{N\sigma}{A}}$.

Go to 3-1.

2-2 *(from 3-1 or 5-1)*

If n is the number of alphas scattered more than 90°, then the experimental determination of σ is given by

$\sigma = \boxed{\frac{n}{N_a} \; ; \; \frac{nA}{N_a N} \; ; \; \frac{nA}{N_a} \; ; \; \frac{n}{N_a A} \; ; \; \text{neither}}$ where N is the number of $\boxed{\text{electrons ; atoms}}$ in the foil. A is the total area of all the nuclei $\boxed{\text{true ; false}}$.

If you are confused where this formula came from, solve for σ in Frame 2-1.

(see above frame).

Go to 4-1.

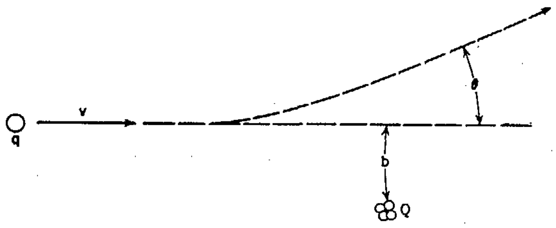
2-3 *(from 4-1)*

The ratio of electron to proton mass is about $\boxed{1 \; ; \; \frac{1}{2} \; ; \; \frac{1}{4} \; ; \; \frac{1}{200} \; ; \; \frac{1}{2000} \; ; \; \frac{1}{4000}}$.

In an atom such as carbon the fraction of atomic mass not in the nucleus is about $\boxed{\frac{1}{2} \; ; \; \frac{1}{2000} \; ; \; \frac{1}{4000}}$. This is the ratio of masses of 6 electrons to $\boxed{6 \; ; \; 12 \; ; \; 14}$ nucleons (neutrons or protons).

Go to 4-2.

3-1
(from 2-1)



In this frame we shall calculate the effective cross sectional area σ of a nucleus. Let Q be the charge of the nucleus and q the charge of the alpha particle. The distance b from the initial line of flight is called the impact parameter. The distance of closest approach will be $\boxed{b\ ;\ \text{greater than } b\ ;\ \text{less than } b}$. The angle of deflection θ $\boxed{\text{increases ; decreases}}$ with increasing b . The exact relation between impact parameter and θ can be calculated using $\boxed{\text{Coulomb's ; Ampere's ; Faraday's}}$ law (the result of such a calculation turns out to be $b = \frac{Qq}{mv^2 \tan\frac{\theta}{2}}$). For a deflection of 90° ; $b = Qq/mv^2$ $\boxed{\text{true ; false}}$. If the initial direction of the alpha is such that b is less than Qq/mv^2, then it will be deflected $\boxed{\text{more ; less}}$ than 90°. This corresponds to a region around the nucleus of area σ where

$$\sigma = \boxed{\pi\left(\frac{Qq}{mv^2}\right)^2\ ;\ 2\pi\left(\frac{Qq}{mv^2}\right)^2\ ;\ 4\pi\,\frac{Qq}{mv^2}} .$$

Hence $\sigma = \boxed{\frac{\pi Q^2q^2}{(KE)^2}\ ;\ \frac{\frac{1}{4}Q^2q^2}{(KE)^2}\ ;\ \frac{\frac{1}{4}\pi Q^2q^2}{(KE)^2}\ ;\ \frac{\frac{1}{2}\pi Q^2q^2}{(KE)^2}}$ is the effective cross sectional area for scattering alphas $\boxed{\text{at any angle ; more than 90° ; less than 90°}}$.

For N_a alphas hitting a foil of area A , the number of alphas scattered more than 90° would be $\boxed{\frac{N_aN\sigma}{A}\ ;\ \frac{N_aN\sigma^2}{A}}$ where N is the number of $\boxed{\text{alphas hitting the foil ; alphas scattered more than 90° ; atoms in the foil}}$.

Thus we see that by measuring the number of alphas scattered more than 90° the effective cross sectional area σ can be experimentally determined. Then the charge of the nucleus can be determined from the formula $Q = \boxed{\frac{2KE}{q}\,(\sigma/\pi)\ ;\ \frac{2KE}{\pi q}\sqrt{\sigma}\ ;\ \frac{2KE}{q}\sqrt{\frac{\sigma}{\pi}}}$.

If red go to 5-1 ; if green go to 2-2.

4-1
(from 2-2)

Rutherford found that the charge of the nucleus was $Q = \boxed{Z \;;\; Ze \;;\; \tfrac{1}{2}Ze}$ where Z is the atomic number and e is the charge of the electron. He also found that all but $\boxed{\frac{1}{2} \;;\; \frac{1}{4} \;;\; \frac{1}{Z} \;;\; \text{neither}}$ of the mass of the atom was in the nucleus.

If red go to 2-3 ; if green go to 4-2.

4-2
(from 2-3 or 4-1)

Let W be the energy of a photon of frequency f and wavelength λ .

Then $f = \frac{h}{W}$ $\boxed{\text{true} \;;\; \text{false}}$. $\lambda = \frac{h}{W}$ $\boxed{\text{true} \;;\; \text{false}}$.

$\lambda = \frac{c}{f}$ $\boxed{\text{true} \;;\; \text{false}}$. $\lambda = \frac{hc}{W}$ $\boxed{\text{true} \;;\; \text{false}}$.

If red go to 6-4 ; if green go to 4-3.

4-3
(from 4-2 or 6-4)

A 5 ev photon is absorbed by an electron on the surface of a metal. The work function of this metal is $W = 2$ ev. The kinetic energy of the electron after leaving the metal will be $\boxed{1 \;;\; 2 \;;\; 3 \;;\; 4 \;;\; 5}$ ev.

Go to 12-2.

4-4
(from 6-5)

In this closed system of electron plus metal, mechanical energy will be conserved (assuming no friction) $\boxed{\text{true} \;;\; \text{false}}$.

Until this electron collides with other electrons the quantity KE + U will be zero whether it is inside or outside the metal. Inside the metal KE = 5 ev and $U = \boxed{-5 \;;\; 0 \;;\; 5}$ ev.

Go to 7-1.

5-1 *(from 3-1)*

We had already derived the result $\sigma = \frac{\pi Q^2 q^2}{4(\mathrm{KE})^2}$ $\boxed{\text{true ; false}}$.

This equation can be solved for Q^2 by multiplying both sides by $\boxed{\frac{4(\mathrm{KE})^2}{\pi q^2} \; ; \; \frac{\pi q^2}{4(\mathrm{KE})^2} \; ; \; 4(\mathrm{KE})^2}$. The result is $Q^2 = \frac{4(\mathrm{KE})^2 \sigma}{\pi q^2}$ $\boxed{\text{true ; false}}$.

σ is determined experimentally by measuring the $\boxed{\text{energy ; number}}$ of the alphas scattered more than 90° .

Go to 2-2.

5-2 *(from 7-3 or 9-3)*

As the energy of a photon decreases, its wavelength $\boxed{\text{increases ; decreases ; remains the same}}$.

If red go to 7-4 ; if green go to 8-1.

5-3 *(from 12-2)*

According to the theory of metals conduction electrons have kinetic energy while in the metal and are bound to the metal by an attractive electrostatic force. For a certain metal the maximum kinetic energy of the conduction electrons in the metal is 3 ev, but these electrons would need an additional 2 ev to leave the surface. The work function of this metal is $\boxed{1 \; ; \; 2 \; ; \; 3 \; ; \; 4 \; ; \; 5}$ ev. Electrons having a total kinetic energy of $\boxed{2 \; ; \; 3 \; ; \; 4 \; ; \; 5 \; ; \; 6}$ ev would just barely be able to leave this metal and would lose $\boxed{2 \; ; \; 3 \; ; \; 4 \; ; \; 5 \; ; \; 6}$ ev of kinetic energy in the process of leaving the metal. Suppose one of these 3 ev electrons absorbs a 4 ev photon. The kinetic energy of this electron will be $\boxed{3 \; ; \; 4 \; ; \; 5 \; ; \; 7}$ ev before leaving the surface. After leaving the surface its kinetic energy will be $\boxed{1 \; ; \; 2 \; ; \; 3 \; ; \; 4 \; ; \; 5}$ ev less or $\mathrm{KE}_{\text{final}} =$ $\boxed{2 \; ; \; 3 \; ; \; 4 \; ; \; 5 \; ; \; 7}$ ev.

If red go to 6-1 ; if green go to 6-2.

6-1 *(from 5-3)*

In the previous problem a surface electron absorbs a photon of energy $hf = 4$ ev. If the work function $\mathcal{W} = 2$ ev, the kinetic energy left over after leaving the metal will be $\boxed{\mathcal{W} - hf \;;\; hf - \mathcal{W} \;;\; hf + \mathcal{W}}$ which is $\boxed{1 \;;\; 2 \;;\; 3 \;;\; 4 \;;\; 5}$ ev.

Go to 6-2.

6-2 *(from 5-3 or 6-1)*

In leaving the surface of a metal the kinetic energy of an electron is decreased by an amount equal to the work function $\boxed{\text{true ; false}}$.

Go to 6-3.

6-3 *(from 6-2)*

The additional kinetic energy necessary for an electron to leave the metal is the work function $\boxed{\text{true ; false}}$.

Go to 6-5.

6-4 *(from 4-2)*

$hf = W$ $\boxed{\text{true ; false}}$.

$h\,(c/\lambda) = W$ $\boxed{\text{true ; false}}$. Solving for λ gives $\lambda = \boxed{\frac{c}{hW} \;;\; \frac{W}{hc} \;;\; \frac{hW}{c} \;;\; \frac{hc}{W}}$

Go to 4-3.

6-5 *(from 6-3)*

An electron outside a metal surface has KE = 0 and potential energy $U = 0$. Its total energy (KE + U) is zero $\boxed{\text{true ; false}}$. The positive atomic nuclei of the metal will attract this electron $\boxed{\text{true ; false}}$. Suppose this attractive potential gives the electron 5 ev of kinetic energy by the time it has entered the metal. The sum (KE + U) inside the metal will be $\boxed{0 \;;\; 5 \;;\; -5 \;;\; 10}$ ev. If (KE + U) = 0 and KE = 5 ev, then $U = \boxed{0 \;;\; 5 \;;\; -5 \;;\; 10}$ ev.

If red go to 4-4 ; if green go to 7-1.

7-1
(from 4-4 or 6-5)

Inside this metal $U = -5$ ev. If the maximum KE of the conduction electrons is 3 ev, it will take $\boxed{0 \;;\; 1 \;;\; 2 \;;\; 3 \;;\; 5}$ ev of additional energy to remove one of these conduction electrons from the surface. Hence the work function would be $\boxed{0 \;;\; 1 \;;\; 2 \;;\; 3 \;;\; 4 \;;\; 5}$ ev.

We see that there is a simple relation between work function $\mathcal{W}$, potential energy U, and the maximum kinetic energy KE_0 of the conduction electrons. This relation is $-U = \boxed{KE_0 + \mathcal{W} \;;\; KE_0 - \mathcal{W} \;;\; \mathcal{W} - KE_0}$ where U is a $\boxed{\text{positive} \;;\; \text{negative}}$ number. This relation will be studied in more detail in Chapter 14.

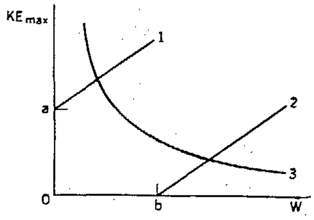
Go to 7-2.

7-2
(from 7-1)

In the photoelectric effect the maximum kinetic energy of the emitted electrons is related to the work function by the equation $\mathcal{W} = \boxed{hf - KE_{max} \;;\; KE_{max} - hf \;;\; KE_{max}}$.

Go to 7-3.

7-3
(from 7-2)



In the photoelectric effect a plot of the maximum KE of the electrons vs. the photon energy W would look like curve $\boxed{1 \;;\; 2 \;;\; 3}$.

In the above curve, the work function $\mathcal{W}$ has the value $\boxed{a \;;\; b \;;\; \frac{1}{b} \;;\; \text{the slope}}$.

If red go to 9-3 ; if green go to 5-2.

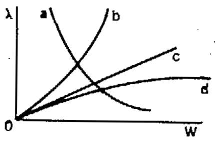
7-4
(from 5-2)

For the solution of the previous problem refer to Frame 6-4.

Go to 8-1.

8-1 *(from 5-2 or 7-4)*

A plot of λ vs. W for a photon would look like curve $\boxed{a \;;\; b \;;\; c \;;\; d}$.



Go to 8-2.

8-2 *(from 8-1)*

According to relativity theory, inertial mass is always given by

$M = \boxed{\frac{W_0}{c^2} \;;\; \frac{\text{KE}}{c^2} \;;\; \frac{W}{c^2}}$. The mass of a 10 ev (1.6×10^{-11} ergs) photon is

$M = \boxed{1.8 \times 10^{-32} \;;\; 1.6 \times 10^{-11} \;;\; 1.8 \times 10^{8}}$ grams.

Go to 11-2.

8-3 *(from 11-3)*

The numerical relation between λ and KE of a photon is $\text{KE(in ev)} = \frac{12340}{\lambda \text{ (in } A)}$ $\boxed{\text{true ; false}}$.

Go to 8-4.

8-4 *(from 8-3)*

The numerical relation between λ and KE of an electron is $\lambda \text{ (in } A) = \frac{12340}{\text{KE (in ev)}}$ $\boxed{\text{true ; false}}$.

Go to 9-1.

8-5 *(from 9-1)*

For a photon $\lambda = \boxed{\frac{hc}{W} \;;\; \frac{hW}{c} \;;\; \frac{hc^2}{W}}$.

The kinetic energy of a photon is the same as its total energy W $\boxed{\text{true ; false}}$.

Hence $\lambda = hc/\text{KE}$ for $\boxed{\text{photons ; electrons ; both photons and electrons}}$.

Go to 10-1.

9-1 *(from 8-4)*

For small velocities, the relation between KE and momentum is KE = $\boxed{\frac{mP^2}{2} \;;\; \frac{P^2}{2m} \;;\; \frac{P^2}{2m^2}}$. The momentum of a non-relativistic electron is P = $\boxed{\sqrt{2m\text{KE}} \;;\; \sqrt{\frac{\text{KE}}{2m}} \;;\; \sqrt{\frac{2\text{KE}}{m}}}$. The wavelength of any particle in terms of its momentum is $\lambda = h/P$ $\boxed{\text{true ; false}}$. The wavelength of an electron in terms of its KE is λ = $\boxed{\frac{h}{\sqrt{2m\text{KE}}} \;;\; \frac{h}{2m\text{KE}} \;;\; \sqrt{\frac{h}{2m\text{KE}}}}$

This equation also holds true for a photon $\boxed{\text{true ; false}}$.

Go to 8-5.

9-2 *(from 10-3)*

If the amplitude is 3 times as much, the wave intensity at electron A is $\boxed{\sqrt{3} \;;\; 3 \;;\; 9}$ times as much as at B . The number of photons passing by A is $\boxed{\sqrt{3} \;;\; 3 \;;\; 9}$ times as many as are passing by B .

Go to 11-1.

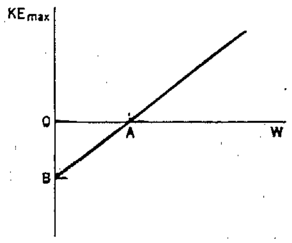
9-3 *(from 7-3)*

KE$_{\text{max}}$ = $\boxed{W - w \;;\; w - W}$ where $W = hf$.

When KE$_{\text{max}}$ = 0 , $W = w$ $\boxed{\text{true ; false}}$.

Point $\boxed{A \;;\; B}$ corresponds to KE$_{\text{max}}$ = 0 .

The value of this point as read off the $\boxed{\text{vertical ; horizontal}}$ axis will be w .



Go to 5-2.

10-1 *(from 8-5)*

Let us assign letters to the following equations:

a. ($W = Mc^2$) ; b. ($W = hf$) ; c. ($\lambda = h/P$) ; d. ($\Delta x \cdot \Delta P \approx h$) ; e. ($hf = \mathrm{KE} + \mathcal{W}$).

Make the appropriate identification of the above equations:

wave nature of matter equation $\boxed{\text{a ; b ; c ; d ; e}}$.

photo-electric effect $\boxed{\text{a ; b ; c ; d ; e}}$.

quantization of light $\boxed{\text{a ; b ; c ; d ; e}}$.

uncertainty of principle $\boxed{\text{a ; b ; c ; d ; e}}$.

Which of the above equations are identified with the following men:

Planck $\boxed{\text{a ; b ; c ; d ; e}}$.

Einstein $\boxed{\text{a ; b ; c ; d ; e}}$.

DeBroglie $\boxed{\text{a ; b ; c ; d ; e}}$.

Heisenberg $\boxed{\text{a ; b ; c ; d ; e}}$.

Go to 10-2.

10-2 *(from 10-1)*

A light beam of wavelength 3000Å is shined on cesium metal. Suppose the light intensity hitting electron A is three times that hitting electron B. $\boxed{1 \;;\; \sqrt{3} \;;\; 3 \;;\; 9}$ times as many photons pass by electron A as B. The chance of electron A absorbing a photon is $\boxed{\sqrt{3} \;;\; 3 \;;\; 9 \;;\; \text{same as}}$ the chance of electron B absorbing a photon in the same amount of time. The wave amplitude of the electric field at electron A is $\boxed{\sqrt{3} \;;\; 3 \;;\; 9}$ times that at electron B.

Go to 10-3.

10-3 *(from 10-2)*

If the amplitude of the light wave shining on electron A is 3 times that shining on electron B, the chance of electron A absorbing a photon is $\boxed{1 \;;\; \sqrt{3} \;;\; 3 \;;\; 9}$ times that of electron B absorbing a photon.

If red go to 9-2 ; if green go to 11-1.

11-1 *(from 10-3 or 9-2)*

Blue light of wavelength 4000Å strikes a double slit. At point P_1 the wave amplitudes from slits A and B are 10 and -9 units respectively. Hence point P_1 is near an interference $\boxed{\text{maximum ; minimum ; neither}}$. The resultant wave amplitude at P_1 would be $\boxed{1 \ ; \ -1 \ ; \ 19 \ ; \ \text{neither}}$ units. If the wave amplitudes from slits A and B are +9 and +10 units when at P_2 , the ratio of the amplitude at P_2 to that at P_1 is $\boxed{19 \ ; \ 1 \ ; \ 361 \ ; \ \text{neither}}$. The number of photons per second passing P_2 is $\boxed{1 \ ; \ 19 \ ; \ 361 \ ; \ \text{neither}}$ times the number of photons per second passing P_1 .

If red go to 12-1 ; if green go to 11-4.

11-2 *(from 8-2)*

If the mass of a photon is $M = hf/c^2$, its momentum will be

$$P = \boxed{\frac{hf}{c^3} \ ; \ \frac{hf}{c} \ ; \ hf} \ .$$

Go to 11-3.

11-3 *(from 11-2)*

The momentum of a photon is its velocity times (hf/c^2) $\boxed{\text{true ; false}}$.

The velocity is $v = \boxed{\frac{c}{f} \ ; \ \frac{c^2}{f} \ ; \ c \ ; \ \text{neither}}$.

Go to 8-3.

11-4 *(from 11-1 or 12-1)*

In the ground state of the hydrogen atom the wave amplitude of the electron is maximum at the position of the proton and drops off exponentially with distance from the center. At a distance of 0.5×10^{-8} cm the wave amplitude is 1/2.7 times its value at the center. The chance of finding the electron at the center of the hydrogen atom is $\boxed{1 \ ; \ 2.7 \ ; \ 2.7^2 \ ; \ \text{neither}}$ times the chance of finding it at a point 0.5×10^{-8} cm from the center.

Go to 12-3.

12-1 *(from 11-1)*

If the ratio of the amplitudes is 19, the ratio of the intensities will be $\boxed{\sqrt{19}\ ;\ 19^2}$.

The number of photons per sec is proportional to the wave $\boxed{\text{amplitude}\ ;\ \text{intensity}}$.

Go to 11-4.

12-2 *(from 4-3)*

Suppose the previous electron loses 1 ev by collisions inside the metal before it leaves the surface. Then the kinetic energy of this electron after leaving the metal would be $\boxed{1\ ;\ 2\ ;\ 3\ ;\ 4\ ;\ 5}$ ev.

Go to 5-3.

12-3 *(from 11-4)*

Review Questions:

1. What is the energy of a photon in terms of h , c , and f ?

   $W = \boxed{\qquad}$

2. What is the kinetic energy of a non-relativistic electron in terms of m , h , and λ ? KE $= \boxed{\qquad}$

3. The probability of finding a particle is proportional to the wave amplitude.

   True or false? $\boxed{\qquad}$

4. If the work function of a metal is 4 ev, what will be the minimum photon energy capable of producing photoelectrons from this metal?

   $W = \boxed{\qquad}$ ev.

   What will be the wavelength of such photons?

   $\lambda = \boxed{\qquad}$

End of Chapter 12 Program.

AN INTRODUCTION TO PHYSICS, Unit 2, Motion in the Heavens. Harvard Project Physics (1) 1966, 82 pp.

This document is only one of many instructional materials being developed by Harvard Project Physics. Like all existing Project materials - additional text units, laboratory experiments, teachers guide, and the rest - it is now in an experimental, intermediate stage. This text is based on earlier versions used in cooperating schools, and its development has profited from the help of many friends and colleagues, both within Project Physics and outside that group. Successive revisions in this text are planned in the light of further experience and use. In the final experimental edition scheduled for 1967, a detailed acknowledgment will appear of those contributions that were found to be of greatest use and permanence in the development of the new course.

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The Origin of Planetary Forces
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AN INTRODUCTION TO PHYSICS, Unit 2, Teachers' Guide, Motion in the Heavens, Harvard Project Physics, 1966, 280 pp.

DEVELOPMENT OF CONCEPTS OF PHYSICS (1), Arnold B. Arons, Reading, Massachusetts, 1965, Addison-Wesley Publishing Company, Inc., xx + 972 pp.

Development of Concepts of Physics is a book that should be on the shelves of all teachers in college and high school who wish to enrich their course with the story of physics (natural philosophy) and the men who erected our present structure. And it should not merely be on the shelf. It should be used and made available to students.

The guiding motif of the author, which is apparent throughout the book, is expressed well by the author in the closing of chapter 35 on the Early Theory of Atomic Structure. We quote : "Our story has focused not only on what it is that we think we know, but on how we know it. What is the nature of scientific evidence? of scientific explanation? The knowledge we have described would not exist without discoveries of facts, phenomena, and relationships, but neither would it exist without the attendant creation of concepts and theories - creations that involve imaginative acts of intelligence and perception and are not themselves 'facts' lying on the surface for all to behold. Time and again these abstract constructs have led to the recognition of relationships that lay close at hand but did not speak for themselves ; time and again they led to the deliberate design of new experiments and the discovery of new facts."

The book was written as a result of experience extending over a number of years in a core curriculum at Amherst College. In 1959 Professor Arons (2) wrote :

"The objective was a course which would deal with the main stream of physical concepts, laws, and ideas ; would examine these matters in some depth, with sophistication and with adequate mathematical tools ; would consider logical, epistemological, philosophical, and historical aspects ; and would be of such nature in subject matter and content as to be simultaneously a proper introductory course for science majors, a terminal course in physical science for nonscience majors, and a 'general education' course for both groups."

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1. Reviewed by J.W.Buchta, Washington, The Physics Teacher, Vol.4, No.2, Feb.66, p.333
2. Am. Journ. Physics, 27, 658 (1959)

In the opinion of this reviewer, these objectives have been met in the present book.

The book is, with its historical and philosophical features, long. But, even so, a number of topics usually included in texts are omitted. One will not, for example, find a chapter on sound although there is a long chapter on wave motion, the "kinematics", not the "dynamics" of waves. In accordance with the objective of presenting "physical science", there are chapters on subjects in astronomy (planetary motion and universal gravitation). In fact, six chapters on these topics are reprinted from Holton's Introduction to Concepts and Theories in Physical Science. Full treatment is given the laws of definite and multiple proportions, Avogadro's hypothesis, topics sometimes reserved for the chemists.

The desired and often necessary mathematics beyond a good high school background is included in the text. Three chapters, (1) Cartesian Geometry ; Functions and Limits, (2) Derivatives and Antiderivatives, (3) Fundamental Theorum of the Integral Calculus are included. The rigor of treatment of these topics may not always satisfy a mathematician but it is ample from the physicist's point of view. The calculus is not used excessively but moments of inertia are calculated and by use of the calculus it is shown that the tangential velocity is equal to $r\omega$.

The term "electromotive force" occurs only once - in a footnote to account for the use of EMF. The trend toward avoidance of the term electromotive force has been noted recently. Possibly we have a new "word" - EMF - in the physics vocabulary. The author is generally careful in the use of terms but at least once batteries are sources of "electricity" and often "current flows", or "flow of current" are used. The reviewer has an idiosyncrasy regarding the use of these terms. Why not omit the term "flows" when speaking of a current? A charge flows, but does a current flow? Simply say "the current in the wire" rather than "the current flows in the wire".

Problems are liberally scattered throughout the book. These often are not numerical exercises but rather call for discussion and analysis of situations. Appropriate references for additional readings are given for each chapter.

The book can be highly recommended as a reference and also as a text for those who have a course similar to that at Amherst.

PHYSICS, ITS METHODS AND MEANINGS(1), Alexander Taffel, Boston, 1965, Allyn and Bacon, Inc., ix + 566 pp.

Such topics as determination of the earth's mass, derivation of the general gas law from kinetic theory, all of Bohr's hypotheses for the theory of the hydrogen atom, matter waves and the antineutrino, etc. set the level of this text. It is a bit surprising to find "electric currents are described in terms of electron flow from negative to positive in line with modern thinking" written by its author, the principal of the Bronx High School, many of whose pupils will have to change this convention when they enter advanced work. Of course, he is in good company, for eight of the eleven texts under review use the left-hand rule for predicting the direction of magnetic flux due to a current.

Another matter of usage involves temperature scales. In 1948 the Ninth General Conference on Weights and Measures advocated that the name "Celsius" replace "Centigrade". Although this text mentions the Celsius scale, it continues to use the word "Centigrade". This procedure is adopted by about half the texts. If a usage is officially requested, it should be adopted whole-heartedly.

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1. Reviewed by Noel C. Little, Everett J. Ford, Brunswick, and Lester G. Paldy, Cold Spring Harbor, The Physics Teacher,, Vol. 4, No 2, Feb. 66, pp.88-93

The coverage is greater than that of the PSSC text, particularly in statics of rigid bodies and classical calorimetry, where one learns of "hidden heat" rather than of latent, but, as in that text, Archimedes is forgotten, or perhaps relegated to the lower grades. There is also greater dependence on formulae, on summaries and on a glossary. "Student activities" replace the "home, desk, and lab" of the PSSC text.

FOUNDATIONS OF PHYSICS(1), Robert L. Lehrman and Clifford Swartz, New York, 1965, Holt, Rinehart and Winston, Inc., vii + 694 pp.

This text has presented a problem to the reviewers. On initial examination one of us wrote "This is an excellent textbook." Another characterized it as providing "a rigorous and clear operational development of physics." Yet an unpublished review was brought to our attention which criticized it severely "for numerous errors in presenting and interpreting the laws and concepts of physics," and then listed some seventeen documented instances. To give one example (page 104) : "If you lean against a brick wall, the wall pushes back against you and you stay in equilibrium" ; the critic goes on to say the explanation shows the authors' lack of understanding of the third law of Newton. The best these reviewers can say is to read pages 102 and 103, where equilibrium is discussed in detail. This criticism does serve to emphasize the care that must be taken in the exposition of fundamental principles. It is difficult to satisfy everybody, but the problem of the teacher is to meet the needs of the student.

All will agree, however, that this text endeavors to carry the student to the frontiers of physics. Over one-third of the text is devoted to quantum theory and nuclear physics. You will find 25 pages devoted to reference frames and the theory of relativity. It may be that the authors have gone too far with leptons, baryons, isotopic spin, space parity, strangeness, and the like. The final chapter deals with the expanding universe. But the philosophy behind the text is sound, namely, that it is meaningless to talk about things you cannot measure, that physics is a cultural imperative. Matters are kept well in hand by a frequent and judicious use of dimensional analysis. The right-hand rule relates current to magnetic field.

PHYSICS FUNDAMENTALS AND FRONTIERS(1), Robert Stollberg and Faith Fitch Hill, Boston, 1965, Houghton Mifflin Company, vii + 696 pp.

This text by a former president of NSTA and by one who has taught physics in the experimental schools of Teachers College has all the earmarks of a professional job. There is black and white and red and blue printing. Even the teachers' manual on green paper and the accompanying fully annotated teachers' text with many blue interlineations carry on a color scheme. Eight colored plates are used to vividly explain the action of prisms, selective reflection and transmission, types of spectra, eye fatigue and color television. Plastic transparent overlays give a kinetic meaning to temperature and change subzero ice to superheated steam. They are used again to explain electromagnetic induction and the motor and generator effects.

The authors admit that their text offers all teachers and all students a choice of several ways of presenting physics yet maintain that an essential core of principles is clearly delineated. The teachers' edition has many sections with the notation : "This section can be omitted."

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1. Reviewed by Noel C. Little, Everett J. Ford, Brunswick, and Lester G. Paldy, Cold Spring Harbor, The Physics Teacher, Vol. 4, No 2, Feb. 66, pp.88-93

The formal mathematics is at a low level. For example, the expression for centripetal acceleration is quoted without derivation on the basis that assumptions about limits of ratios are beyond the ability of most high school students. In fact, no attempt is made to introduce calculus concepts as might be done in an intuitive way by means of a graphical analysis. To comprehend the slope of a curve does not seem too difficult for a student who is asked to understand radioactive decay in terms of half lives. On the other hand, the details of arithmetical computation are superb.

The authors point out that the simplest form of dimensional analysis involves labeling all quantities with the proper units to see whether or not the answer to a problem will come out with the proper units. This method is used consistently. It is a short step to the use of symbols for fundamental quantities and the more sophisticated form of dimensional analysis.

MODERN PHYSICS. REVISED EDITION (1), Charles E. Dull, H. Clark Metcalfe and John E. Williams, New York, 1964, Holt, Rinehart and Winston, Inc., viii + 728 pp.

This text is a revision of an old standby which carried the name of the senior author The use of the word "modern" in the title is in no way intended to imply the deletion of classical physics from its pages, although many a teacher would have preferred a quantitative rather than a qualitative treatment of the Bohr theory of the hydrogen atom. It contains the usual treatments of the principles of Pascal and Archimedes, statics of rigid and deformable bodies and calorimetry. Simple harmonic motion as well as moments of inertia and precession are included. In fact, the word "modern" could be interpreted to mean the inclusion of all of physics to date. To obtain student reaction, the authors have used the device of listing near the close of each chapter a list of "Terms to Define". There are 834 such items.

The new is skillfully intermingled with the old. The mass energy relation and the formula for the increase of mass with speed of the special theory of relativity are taken in stride along with levers and pulleys. The authors give a straight-forward exposition of facts, unafraid to use algebraic equations and numerical problems.

For the capable and inspiring teacher who will make a judicious selection this text affords a dependable backlog of material designed to spark in students the spirit of scientific research. Although the chapter on wave motion shows PSSC influence, in general, the text does not reflect the modern philosophy of physics teaching.

PHYSICS : A MODERN APPROACH (1), L. Paul Elliott and William F. Wilcox, New York, 1957, The Macmillan Company, xii + 658 pp.

During recent years there have been important changes in the teaching of physics. The phenomenal growth of the subject matter of physics during the last 50 years has been one of the factors involved. Another factor is the realization that much of the subject matter of the high school physics course of 20 years ago can be, and is being, taught in general science course in the 7th, 8th and 9th grades and even earlier. In his passage from the kindergarten through the 6th grade, the elementary school pupil of today is learning most of the science which in the memory of many of us was first encountered in the 9th grade. Many of today's 7th, 8th or 9th grade pupils may well have studied much of the material appearing in Physics : A Modern Approach or in any other text of the same vintage. Following are a few of these topics : simple machines, heat and temperature, expansion of solids, liquids

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1. Reviewed by Noel C. Little, Everett J. Ford, Brunswick, and Lester G. Paldy, Cold Spring Harbor, The Physics Teacher, Vol. 4, No. 2, Feb. 66, pp. 88-93

and gases, the transference of heat by conduction, convection and radiation, home heating systems, the common air pump, the hydrostatic paradox, mercury and aneroid barometers, hydraulic press, humidity and other weather phenomena, musical sounds, the eye and optical instruments and color. This overlapping between general science and high school science may well be a contributing factor to the decline in interest shown at the high school level. The teaching of physics and related science at all levels is changing so rapidly that a text, in order to continue to be useful, must be rewritten or radically revised at frequent intervals.

We have been underestimating the capacities of our young people to learn at an early age. We must also be fully aware that as a result of exposure to TV, the automobile, the airplane, etc., and almost daily references to nuclear energy and technological applications of electronic principles, there is more of an incentive for all young people to learn something about physics than there was 20 years ago. We should also bear in mind that the degree of sophistication which young people have attained is likely to make them intolerant of wordy explanations of phenomena with which they have become thoroughly familiar in earlier general science or elementary science courses. A typical TV science program showed 6th-graders performing an exercise involving simple machine elements and the operation of the DC motor.

The contents of Physics : A Modern Approach consists of 19 units in which are contained 53 chapters. Each chapter begins with a problem the solution to which is unknown to the pupil. An explanation of related principles follows. Sample problems are included in the body of the text. A "summary and conclusions" section appears at the end of the chapter, followed by questions for review, problems, projects, and recommendations for reading. There are numerous photographs and diagrams. Red ink is used effectively. An appendix lists formulae ; there is a glossary, table of constants and useful data, and an adequate index.

The physics contained in the text seems to be just a cut above that found in some recently published general science texts. One often has the impression that there is too much talk with too little said.

PHYSICS FOR THE SPACE AGE. REVISED EDITION(1), Richard W. Schulz and Robert T. Lagemann, Chicago, 1966, J.B. Lippincott Company, xiii + 479 pp.

This text is designed for the upper 50 per cent of 11th- and 12th-grade students who are college bound. After a somewhat cursory introductory chapter on the nature of physics, which includes a picture of Nobel laureates along with the enumeration of the fundamental concepts to be used, the authors devote unit one to heat. The usual topics - temperature, expansion, calorimetry, change of state, transfer of heat by conduction, convection and radiation - are discussed in an elementary way. Heat pumps and refrigerators are mentioned with no reference to the second law of thermo-dynamics.

Force and motion constitute unit two. Statics is followed by linear kinematics. Newton's law of motion and universal gravitation are simply expressed with no distinction made between inertial and gravitational mass. Physicists will be disturbed by the statement that angular acceleration is acquired by objects moving uniformly in a circle and is equal to the expression for centripetal acceleration to be derived in more advanced physics courses.

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1. Reviewed by Noel C. Little, Everett J. Ford, Brunswick, and Lester G. Paldy, Cold Spring Harbor, The Physics Teacher, Vol. 4, No. 2, Feb. 66, pp. 88-93

Unit three on work and energy vindicates the subtitle of the text, "For the Space Age", by telling of rockets and satellites, but unit four on forces in fluids deals with such classical topics as we associate with the names of Archimedes, Torricelli, Bernoulli and Boyle. Unit 5 on wave motion deals mostly with sound and light. Decibels are discussed without the use of the word "logarithm". Reduction of glare calls for a discussion of polarized light.

The college bound student will appreciate in unit 6 on electricity and magnetism that the convention for current is such as to give the right-hand rule for its relation to magnetic field.

The final unit on atomic and nuclear physics, like the greater part of the rest of the text, is largely descriptive and qualitative. Many students who have mastered this text will have a rude awakening when they meet the requirements of rigorous derivations and quantitative analysis of the first-year college course.

ELEMENTS OF PHYSICS(1), revised by Paul J. Boylan (Original authors : D.Lee Baker, Raymond B.Brownlee and Robert W.Fuller), Boston 1965, Allyn and Bacon, Inc., xiv + 677 pp.

This text is a revised edition of the Baker, Brownlee and Fuller which was very popular in non-college preparatory high school physics courses 35 or 40 years ago. It treats a large body of material in an essentially qualitative way. The text gives no evidence of having been affected by the renaissance in the teaching of physics courses which has occurred during the last ten years. Under various headings, such as, "Old Words with New Meanings", "Enlarge Your Vocabulary", "Terms to be Mastered", etc., are listed 517 items, with a paragraph reference for each. Is rote memory being encouraged ? The 100 short experiments distributed throughout the text will give the pupil a better feeling for the nature of physics.

As always in qualitative treatments there are many statements which to many seem in error. For example, on page 45, in the illustration of Mariotte's bottle, the stream emitted half-way from water surface to bottom of the flask should strike the table top farthest out. (See Physics Teacher, Sept. 1963.) Again, on page 21, the author, in the first column, in order to avoid confusing mass with weight agreed to use pound as a unit of force and define density as mass per unit volume. In the second column of the same page pound is used as a unit of mass in expressing the density of water as 62.5 pounds per cubic foot. Is everyday usage an excuse, even in a qualitative treatment, for inconsistency ? Yet again, on page 464, in the discussion of voltage we find the terms "energy" and "force" used almost synonymously. Is it too difficult to tell the student that EMF is not a force ?

THE PHYSICAL WORLD. SECOND EDITION(1), Richard Brinckerhoff, Burnett Cross, Fletcher Watson and Paul F.Brandwein, New York, 1963, Harcourt, Brace and World, Inc., xii + 497 pp.

This book is not a text on physics, but rather one on all the physical sciences. It starts with the earth as a planet, discussing its size and shape, its rotation and revolution, the wandering of its magnetic poles, the gravitational pull on it of sun and moon, and their tidal effect, including tidal friction. (The student will learn incorrectly how the tides really work as no mention is made of the differential pull involved nor explanation given of why there should be a high tide opposite the moon.) Then one turns to a description of the chemical composition of the earth's crust and the close packing of oxygen and silicon atoms. Oceanography is discussed next - the dollar value of a cubic mile of sea water, surface currents and the rise and fall of the ocean floor. Finally the ocean of air up through the clouds and the stratosphere to the moving layers of the ionosphere is breezily treated. All this within a dozen and a half pages !

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1. Reviewed by Noel C. Little, Everett J.Ford, Brunswick, and Lester G. Paldy, Cold Spring Harbor, The Physics Teacher, Vol. 4, No.2, Feb.66, pp.88-93

The rate shows down a bit as one "does" geology, but at page 50 one meets the atom and "does" it inside and out. By the time page 135 is reached, one has been pretty well exposed to chemistry from the Haber process for construction of ammonia molecules to nuclear reactors for the destruction of uranium atoms. Now one comes to physics - all about machines, from simple levers to engines of every sort. Temperature is introduced. You spend most of your money trying to control it, to keep your body at 98.6 degrees Fahrenheit and avoid all the terrors of the weather described in a chapter on meteorology.

In unit seven electricity is put to work, in unit eight light helps us see and in unit nine sound serves as means of communication, from noise to music, from teletype to television.

The grand finale, unit ten, is entitled "The Universe". Again the pace speeds up, and in 50 pages one "does" all of astronomy, including space travel.

A brief postscript of 4 pages deals with the arithmetic of scientific measurements, and there are 30 pages outlining 84 further simple experiments.

The story is fascinatingly told but with such a preliminary skimming of the realm of science in the earlier grades the student may find the hard work of the rigorous analysis of the principles of physics less exciting as he meets them later on.

PHYSICS FOR MODERN TIMES[(1)], Abraham Marcus, Englewood Cliffs, N.J., 1952, Prentice-Hall, Inc., xxi + 762 pp.

This text, which was first published in 1952, represents the outcome of an attempt to develop a physics program for high school students who are not going to continue their formal education. It is basically concerned with the "concrete objects of the student's environment, not the abstractions", and represents a wealth of essentially technological information.

The book is weakest in its general theoretical explanations, and strongest in its explicit treatment of various machines, instruments and devices. The weaknesses are apparent. The author could not really mean (p.13) that 1800 protons placed side by side would equal the diameter of an electron. He is obscure again on p.38 when he states that a rock released from a whirling string would fly off in a straight line "away from you". One hopes that he does not mean radially away from you.

It is interesting to read a book which stands out in stark relief from texts which develop material in a more general and fundamental way. All the pulleys, levers, engines and machines which have been removed from such texts here are bound in one volume ! There is even a picture of a pulley on the cover !

The chapters on transportation go from the oxcart via covered wagon to iron horse and horseless carriage by land and from floating log via rowboat and paddle wheel steamer to screw driven ships by sea. The submarine, the balloon, the airplane and the elevator are included. But should not ships propelled by nuclear reactors be included in a Physics for Modern Times ?

One's first inclination might be to ignore such an obvious throwback to the bad old days, but after a little reflection one also recognizes that a book like this might be interesting to the student who is not reached by any of the present courses. A careful teacher who is willing to take the time to correct some of the misinterpretations could use various sections in a general science or physical science course, or perhaps in an industrial arts course. The lack of mathematics and the descriptive questions are appropriate for many students who are bored by abstraction and generalization. These students will never resent being told that absolute zero means no molecular motion. Any teacher who is interested in a course for students that

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1. Reviewed by Noel C. Little, Everett J. Ford, Brunswick, and Lester G. Paldy, Cold Spring Harbor, The Physics Teacher, Vol.4, No. 2, Feb.66, pp.88-93.

are primarily interested in things and how they work should look at this book. The lack of pretentiousness, the pleasant style and good diagrams all might contribute to its potential usefulness in some specific learning situations.

UNIVERSITY PHYSICS, EXPERIMENT AND THEORY(1), George D. Freier, New York, 1965, Appleton-Century-Crofts division of Meredith Publishing Co., xx + 593 pp.

Of the many new, attractive physics textbooks at the college-university level, Professor Freier's is the freshest in concept and the most successful in execution. The author states that the book was planned "as a collection of simple demonstrations set into a rigorous theoretical development of the subject matter of physics". The execution is such as to illustrate invitingly the experimental basis of physics. Students are not asked to estimate data from murky photographs. Experimental details are not labored. Rather the beautifully clear drawings and concise descriptions serve (a) to suggest lecture demonstrations, (b) to invite students to experiment with simple equipment, or (c) to say convincingly "it may be shown that..." to one who may be reading the text without access to laboratory equipment.

The treatment of physics is general and well balanced. Where possible the student is led to the forefront of physics and shown problems which are currently under investigation. Engineering applications are not stressed. Rationalized MKSA units are generally used, but not exclusively. Calculus and vector notation is used where appropriate. Answers are given to all numerical problems. The problem sets are interesting and contain some problems to challenge the better students, as well as some that are simple or even whimsical : "A cat slides down an ebonite rod and falls from the rod into a metal pail A resting on an insulated shelf with two other metal pails B and C which are in contact but neither is in contact with A. The shelf breaks when the cat lands in A and all pails fall separated to the insulated floor. The cat then runs away. (a) What is the sign of the charge on each pail at the end of the process ? (b) Each pail is acted on by two electrostatic forces, one from each of the other two pails. Describe the repulsive or attractive nature of each of these forces. (c) Are any of the charges equal in magnitude ?"

Some topics not usually presented in a first-year text are discussed in University Physics, and other topics receive especially nice treatment. Examples of both are : Coriolis acceleration, special relativity, rocket propulsion, collisions, center-of-mass system of coordinates, complex numbers (in harmonic motion), dimensional analysis, meteorology, electric displacement and polarizability, a-c parallel circuit, Hall effect, transmission line, acoustics, music, Fermat's principle, thick lens, wave equation for radiation, Fresnel's equations, group velocity of light, dispersion and absorption, optical cross sections, quantized classical oscillator, Wein's displacement law, Debeye specific heats, Mossbauer effect, lasers.

The publisher is to be commended for the excellence of the illustrating, styling, and binding of University Physics. The illustrations are remarkable for their clarity and three-dimensional portrayals. Yet the illustrations, many of them in the margins, have been kept small and they are well placed with respect to the relevant text.

A physics department that adopts Freier's textbook, and its spirit, will be in danger of increasing the enrollment in its upperclass courses. Maybe even the number of its physics majors.

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1. Reviewed by Robert L. Weber, The Pennsylvania State University, University Park, Pa. "The Physics Teacher", Vol. 3, Number 6, September 1965, p. 278.

NOVEL EXPERIMENTS IN PHYSICS, a selection of Laboratory notes now used in Colleges and Universities, project sponsored by the Committee on Apparatus for Educational Institutions of the American Association of Physics Teachers, published by the American Institute of Physics, 335 East 45 Street, New York 10017, April 1964.

SUMMER WORKSHOP IN INTRODUCTORY COLLEGE PHYSICS (1), Robert Resnick and Harry F. Meiners

Demonstration and laboratory apparatus for the introductory college physics course was developed during a summer workshop. A report containing descriptions of 48 completed projects was prepared and distributed to 600 interested individuals and institutions. The report contains a detailed drawing and a materials list for each piece of equipment, as well as directions for use and other pertinent comments. Projects include ion motor, driven linear oscillator, stroboscopic techniques, fluorescent optical models, hysteresis demonstrator, discharge tube, photoelectric trigger, measurement of Hall coefficient, harmonic analyzer, plastic solid-CO_2 pucks, Bragg reflection with ripples, two-dimensional kinetic theory model, X-Y plotter, and orbital motion.

The 185-page volume, Demonstration and Laboratory Apparatus Report of the 1960 Summer Visiting Professor Workshop, may be purchased from the Rensselaer Union Book Store, Rensselaer Polytechnic Institute.
American Institute of Physics Newsletter (March 1961)
Proceedings of the American Association of Physics Teachers, American Journal of Physics, 29, xii (1961)

SOURCEBOOK FOR DEMONSTRATION EXPERIMENTS IN PHYSICS (1), Harry F. Meiners and Robert Resnick

The aim of this project is to prepare a new reference text which will bring together the best demonstration equipment and techniques in physics now available. Rensselaer Polytechnic Institute serves as the coordinating center for this program of the American Association of Physics Teachers. The new book, to be entitled A Reference Source for Demonstration Experiments in Physics, will consist of descriptions of demonstration equipment including their use in lectures, photographs, lists and sources of materials and, where appropriate, working schematics to make possible construction by individuals. Emphasis in the selection of material is placed on demonstrations related to the fundamental concepts of contemporary physics, e.g., demonstrations of the conservation laws of energy, momentum, and angular momentum ; kinetic theory demonstrations ; demonstrations of quantum effects such as the Franck-Hertz experiment and the diffraction of electrons ; demonstrations of the microscopic properties of solids, such as magnetic domains and the Hall effect ; demonstrations of scattering and resonance phenomena ; demonstrations of electric and magnetic field patterns ; demonstrations of wave phenomena ; and demonstrations of the velocity of light.

In addition, there will be invited articles by the following authors : Sir Lawrence Bragg, "The role and purpose of lecture demonstrations in England as illustrated by the tradition at the Royal Institution" ; Walter Eppenstein, "Overhead projection" ; Gerald J. Holton, "What is conveyed by demonstration? Some reflections and styles" ; Everett M. Hafner, "Corridor

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1. Extract from : Science Course Improvement Projects. National Science Foundation, NSF 64-8, July 1964

demonstrations" ; Robert I. Hulsizer, "Films as a lecture aid" ; Rosalie C. Hoyt, "Closed-circuit television" ; Harry F. Meiners, "Stroboscopic effects" ; R.W. Pohl, "Shadow projection" ; Eric M. Rogers, "The role and purpose of lecture demonstrations in the United States" ; and P.H. Scherrer, "The role and purpose of lecture demonstrations in Switzerland".

The two-volume reference work will be published by The Ronald Press Company, 15 East 26th Street, New York, N.Y., 10010 in late 1965.

A brochure explaining all aspects of the program is available on request from Professor Meiners.

PREPARATION OF RESOURCE LETTERS ON PHYSICS (1), Arnold B. Arons.

These letters constitute an effort to improve course content by giving the college or university teacher ready access to basic literature of a field by : (1) guiding them into the literature of both old and new areas of subject matter with which they may be unfamiliar but which they would like to work into new or existing courses ; (2) indicating published material which might be useful to students in course work or in special projects ; (3) giving references to available films, demonstrations, and laboratory equipment in a given subject area ; and (4) calling attention to historical and philosophical material that might be useful in extending the intellectual content of technical courses.

A resource letter is not meant to be a definitive or exhaustive bibliography, but rather an annotated guide that leads an individual into the field through the best starting points to the more advanced levels. The difficulty of references is evaluated as elementary, intermediate, or advanced. Certain references are starred to indicate that they are particularly important and fundamental to penetration into the subject matter. From among the starred references in the resource letter, about 100 pages of material are selected comprising important items scattered in journals and not available in textbooks ; these items are then reprinted in a booklet that is offered for sale by the American Institute of Physics. (The reprint booklet part of this project is supported by the American Association of Physics Teachers.)

Resource letters on the following subjects have been issued to date : Polarized Light; Plasma Physics ; Special Relativity ; Mössbauer Effect ; Kinematics and Dynamics of Satellite Orbits ; Quantum and Statistical Aspects of Light ; Evolution of the Electromagnetic Field Concept ; Friction. Resource letters on the following subjects are in preparation ; Superconductivity ; Semiconductors ; Discovery of the Electron ; Nuclear Physics ; Evolution of the Energy Concept ; Philosophical Foundations of Mechanics ; Nuclear Magnetic Resonance ; Masers and Optical Pumping ; Ferromagnetism ; Molecular Beams.

Copies of resource letters may be obtained by sending a request with a stamped and self-addressed envelope to the American Institute of Physics.

APPARATUS FOR COLLEGE PHYSICS (1), Walter Eppenstein and Robert Resnick.

It is planned to conceive, design, and construct laboratory and lecture demonstration apparatus in order to meet known national needs in introductory college physics courses. Five visiting physicists will work directly with six physicists from the Rensselaer faculty and a supporting technical staff during a two-month period in summer 1964, after a spring conference of all participants. Projects started by the group during the summer will be completed at Rensselaer and the resulting apparatus will be tested in classes. A final report, planned

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1. Extract from : Science Course Improvement Projects, National Science Foundation, NSF 64-8, July 1964.

for the early spring of 1965, will include photographs and design drawings of all apparatus, and discussions of classroom use and operating procedures for experiments and demonstrations ; it will be widely distributed to interested persons and organizations.

MOMENTUM BOOKS

As a result of actions taken by the Commission on College Physics and the American Association of Physics Teachers, a series of "monographs for college students and instructors on selected topics in physics, and monographs on historical developments, on connective material with other subject matter areas and on scientific bases for special technologies" was inaugurated several years ago. Initially E.U. Condon served as editor. Now Walter C. Michels fills that post. The books are published by The Van Nostrand Co., Princeton, New Jersey. They are paperbound, usually run about 160 pages, and cost less than $2.00.

The current list of titles, known as the Momentum Books, follows :

1. Elementary particles
   David H. Frisch and Alan M. Thorndike, 1964
2. Radio exploration of the planetary system
   Alex G. Smith and Thomas D. Carr, 1964
3. The discovery of the electron
   David L. Anderson, 1964
4. Waves and oscillations
   R.A. Waldron, 1964
5. Crystals and light : An introduction to optical crystallography
   Elizabeth A. Wood, 1964
6. Temperatures very low and very high
   Mark W. Zemansky, 1964
7. Polarized light
   William A. Shurcliff and Stanley S. Ballard, 1964
8. Structure of atomic nuclei
   C. Sharp Cook, 1964
9. An introduction to the special theory of relativity
   Robert Katz, 1964

EDUCATIONAL TESTING SERVICE ANNUAL REPORT, Princeton, New Jersey 08540, 1947 Center Street, Berkeley, California 94704.

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FILMS IN MAGI - CARTRIDGES (1)

The Ealing Corporation, 2225 Massachusetts Avenue, Cambridge, Massachusetts 02140

<u>Physics</u>

Demonstrations :

- Radioactive Decay
- Scintillation Spectrometry
- Absorption Spectra
- Ferromagnetic Domain Wall Motion
- Paramagnetism of Liquid Oxygen
- Critical Temperature
- Diffraction - Single Slit
- Diffraction - Double Slit
- Resolving Power
- Michelson Interferometer
- Coupled Oscillators - Equal Masses
- Coupled Oscillators - Unequal Masses
- Measurement of "G" - Cavendish Experiment
- Inertial Forces - Translational Acceleration
- Inertial Forces - Centripetal Acceleration
- The Wilberforce Pendulum
- Temperature Waves
- Noncurrent Wavefronts
- Tacoma Narrows Bridge Collapse

<u>Kinematics and Dynamics</u>

- Constant Velocity and Uniform Acceleration
- Newton's First and Second Laws
- Newton's Third Law
- Conservation of Momentum - Inelastic Collisions
- Conservation of Energy
- Conservation of Momentum - Elastic Collisions
- Simple Harmonic Motion - The Stringless Pendulum
- Center-of-mass Pendulum
- How An Air Track Works
- Ripple Tank, Coupled
  - Oscillator and Vector Kinematics Series - See Listing Under Educational Services Inc.

Educational Services, Inc. 39 Chapel Street, Newton, Massachusetts 02158

<u>Fluid Mechanics Teaching Films</u>

(Produced in collaboration with the National Committee for Fluid Mechanics Films). Distributed commercially by : Encyclopaedia Britannica Films Inc. 425 N. Michigan Ave. Chicago, Ill. 60611

- Some Regimes of Boundary Layer Transition
- Structure of the Turbulent Boundary Layer
- Shear Deformation of Viscous Fluids
- Separated Flows (Part 1)
- Separated Flows (Part II)
- Boundary Layer Formation
- Propagating Stall in Cascades

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1. From : Source Directory Educational Single-Concept Films available in Magi-Cartridges, third edition, March 1966, Technicolor Corporation, 1985 Placentia Ave., Costa Mesa, California (U.S.A.)

The Occurrence of Turbulence
Generation of Circulation and Lift for an Airfoil
The Magnus Effect
Flow Separation and Vortex Shedding
The Bathtub Vortex
Visualization of Vorticity with Vorticity Meter (Part I)
Visualization of Vorticity with Vorticity Meter (Part II)
Incompressible Flow through Area Contractions and Expansions
Flow from a Reservoir to a Duct
Tollmien-Schlichting Waves
Wing-Tip Vortex
Tornadoes in the Laboratory and in Nature
Transonic Flow Past a Symmetrical Airfoil (Color)
Occurrence of Supersonic Zones on Airfoils in Subsonic Flow
Shock-Boundary Layer Interaction on Transonic Airflow
Instabilities in Circular Couette Flow
Turbulent Flow between Concentric Rotating Cylinders
Stagnation Pressure
Radial Flow between Parallel Disks
Venturi Passage
Streamline Curvature and Normal Pressure Gradient
Streamwise Pressure Gradient in Inviscid Flow
Elastoid-Inertia Oscillations in Rotating Fluid Cylinder
Velocities near an Airfoil
Current Induced Instability of a Mercury Jet
Pathlines, Streaklines, Streamlines and Timelines in Steady Flow
Pathlines, Streaklines, Streamlines and Timelines in Unsteady Flow
Flow Regimes in Subsonic Diffusers
Simple Supersonic Inlet
Wide-Angle Diffuser with Suction
Flow Through Right-Angle Bends
Flow Through Ported Chambers
Flow Through Tee-Elbow
The Sink Vortex
Examples of Surface Tension (Color)
Surface Tension and Contact Angles (Color)
Formation of Bubbles (Color)
Surface Tension and Curved Surfaces (Color)
Breakup of Liquids into Drops (Color)
Motions caused by Composition Gradient along Liquid Surfaces(Color)
Motions caused by Electrical and Chemical Effects on Liquid Surfaces (Color)
Motions caused by Temperature Gradient along Liquid Surfaces (Color)

Physics

(Produced in collaboration with the College Physics Film Program).
Distributed commercially by :
The Ealing Corporation, 2225 Massachusetts Ave., Cambridge, Mass. 02140
Macalaster Scientific Corporation, 60 Arsenal Street, Watertown, Mass. 02172
McGraw-Hill Book Company, 330 W. 42nd Street, New York, N.Y. 10036
Modern Learning Aids, 3 East 54 Street, New York, N.Y. 10022
Science Electronics, Simon and Ledge Streets, Nashua, New Hampshire

Coupled Oscillator Series :

Energy Transfer
Other Oscillators
Normal Modes

Ripple Tank Wave Phenomena Series :
- Reflection of Straight Waves from Straight Barriers
- Reflection of Circular Waves from Various Barriers
- Reflection of Waves from Concave Barriers
- Refraction of Waves
- Barrier Penetration by Waves
- Bragg Reflection of Waves
- Doppler Effect
- Formation of Shock Waves
- Superposition of Pulses
- Interference of Waves
- The Effect of Phases Differences between Sources
- Single Slit Diffraction of Waves
- Multiple Slit Diffraction of Waves
- Diffraction and Scattering of Waves around Obstacles

Vector Kinematics Series :
- The Velocity Vector
- Velocity in Circular and Simple Harmonic Motion
- The Acceleration Vector
- The Velocity and Acceleration in Circular Motion
- Velocity and Acceleration in Simple Harmonic Motion
- Velocity and Acceleration in Free Fall

Encyclopaedia Britannica Films Inc., 425 North Michigan Avenue, Chicago, Illinois 60611

Physics - Ripple Tank Series
- Plane and Spherical Waves : Diffraction at Obstacles
- Diffraction at an Aperture
- Reflection at Plane and Curved Surfaces
- Refraction
- Interference

Physics
- Chain Reaction - Controlled Chain Reaction
- Critical Size
- Rutherford-Royds' Identification of Alpha Particles
- Aston's Mass Spectrograph
- Thomson's Positive Ray Parabola

International Communications Foundation , 870 Monterey Pass Road, Monterey Park
California.

Science
- Basic Electricity and Magnetism Series :
  - What is Electricity (Static) ?
  - Electricity and Different Materials
  - Electricity (Static) by Induction and Conduction
  - What is Magnetism ?
  - Magnetic Fields, Part 1
  - Magnetic Fields, Part II
  - Electric Current and its Magnetic Field
  - Voltaic Cells
  - Constant Voltage - Depolarization
  - Lead - Acid Storage Battery
  - Voltaic Cells in Series and Parallel
  - Resistance

- Ohm's Law
- Resistors in Series and Parallel
- Magnetism Produces Electricity

<u>Wave Motion series</u> :
(Produced by Gateway Films, London)

<u>Interference</u> :
- Two Sources in Phase
- Movement of Two Sources
- Change of Phase
- Change of Frequency

<u>Diffraction</u>
- Diffraction at an Aperture (Fixed Wavelength)
- Diffraction at an Aperture (Wavelength varied)
- Diffraction at a Straight Edge
- Diffraction at a Narrow Obstacle

<u>Nuclear Radiation</u> (Produced by CENCO Educational Films)
- Nuclear Radiation - Detectors, Part I
- Nuclear Radiation - Detectors, Part II
- Nuclear Radiation - Detectors, Part III
- Biological Effects of Nuclear Radiation
- Atmospheric Distribution of Nuclear Fallout

<u>Heat Series</u> :
- Most Solids Melt
- Liquids Evaporate
- Heat Expands Metals
- Heat Expands Liquids
- Heat Expands Gases
- Gases Condense as they Cool
- Evaporation Causes Cooling
- Heat Affects the Pressure of Gases
- Boiling Points of Water
- Heat Travels by Conduction, Convection and Radiation
- Heat is Reflected and Absorbed
- Materials Conduct Heat at Different Rates
- Heat is Produced in Different Ways
- Heat Can Do Work
- Conditions Necessary for Combustion

Fred Lasse Productions, 245 South Oak Street, Itasca, Illinois 60143

<u>Physics</u>

<u>Fire</u> : Conditions for Combustion
- Why do some fuels start to burn sooner than others ?
- Can water be heated in a paper dish ?
- Why does a fire go out in an enclosed space ?
- How does carbon dioxide put out a fire ?
- How does a soda-acid fire extinguisher put out a fire ?

<u>Magnetism</u> : An Invisible Force
- Can magnets attract through some materials ?
- Where is a magnet the strongest ?
- What happens when a magnet is suspended and free to turn ?
- How do the poles of magnets affect each other ?
- How do you make a temporary magnet ?
- How do you make a permanent magnet ?
- What happens when a magnet is broken in half ? in quarters ?

Electricity : Cells and Circuits

How do you connect a battery, bulb and switch to make the bulb light ?

How can you make a simple galvanometer ?

Will water conduct electricity ? A salt solution ?

Will a sugar solution conduct electricity ? Vinegar ?

What is needed to make a wet cell ?

What happens when lights are connected in a parallel circuit ?

What happens when lights are connected in a series circuit ?

Electromagnets : Electricity makes Magnets

Does a wire carrying electric current act like a magnet ?

Does a coil of wire carrying an electric current have poles ? What happens when the current is reversed ?

How do you make an electromagnet ?

How can you increase the strength of an electromagnet ?

Do the poles of an electromagnet act like the poles of a permanent magnet ?

How does electricity turn a motor ?

FILMS

Educational Services Inc., 47 Galen Street, Waterloo, Massachusetts (1)

The Size of Atoms from an Atomic Beam Experiment,
John King, MIT (28 min.)

Angular Momentum, A Vector Quantity,
Aaron Lemonick, Princeton (27 min.)

The Ultimate Speed, An exploration with High Energy Electrons,
William Bertozzi, MIT (38 min.)

Time Dilation, An Experiment with μ - Mesons ,
David H. Frisch, MIT ; James H. Smith, Illinois (36 min.)

Momentum of Electrons
John King, MIT (color, 10 min.)

Reflection and Refraction, Ripple Tank Wave Phenomena I,
James Strickland, ESI (17 min.)

Interference and Diffraction, Ripple Tank Wave Phenomena II,
James Strickland, ESI (19 min.)

Barrier Penetration, Bragg Reflection, Doppler Effect,
Ripple Tank Wave Phenomena III,
James Strickland, ESI (23 min.)

Solder Glass Technique
John G. King and Jan Orsula, MIT (color, 20 min.)

An Excerpt of the PSSC Film, "Forces",
Jerrold Zacharias, MIT (8 min.)

Excerpt I of the PSSC Film, "Frames of Reference",
Patterson Hume and Donald Ivey, Toronto (7 min.)

Excerpt II of the PSSC Film, "Frames of Reference",
Patterson Hume and Donald Ivey, Toronto, (6 min.)

An Excerpt of the PSSC Film, "Photoelectric Effect",
John Strong, Johns Hopkins (color, 9 min.)

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1. List from Progress Report, American Journal of Physics, Vol. 32, No 6, p.413

Audio-Visual Center, Michigan State University

- Film on Low Temperature Phenomena (Secondary, College), Alfred Leitner (1)

A 16mm. black-and-white, sound film, Liquid Helium II, The Superfluid (38min.), has been produced. It records a transfer of liquid helium at 4.2°K and describes the properties of helium I briefly. The liquid is then cooled by evaporation to the lambda point, demonstrating the transition to helium II. The viscosity paradox is proved by superleak and by the rotating cylinder method. The two-fluid model is discussed. The fountain effect is shown in two experiments, proving the zero entropy of the superfluid. The Rollin creeping film is demonstrated. The phenomenon of second sound is demonstrated by the pulse technique, and the speed of second sound near 1.6°K is measured.

The film is available for rental or purchase from the Audio-Visual Center, Michigan State University. A script with explanatory comments will be supplied to purchasers of the film.

- Film on Superconductivity, Alfred Leitner (1)

The film (16mm, black-and-white, sound, 30min.) will demonstrate some of the macroscopic properties of the phenomenon known as superconductivity as a means of bringing before college and university physics classes the elements of an interesting and active field of modern physics. Among the effects to be shown are (1) resistance change at a fixed temperature in zero magnetic field, (2) persistent current in a superconducting ring, (3) rejection of magnetic flux by a superconductor, (4) the floating magnet, and (5) effect of an external magnetic field on the transition temperature.

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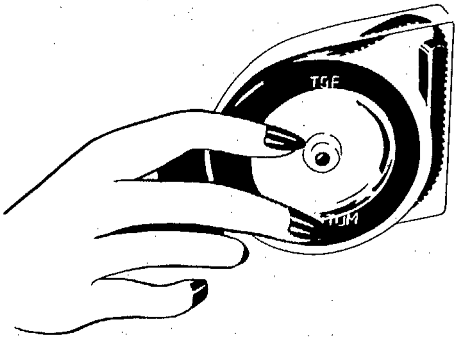
1. Extract from : Science Course Improvement Projects, National Science Foundation, July 1964 (NSF 64-8), pp. 73 and 75.

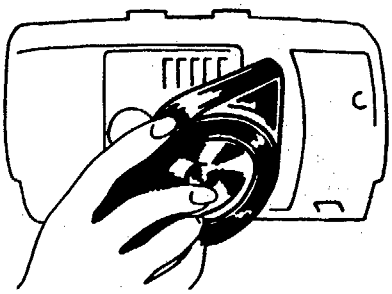
FILMS IN MAGI-CARTRIDGES

Technicolor 250, ready for use in 3 seconds

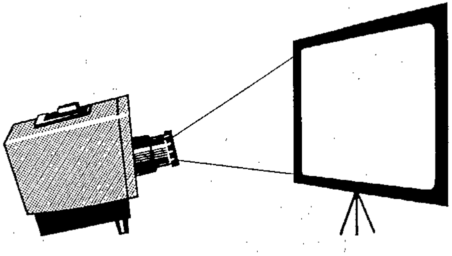
Take the cartridge

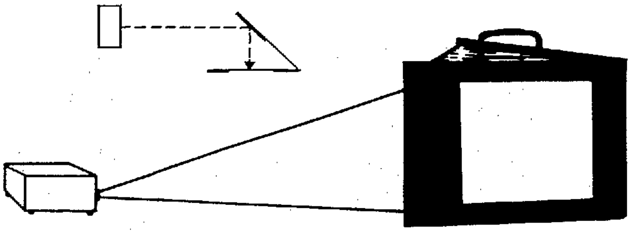


... slip it into the projector

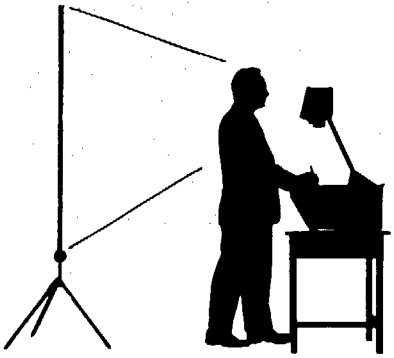


... and begin projecting





THE OVERHEAD PROJECTOR



FRANCE

LA FORMATION DES MAITRES DE L'ENSEIGNEMENT DU SECOND DEGRE

par M. Eurin, président de l'Union des physiciens.

La formation des Maîtres de l'Enseignement du Second Degré est un problème fondamental dans toutes les disciplines, car l'adolescent est toujours imprégné de l'enseignement qu'il a reçu de 14 à 19 ans. C'est souvent vers la fin de cette période de sa scolarité que la vocation professionnelle de l'adulte se décide.

Avant d'aborder les moyens propres à la formation idéale d'un professeur de physique qui doit enseigner aux élèves des classes secondaires, il est peut-être bon de rechercher d'abord les qualités que l'on peut exiger de ce maître, Je crois que l'on peut résumer brièvement celles-ci dans une phrase que l'on trouve dans les "Cahiers pédagogiques", publication de l'Institut Pédagogique National Français (N°11, du 15 janvier 1959) :

> "Des professeurs, formés, informés, convaincus. Formés scientifiquement et pédagogiquement. Informés et tenus au courant, sans que pour cela ils aient à faire preuve d'héroïsme, des développements d'une science qui s'accroît sans cesse. Convaincus, enfin, de la beauté de leur métier et de l'importance de leur tâche."

Le professeur de physique doit, plus que tout autre, savoir trouver, par la domination théorique de son sujet, par son habileté manuelle et son sens du spectaculaire, la corde sensible de son auditoire afin que celui-ci pense en même temps que lui, devine ce qu'il va dire, entre en résonance avec lui. S'il doit user des moyens audio-visuels mis à sa disposition, il ne doit pas oublier que la phrase nette, la terminologie précise, la clarté et la logique restent le moyen le plus sûr d'expression et de transmission des connaissances, celui qui les humanise.

L'ensemble de toutes ces qualités constitue un niveau de perfection difficile à atteindre et heureux sera l'étudiant qui aura rencontré dans sa vie scolaire des professeurs ayant su lui communiquer leur enthousiasme.

I. Formation du professeur de physique

Nous distinguerons la formation théorique et la formation pédagogique.

A - Formation théorique

Nous supposerons que le futur professeur quitte le lycée ou le gymnase vers l'âge de 18 ans et a obtenu un diplôme analogue au baccalauréat français. Il entre alors à l'Université. Il est alors indispensable de mener de front pendant deux ans au moins la formation mathématique, la mise au point et le développement des connaissances générales de physique que l'étudiant a reçues au cours de sa scolarité. Ces deux années doivent décider de son orientation définitive : il faut donc y faire un effort considérable pour rendre attrayantes les questions de physique qui seront approfondies. Le choix des travaux pratiques sera particulièrement important. Combien de fois n'ai-je pas entendu d'anciens élèves me dire en parlant de travaux pratiques faits dans une grande école scientifique : j'aurais fait volontiers de la physique, mais j'en suis détourné par les travaux pratiques qui sont fastidieux. Je n'insisterai pas sur les connaissances mathématiques qui devront être acquises au cours de ces deux années ; d'autres voix beaucoup plus autorisées que la mienne en ont déjà exposé le problème.

Après ces deux premières années d'Université au cours desquelles notre étudiant aura consolidé les bases de ses connaissances, nous pensons qu'il lui faudra encore deux autres années pour acquérir ce que nous appellerons une "licence" valable : étude de l'électricité, de l'électromagnétisme, de l'optique, de la mécanique (classique, statistique, quantique), de la thermodynamique, de l'atomistique, etc... Il sera indispensable, au cours de ces deux dernières années de formation théorique, d'inculquer au futur professeur le goût d'apprendre, le désir de se perfectionner sans cesse, de façon à préparer dès lors l'information permanente dont nous parlerons plus loin.

C'est au cours de ces quatre années que l'étudiant doit acquérir également le goût des travaux de laboratoire : un professeur de physique qui ne passe pas beaucoup de temps dans son laboratoire de lycée, si modeste soit-il, perd le contact des choses et ne peut pas être un bon professeur de physique. C'est lui-même, et non pas seulement son aide de laboratoire, qui doit monter ses expériences de cours, étudier les travaux pratiques qu'il veut faire réaliser à ses élèves et ceci jusque dans leurs moindres détails. Pour cela, il faut qu'il soit convaincu de l'importance de ces travaux et c'est au cours de sa formation qu'il acquerra cette aisance et cette conviction. Ce problème est certes difficile à résoudre du fait du grand nombre d'étudiants fréquentant l'Université. Il exige un encadrement important qui devrait être réalisé par des cadres jeunes, venant à peine de terminer leurs études, qui entrent plus facilement en communion de pensées et d'idées avec ceux qu'ils ont à peine quittés.

B - <u>Formation pédagogique</u>

Je ne crois pas beaucoup, pour ma part, à une formation pédagogique théorique, donnée au cours de conférences faites aux étudiants. Celles que j'ai entendues, il y a bien longtemps hélas, ne m'ont pas convaincu de leur nécessité. Il est sans doute certain que la pédagogie théorique a fait de grands progrès mais je suis personnellement persuadé que la pédagogie s'apprend au contact d'un auditoire d'élèves et c'est pourquoi je pense qu'une année de formation pédagogique pratique est indispensable à la formation du Maître. En France, je m'excuse d'en parler mais c'est vraiment le seul cas que je connaisse bien, nos futurs professeurs déjà licenciés, sont confiés pendant une année à des professeurs chevronnés en exercice : ils font au cours de cette année trois stages de deux mois chez trois professeurs distincts, ce qui a l'avantage de leur montrer des méthodes souvent différentes. Ils se voient confier la conduite d'une classe avec tout ce que cela comporte de responsabilité : exposé des leçons, réalisation des expériences de cours, interrogations des élèves, conduite des exercices. Ces stagiaires, par groupe de trois en général, sont ainsi en contact direct avec les élèves, apprennent à les connaître, étudient leur psychologie. L'autorité du directeur de stage se manifeste, après chaque séance, par une étude critique du comportement du stagiaire, discussion amicale et confiante au cours de laquelle chacun expose librement sa propre conception. Cette année de formation s'accompagne aussi de séances de démonstrations collectives d'expériences de classes : nous réunissons dans un établissement tous les stagiaires d'une ville et leurs directeurs de stage ; quelques stagiaires qui ont consacré quelques heures à une recherche expérimentale, proposent des montages plus ou moins originaux. Il serait souhaitable que des conférences sur l'histoire des sciences viennent compléter cette formation.

La valeur formatrice d'un tel stage est incontestable, mais elle dépend évidemment du directeur de ce stage ; il y a là une difficulté qu'il ne faut pas méconnaître. Les résultats sont en général très bons et je vous demande de me croire lorsque je vous dirai que dans les concours de recrutement tels que celui que nous appelons "agrégation", on distingue de suite, à l'exposé d'une leçon, ceux des étudiants qui ont suivi cette année pratique de formation pédagogique et ceci par l'aisance d'exposition, l'habileté expérimentale dont ces candidats font preuve.

Si je résume cette question de la formation des maîtres du Second Degré, nous voyons qu'après les études secondaires qui se terminent vers 18 ans, il faut cinq années de formation pour un professeur qui pourra ainsi débuter à 23 ans. Il y a là un problème social important;si l'on veut que toutes les énergies intellectuelles d'une nation puissent fournir des professeurs, il est alors indispensable d'envisager de donner un salaire aux candidats professeurs. Je ne sais d'ailleurs si les étudiants des autres pays se marient jeunes, mais, en France, c'est un fait qui se développe de plus en plus ; c'est une raison de plus pour l'attribution d'un salaire.

II. Perfectionnement ou information du professeur

La formation du professeur est-elle terminée à 23 ans alors que la Science est en progression géométriquement croissante ? Que sera ce professeur si entre 23 et 63 ans il n'a rien appris, s'il s'est contenté, après ses cours, d'aller prendre une tasse de thé ou de pêcher à la ligne sur les bords de la Seine ou de la Tamise ? Il est donc indispensable de songer à une formation continue, ce que nous pourrions appeler une "information" du professeur en exercice. Quels sont les différents aspects que l'on peut envisager pour cette information ? C'est ce que nous allons examiner rapidement.

Nous pouvons tout d'abord demander que le collège, le lycée, le gymnase où ce professeur enseigne soit pourvu d'une bibliothèque scientifique moderne où notre professeur trouvera les ouvrages généraux récemment parus, les revues de mise au point de questions d'actualité. Mais ce professeur qui aura fait 18, 22 heures de cours par semaine, qui aura à corriger les devoirs de ses nombreux élèves, n'aura pas toujours l'héroïsme de passer quelques heures encore à cette bibliothèque. Il faut donc envisager d'autres moyens, et il nous apparaît que l'une des meilleures méthodes est celle qui consiste à organiser de véritables "séminaires" d'une ou deux semaines au cours desquelles le Maître serait mis au courant par des professeurs d'Université de l'état actuel d'une question. Nous avions organisé il y a quatre ans un séminaire de ce genre : soixante à quatre-vingts professeurs y participaient, une dizaine de professeurs à la Sorbonne nous avaient fait des conférences et au cours de discussions, parfois animées, nous avons essayé d'examiner ensemble ce qui pouvait être modernisé dans notre enseignement. Au mois de septembre prochain, nous organisons un séminaire analogue sur les parties de la physique relatives aux questions spatiales. Malheureusement, ceci ne touchera encore qu'une soixantaine de professeurs volontaires, et ce sont souvent les mêmes, ce qui est très insuffisant. Il paraît nécessaire d'envisager des cours plus nombreux, plus longs mais que de problèmes se posent alors, le recrutement des conférenciers en particulier. Un autre aspect important de cette information des maîtres est d'ordre technique : le matériel d'enseignement se perfectionne et il faut que le professeur apprenne à l'utiliser dans les meilleures conditions. Il y aurait aussi beaucoup à dire sur l'information du professeur de physique dans le domaine des mathématiques : les mathématiques dites "modernes" ayant pénétré dans nos établissements secondaires, il est indispensable que le professeur de physique parle le même langage que son collègue de mathématiques et use des mêmes notations, symboles que ceux qui sont familiers à ses élèves. C'est un point important psychologiquement vis-à-vis des élèves et de l'intérêt qu'ils peuvent porter à l'enseignement de la physique ; mais ce point serait trop long à développer ici, et je ne veux pas abuser de votre attention dont je vous remercie.

STAGES ET COLLOQUES[1]

Stage d'information sur les sciences et techniques spatiales, pour les professeurs de physique du second degré, Faculté des sciences de Dijon (6-12 septembre 1965)

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[1] Extrait du Bulletin de l'Union des physiciens, N°484, juin-juillet 1965, p .725-739.

Programme (extraits)

Physique de l'atmosphère	M. Guy Israel
Astrophysique spatiale	M. Bonnet
Particules et champs (magnétosphère - vent solaire - rayons cosmiques).	M. Cambou
Accumulateurs électro-chimiques ou piles à combustibles	M. Bonnemay
Piles solaires	M. Desvignes
La conversion photo-voltaïque ; la conversion thermo-électrique : deux applications des semi-conducteurs aux générateurs autonomes pour l'espace	M. Rodot
Exploration des planètes	M. A. Dollfus
Réentrée - freinage aéro-dynamique	M. E. Brun
L'homme dans l'espace	Médecin-Général Grandpierre
Phénomènes de combustion (fusées)	M. Barrère
Mécanique des trajectoires : orbites	M. J.C. Poggi
Techniques des ballons stratosphériques	M Regyra

Stage de Saclay, organisé par l'Institut national des sciences et techniques nucléaires (6-17 septembre 1965)

Programme (extraits)

Radioactivité, fission, fusion	
Physique nucléaire des basses et moyennes énergies	
Principes des réacteurs nucléaires	
Etude d'un milieu nucléaire	
Particules fondamentales	
Réacteurs français	
Les rayons cosmiques et la physique des hautes énergies	M. Leprince-Ringuet Membre de l'Institut
Les accélérateurs des particules	M. Blanc-Lapierre
La fusion thermonucléaire contrôlée	
Applications et techniques des radioisotopes	
Les très basses températures (Exposé et manipulations)	
La protection sanitaire dans les centres nucléaires	
Problèmes économiques dans le domaine nucléaire	M. Gaussens Adjoint au Chef du Département des Programmes
Physique nucléaire spatiale	M. Cambou Professeur à la Faculté des Sciences de Toulouse
Autres recherches de Physique au C.E.A.	M. H. Baissas Inspecteur Général de l'Instruction Publique Directeur de la Physique du C.E.N.S.
L'énergie Nucléaire et l'opinion publique	M. Pelletier Chef du Service des Relations Publiques

Journées de Physique d'Aix-en-Provence (17-20 septembre 1965)

Programme (sommaire)

Table ronde I sur l'enseignement des éléments de physique nucléaire et de physique quantique dans le secondaire et le supérieur non spécialisé

Table ronde II sur les propriétés physiques des couches minces (propriétés optiques - électriques - magnétiques - couches supraconductrices ou semiconductrices)

Table ronde III sur l'utilisation des faisceaux intenses de neutrons en physique

Visite de l'Observatoire de Haute Provence (St Michel)

Stage sur la physique des milieux condensés (projet), organisé par l'Association pour le développement de l'enseignement et des recherches auprès des Facultés des sciences de l'Université de Paris ADERP, 4-13 juillet 1966, Faculté des Sciences, Orsay.

Un stage sur la Physique des Milieux Condensés sera organisé, du 4 au 13 juillet, à la Faculté des Sciences d'Orsay, à l'intention des enseignants du secondaire et des ingénieurs de l'industrie.

Les progrès rapides réalisés ces vingt dernières années, dans cette branche de la Physique, ont été si considérables qu'il est souvent difficile d'en avoir une bonne vue d'ensemble. De plus, la traduction industrielle de ces recherches se fait dans des délais de plus en plus rapprochés. C'est pourquoi la nécessité d'ouvrir aux enseignants et aux ingénieurs de l'industrie des perspectives nouvelles et précises sur cette partie de la Physique est apparue.

On sait que la matière est formée d'atomes qui, dans les milieux condensés (métaux, sels...), forment des empilements réguliers ou réseaux. Ces atomes sont formés d'un minuscule noyau autour duquel gravitent des électrons, la cohésion étant assurée par les forces électriques coulombiennes qui s'exercent entre les différentes particules (noyaux et électrons). Les propriétés du solide sont déterminées, en grande partie, par le cortège électronique, propriétés qui tiennent à la nature ondulatoire du mouvement des électrons. La connaissance de ces propriétés a permis de comprendre l'existence des différents types de solides rencontrés dans la nature, leurs propriétés électriques et magnétiques (conductibilité électrique, ferro-magnétisme, ferrites), les rapports matière-lumière (absorption, couleur). Il est également fort probable que les problèmes biologiques (hérédité par ex.) sont en rapport avec la structure électronique des macromolécules.

Du point de vue pratique, l'activité industrielle est considérablement influencée par ces développements. Ainsi, l'électronique nécessite maintenant une connaissance approfondie des processus quantiques (transistor par ex.). De même, les notions de structure électronique et atomique des solides constituent la base de la métallurgie physique (contrôle des défauts, dommages de radiations...).

Ce stage comprendra un cycle de conférences, complété par des visites de laboratoires:

Conférences -

Les exposés seront faits par des Professeurs d'Université et des Ingénieurs spécialistes dans leur branche respective et qui sont à l'avant-garde de la recherche scientifique, tant en France que dans le monde. Chaque conférencier présentera, dans un langage aussi simple que possible (x), quelques expériences fondamentales.

Visites de Laboratoires -

Ces visites permettront aux auditeurs de prendre contact avec quelques techniques d'avant-garde utilisées dans les laboratoires (microscopie électronique, résonance magnétique...). L'aspect technologique de la recherche sera également présenté (obtention de très basses températures et de champs magnétiques élevés)

(x) Pour apprécier au maximum les conférences, les participants sont invités à consulter quelques livres parmi lesquels on peut citer :
- "Introduction élémentaire à la Physique du Solide" par Kittel, chez Dunod,
- "Optique" par Bruhat, revu par Kastler, chez Masson,
- "Eléments de Physique Moderne" par G. Guinier, chez Bordas.

Programme

Thèmes des Conférences :

Introduction à la Physique Atomique
Microscopie électronique
par M. Castaing, Professeur à la Faculté des Sciences d'Orsay
Métallurgie Moderne
par M. Crussard, Directeur Scientifique de la Société Péchiney
Dommages de radiations et applications
Vibrations de réseau et hypersons
par M. Dreyfus, Professeur au Centre de Recherches des Très Basses Températures de Grenoble
Structure électronique des solides (2 conférences)
par M. Friedel, Professeur à la Faculté des Sciences d'Orsay
Propriétés de transport électrique
par M. Bok, Professeur à l'Ecole Normale Supérieure de Paris
Applications des semi-conducteurs (2 conférences)
par M. Veilex, Chef du Laboratoire de Recherches Générales à la Radiotechnique
Spectres optiques d'impuretés de transition dans les cristaux ioniques
par M. Margerie, Professeur à la Faculté des Sciences de Caen
Effets Raman et Brillouin
Télécommunications et électronique quantique
Propriétés magnétiques des solides -Structure en domaines
par M. L. Neel, Membre de l'Institut, Professeur à la Faculté des Sciences de Grenoble
Ondes de spin par M. J. Winter, Ingénieur au Centre d'Etudes Nucléaires de Saclay
Résonance Magnétique
par M. Abragam, Directeur de la Physique au Commissariat à l'Energie Atomique
Production et utilisation des basses températures
par M. Froideveaux, Professeur à la Faculté des Sciences d'Orsay
Fluides quantiques : supraconducteurs et Hélium 4
par M. De Gennes, Professeur à la Faculté des Sciences d'Orsay
Macromolécules et Biologie

Visites de Laboratoires :

Ces visites comprendront les laboratoires suivants :
Laboratoire d'Optique et de Rayons X
Laboratoire d'Electronique
Laboratoire de Résonance Magnétique nucléaire et des supraconducteurs
Pile atomique de Saclay
Microscope électronique et fabrication de films minces
Laboratoire de semi-conducteurs.

SECTIONS LITTERAIRES - AVANT PROJET D'UN PROGRAMME DE SCIENCES PHYSIQUES(1)

Introduction

Il est nécessaire que chaque élève, au cours de ses études secondaires, acquière une culture générale suffisante pour comprendre le monde qui l'entoure. Il importe donc qu'un

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1. Extrait du Bulletin de l'Union des physiciens, N1483, avril-mai 1965, p. 641 à 651.

enseignement de sciences physiques soit dispensé dans toutes les sections du second cycle. Mais il est indispensable que le fond et la forme de cet enseignement soient fondamentalement distincts dans les sections scientifiques et dans les sections littéraires ; en effet la formation d'un esprit qui a seulement à prendre conscience des phénomènes réels devra être conçue tout autrement que celle d'un esprit qui aura à analyser, et même à maîtriser, ces phénomènes.

Le programme que nous proposons s'inspire de l'idée générale qui vient d'être précisée. Il s'étend à suffisamment de connaissances pour que son aspect de culture générale paraisse clairement. Ce programme ne doit surtout pas être considéré comme un démarquage du programme des sections scientifiques ; il doit abandonner résolument toute question constituant une spécialisation, même si cette question nous est habituellement chère. Il doit aussi abandonner tout formalisme mathématique non indispensable. L'enseignement doit, au contraire, s'appuyer constamment sur l'expérience démonstrative, et surtout sur l'observation du monde réel ; il débouchera, dans la mesure du possible, sur les applications actuelles des questions étudiées, même dans le cas où ces applications ne sont pas explicitement mentionnées.

Nous pensons que, faite dans cet esprit, l'étude des sciences physiques peut être abordée avec intérêt et avec fruit par les élèves des sections littéraires.

I. Espace. Temps. Matière

1) L'espace :
Repérage d'une position. Mesure des distances. Unités. Echelles des distances (1)

2) Le temps :
Le temps associé au mouvement d'un objet ; existence de phénomènes périodiques. Unités. Echelle des temps
Notions de cinématique : mouvement rectiligne uniforme ; vitesse. Notion de vitesse instantanée (2). Diagramme des vitesses. Notion d'accélération
Généralisation de la notion de vitesse. Vitesse du son, vitesse de la lumière.

3) Matière et masse :
Comparaison des masses au moyen de la balance. Unités. Echelle des masses. Masse volumique.

II. Force. Travail. Energie

1) Notion de force :
Expériences illustrant les effets statiques et dynamiques des forces. Poids ; mesure statique des forces ; unités. La force grandeur vectorielle
Chute d'un corps ; constance en un lieu déterminé du rapport p/m ; relation $\vec{p} = m\vec{g}$;
relation $\vec{f} = m\vec{\gamma}$ (On admettra cette relation sans justification quantitative)

2) Différents types de forces :
Forces de contact, frottements. Forces à distance : force de gravitation ; forces électrostatiques ; forces magnétiques ; notion de champ au sens spatial

3) Travail. Puissance. Energie.
Notion de travail ; unités. Notion de puissance ; unités; échelle des puissances.
Energie cinétique. Energie potentielle de pesanteur.

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1. On entend par "échelle des distances, des temps, etc." des tableaux donnant des indications numériques sur l'ordre de grandeur des phénomènes naturels.
2. La notion de vitesse instantanée pourra être abordée à partir de la vitesse moyenne et à partir de sa mesure par des compteurs ou tachymètres.

III. Les états de la matière

1) Différents états de la matière :
Caractères macroscopiques

2) Les constituants de la matière
Atome, noyau, électrons. Numéro atomique, notion d'élément, symboles. Dimensions et masses des atomes ; nombre d'Avogadro. Définition du corps simple comme assemblage d'atomes identiques
Molécules : exemples de corps simples et composés à structure moléculaire ; formules.
Mélanges et corps purs ; l'air ; l'eau
Ions : Exemples d'ions monoatomiques

3) Etat fluide :
Constitution d'un fluide : gaz, liquides, agitation moléculaire. Forces pressantes ; définition de la pression. Pression atmosphérique ; baromètre métallique
Existence de la force de poussée d'Archimède ; principe d'Archimède. Variations de la pression à l'intérieur d'un fluide en équilibre ; principe fondamental ; le centimètre de mercure comme unité de pression ; pression normale. Applications

4) Température :
Effets qualitatifs ; dilatations. Température absolue définie comme proportionnelle à la pression d'un gaz à volume constant. Mesures usuelles des températures ; thermomètre à mercure ; échelle Celsius. Mise en évidence d'une loi expérimentale : la loi de Mariotte

5) Etat cristallin:
Modèles d'édifices cristallins : atomique (diamant), moléculaire (dioxyde de carbone), ionique (chlorure de sodium), métallique (cuivre)

6) Changements d'état d'un corps pur :
Existence des phénomènes de changements d'état : fusion, solidification, vaporisation, ébullition, liquéfaction, sublimation. Température de changements d'état

7) Mélanges :
Solutions ; séparation des constituants d'un mélange, distillation. Alliages.

IV. Chimie . . . .

V. Electricité

1) Rappel des notions d'électrostatique :
Notions de charge électrique et de champ électrique ; charges positives et charges négatives

2) Effets du courant continu :
Mise en évidence des effets chimiques et calorifiques. Effet magnétique sous son double aspect : champ magnétique créé par un courant et action d'un champ magnétique sur un courant ; existence des moteurs. Sens d'un courant continu ; intensité, sa mesure par un ampèremètre. Existence du courant alternatif ; intensité d'un courant alternatif.
Action d'un champ magnétique sur un faisceau d'électrons. Interprétation du courant électrique dans les conducteurs métalliques
Conduction ionique. Exemple simple d'électrolyse. Electrochimie : préparation du chlore et de la soude ; métallurgie de l'aluminium

3) Energie électrique :
Effet Joule ; notion de quantité de chaleur, usage d'un calorimètre ; relations $W = RI^2t$ et $P = RI^2$, définition de la résistance ; application au courant alternatif.

4) Notion de tension :
Définition par la relation $V = RI$; mesure par un voltmètre ; relation $P = VI$.
Exercices numériques.

5) Production du courant électrique :
Existence des piles et des accumulateurs ; expériences sur les courants induits.

VI. Phénomènes ondulatoires et corpusculaires

1) Phénomènes périodiques dans le temps :
Enregistrement du mouvement d'un pendule ou d'un diapason ; période, fréquence, amplitude. (La représentation par une fonction sinusoïdale ne doit pas être donnée).

2) Propagation :
Propagation d'un ébranlement ; propagation d'un mouvement vibratoire ; vitesse de propagation, longueur d'onde ; propagation du son.

3) Phénomènes lumineux :
Propagation rectiligne ; existence des phénomènes de réflexion et de réfraction ; obtention au moyen d'une lentille d'une image réelle ; foyers ; notion d'image virtuelle.
Exemples d'application : photographie, projection.
Complexité de la lumière blanche ; expérience de dispersion par le prisme, lumière monochromatique ; radiations infra-rouges et ultra-violettes
Possibilité de réalisation d'interférence lumineuse (Une expérience d'interférence à la surface d'un liquide sera présentée à cette occasion) ; longueurs d'onde des radiations lumineuses ; célérité de la lumière

4) Emissions électroniques :
Effet thermoélectronique : production d'un faisceau d'électrons ; déviation par un champ électrique et par un champ magnétique ; oscillographe cathodique
Effet photoémissif : photon

5) Rayons X :
Production et propriétés

6) Physique nucléaire :
Rappel de la constitution de l'atome ; le noyau, proton, neutron, numéro atomique, nombre de masse, isotopes. Défaut de masse ; masse et énergie ; stabilité des noyaux.
Radioactivité ; transmutations ; fission ; fusion.

7) Vue d'ensemble des radiations électromagnétiques.

P.S.- Certains membres du Conseil ont souhaité voir introduits le principe de la conservation de l'énergie et le principe de Carnot ; il resterait à préciser le libellé du paragraphe correspondant et à l'insérer à une place à déterminer.

125 - 150 heures de cours
10 séances de travaux pratiques.

CENTRE D'EQUIPEMENT EN MATERIEL SCIENTIFIQUE

Un centre d'équipement habilité à distribuer du matériel pour l'enseignement des sciences physiques et naturelles à tous les établissements de l'enseignement public fonctionne depuis plus de 10 ans à Paris ; il possède un service de réparations. Ce centre établit chaque année, à l'intention des enseignants, un répertoire intitulé :

> Liste du matériel scientifique qui sera disponible au Centre d'équipement en matériel scientifique au cours de l'année scolaire, publiée par l'Institut pédagogique national.

FILMS(1), Service du film de recherche scientifique de l'Office national des Universités, 96 Boulevard Raspail, Paris 6e.

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1. Deux films réalisés par ce service ont été signalés dans la présente publication (voir : Catalogue de films pour l'enseignement universitaire, p. 16).

BULLETIN DE L'UNION DES PHYSICIENS[1], publication mensuelle, Administration et rédaction, 44 Bd St-Michel, Paris 6e

Travaux pratiques inhabituels :

CONSTRUCTION ET TIR DE FUSEES EXPERIMENTALES PAR LES JEUNES, sous l'égide du Centre national d'études spatiales (CNES)[2], Mlle L. Blosset, chef du service de l'information et de la documentation du CNES.

Dans le cadre du programme d'encouragement à l'étude de l'espace par les jeunes, décidé par M. G. Palewski, ministre d'Etat chargé de la Recherche scientifique et des questions atomiques et spatiales, le CNES apporte son aide aux jeunes gens qui désirent utiliser des fusées pour des expériences scientifiques ou des études techniques dans le domaine spatial.

Après recensement des groupes ou des jeunes isolés intéressés, le Service de l'information et de la documentation du CNES a procédé à la diffusion de documents d'information et de conseils (méthode de travail, travaux préliminaires, etc...). Il faut convaincre que le but valable n'est pas le seul lancement d'une fusée et que celui-ci ne présente d'intérêt que si la fusée constitue un outil permettant des expériences intéressantes. D'autre part, il faut s'assurer que les lancements son effectués selon les règles de sécurité. Mais surtout, et par le biais même de ces lancements, il s'agit de développer chez les jeunes l'esprit scientifique et de susciter éventuellement de nouvelles vocations de chercheurs, d'ingénieurs ou de techniciens.

La première recommandation du CNES aux jeunes a été de ne pas tenter de fabriquer eux-mêmes un propulseur. Le CNES a fait étudier et construire un propulseur capable de lancer verticalement une fusée de masse initiale comprise entre 35 et 27 kg à une altitude de 3.500 à 5.000 m ; ce propulseur, construit par l'Association technique pour l'étude des fusées, est désigné sous le nom de ATEF-74. Il est mis par le CNES à la disposition de groupes de jeunes ayant présenté un programme d'expériences jugé intéressant.

Les clubs régulièrement constitués sont actuellement en France au nombre de 23 et groupent environ 450 membres dont 370 élèves de l'enseignement secondaire (lycées et établissements techniques) et 80 étudiants (enseignement supérieur, élèves ingénieurs).

- 18 clubs sont dits "de lycées" (classes terminales du secondaire). L'âge moyen est de 17 ans.
- 5 clubs correspondant à un niveau d'instruction supérieure. L'âge moyen est de 20-21 ans.

Le délai de préparation des expériences à bord et de fabrication d'une fusée varie de 5 mois environ, pour des groupes bénéficiant déjà d'une expérience antérieure, à 18 mois, pour des groupes préparant leur premier tir.

A l'automne 1963, le programme est entré dans la phase des applications pratiques : celle des tirs. Sept fusées expérimentales ont été tirées au cours de trois campagnes (novembre - décembre 1963, mai et octobre 1964). D'un poids moyen de 30 kg, les fusées ont atteint des altitudes variant entre 2.000 et 4.000 m.

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1. Association des professeurs de sciences physiques des Lycées et Collèges classiques, modernes et techniques de France. Président : M. Eurin, 323 rue St Martin, Paris 3e.
2. Résumé de la conférence prononcée par Mlle Blosset lors du XVe Congrès d'astronautique, Varsovie, 7-12 sept. 1964.

Les matériels et moyens nécessaires aux lancements sont assez importants et complexes. Ils sont fournis :

- par le Ministère des Armées : véhicules et personnel, matériel de campement, énergie électrique, champ de tir ;
- par le CNES : rampe de lancement, propulseurs et artifices, traceurs pyrotechniques, émetteurs-récepteurs pour les liaisons entre postes d'observation au sol, téléphone de campagne (liaison rampe-poste de tir), matériel de réglage de la rampe ;
- par les Clubs : tous autres moyens au sol nécessaires, en plus des matériels construits par eux et indispensables au fonctionnement de la pointe de fusée elle-même.

Voici un aperçu sur les observations et les expériences effectuées lors de ces tirs :

- Détermination de l'accélération, avec enregistrement d'un accélérogramme ;
- Mesure de la pression dynamique maximale atteinte ;
- Etude du comportement de la fusée à l'aide d'un film pris par une camera embarquée;
- Transmission au sol, sous forme de signaux audibles codés, des mesures effectuées à bord (variations de l'altitude par exemple), avec enregistrement des signaux sur magnétophone ou oscillographe ;
- Expériences d'ordre biologique : observations relatives aux réactions de petits rongeurs pendant le vol, avec transmission au sol de ces observations (cardiogramme, encéphalogramme) ;
- Poursuite optique au cours de la partie ascendante de la trajectoire : essai de divers dispositifs (traceurs pyrotechniques ; instruments de visée équipant les postes d'observation reliés entre eux par radio) ;
- Commande d'ouverture du parachute de récupération par minuterie électronique ; essais de divers systèmes de récupération en fonction de la position du parachute.

Les résultats obtenus appellent les remarques suivantes :

Le propulseur ATEF-74 a toujours parfaitement fonctionné.

Les fusées, entièrement conçues et construites par les membres des clubs, possèdaient d'excellentes caractéristiques aérodynamiques, ce qui leur a permis de conserver une bonne stabilité sur leur trajectoire.

La poursuite optique, satisfaisante quand les conditions météorologiques étaient bonnes, s'est révélée insuffisante en cas de mauvais temps. L'expérience acquise a amené à prévoir, pour les prochains lancements, le montage d'une radio-balise à bord de la fusée et l'installation de trois récepteurs au sol.

Si des difficultés ont encore été rencontrées pour les tirs de 1964, lors de la récupération, des essais préliminaires de largage avaient néanmoins permis d'améliorer le fonctionnement des dispositifs prévus.

Des essais en laboratoire ou sur un terrain découvert ont abouti à une nette amélioration des liaisons radio-électriques air-sol, en particulier grâce à une meilleure disposition des installations au sol, après étude poursuivie en vue de l'utilisation rationnelle des accidents topographiques. On doit signaler que, de ce point de vue, la dernière expérience a été un succès complet.

La qualité des expériences d'ordre biologique est, elle aussi, en nette amélioration : à deux reprises, on avait obtenu un cardiogramme et un encéphalogramme partiels d'un rongeur placé à bord de la fusée ; lors de la dernière campagne, un cardiogramme complet a pu être enregistré.

Ces expériences, qu'elles aient abouti à un succès complet ou partiel, ont été extrêmement profitables aux jeunes gens qui les avaient entreprises. Ils ont pu prendre conscience à la fois de la complexité des problèmes mis en jeu et des connaissances théoriques et pratiques indispensables pour obtenir des résultats valables. Dans certains cas, les jeunes ont pu acquérir des notions nouvelles pour eux : pour pallier une éventuelle défaillance de l'un des deux systèmes de commande de largage du parachute, les clubs ont été amenés à monter en parallèle des allumeurs et des minuteries de commande : c'est là une première approche de la notion de fiabilité.

Sur un plan plus général, le travail en commun a développé chez les jeunes qui s'y sont adonnés un remarquable esprit d'équipe et de collaboration. Les jeunes gens possèdant les connaissances scientifiques nécessaires ont pu vérifier expérimentalement certaines notions, à l'occasion de tirs. Les plus jeunes ont été conduits à une recherche empirique des principes à partir d'observations pratiques. Le lancement de fusées expérimentales est l'occasion pour tous d'une activité éducative très enrichissante. Les résultats obtenus montrent que l'étude et le lancement de fusées expérimentales constituent un excellent moyen auxiliaire d'enseignement et un bon début de formation de chercheurs et de techniciens.

HONGRIE / HUNGARY

TEACHING OF PHYSICS IN HUNGARY, by Dezsö Nyilas, Public Education Department, Ministry of Education, Budapest.

The course of study for young people in Hungary is divided into three four-year phases. The first two of these, consisting of the lower and upper divisions of the eight grades of general school (comprehensive school), are compulsory for all, with identical curricula for boys and girls and for urban and rural youngsters alike. The third phase, consisting of the four-year secondary school, is differentiated, but each type of school or secondary course qualifies for continued study at the college or university level.

The First Four Years

In the first four school years (children of from 6 to 9) physics are not taught as a subject, but the complex subject known as environmental studies acquaints students with many phenomena of the physical world. The material of this subject which is related to physics has been selected through the analysis of the every-day environment of schoolchildren rather than any special principle. The main objective is to encourage the youngsters to observe some of the physical properties of every-day substances, to make them aware of this type of experience, to enlarge their natural experience along these lines, and to enable them to apply the knowledge they have gained (for instance, to read the thermometer, to take their own temperature, etc.).

The Second Phase

In the second phase (children between 10 and 13) physics is already taught as a specialized subject. Between 1946 and 1950 physics instruction was given only in the third year of the phase, in three class-hours a week, but from 1951 to 1964 the subject featured already in both final years in three and two hours a week, respectively. Since 1964 physics have been made part of the schedule of each of the last three upper grades, with two hours a week in each. Of course, this progress in the number of class-hours devoted to the subject went hand in hand with changes in contents and methodology.

With consideration for the principles of the school reform started in 1960 (modernization, bringing school closer to practical life, emphasis on the development of the child) and on the basis of former experiences, the total material taught has not increased despite the rise in the total number of class-hours, but, on the contrary, has slightly decreased.

The new syllabus and the instructions attached to the plan encourage two dominant strivings in the educational work in this phase. One of them is to concentrate on phenomena. This means that at this level the emphasis in teaching and studying physics is put on expanding the material of the students' experience, on the analysis and first classification of physical phenomena, on the description of the terminology and symbols of physics, and - on the basis of these conceptual symbols - the interpretation of the concepts themselves. The second goal is to replace lecturing by the teacher and "doing the homework", with the collective "elaboration" of the curriculum. What we mean by elaboration is that just as the former "hammering in" of texts was replaced with more effective lecturing by the teacher against a background of object lessons, demonstrations and experiments, so in our days the even more effective methods which involve active work by the pupils are becoming dominant. Consequently it has become basic to the present methodology of physics teaching on this level to have, in addition to demonstrations by the teacher, well-prepared and well-organized experiments carried out in front of the class or collectively by the pupils during the instruction periods.

Beyond the mastery of a certain body of knowledge, the demands of the new curriculum stipulate that the students should get practice in the measurement of certain physical quantities and in the use of the instruments which have to be applied. This requirement is met by the compulsory laboratory periods for which special class-hours have been allotted in the schedule.

Some of the simpler devices needed for the collective experiments are made by the physics students themselves during a different class called work practice. The study plan for this subject prescribes merely instruction in certain practical tricks used in different trades. Thus, it depends merely on the cooperation of the physics master and the teacher giving instruction in work practice whether students learn to fold metal sheets while they are making ash-trays, or simple instruments for the physics laboratory. Experience indicates that this type of cooperation between the two subjects is very valuable from the point of view of both. When the students make physics instruments during their work practice, they are more active because they are inspired by the fact that they are making a useful and lasting piece. And from the point of view of physics instruction, very valuable are the experiences with the behaviour of materials which the students gain in making these instruments.

The new textbooks and teaching manuals concretize, reflect and at the same time encourage these new methods. The make-up of the textbooks is such that, in addition to the parts containing the substance of the material that has to be learned, there are exercises entitled "Experiment! ", "Think and answer! ", "Observe ! ", "Have you heard? ", "Read ! " and "Interesting Facts" which call attention to many important things connected with the material and have important didactic functions, for they provide a careful selection for introducing new material and for making the material already studied "stick" and become integrated with general knowledge. These extra bits of information have a great deal of practical value, they broaden the students' horizon, help them to recognize the problems of physics in practical life, they encourage thinking in terms of physics, and, in general, teach to think.

The same ambitions are served by the regular programmes of School Television (on the regular channels) which are adjusted to the actual syllabus and course of studies. Their main value is that students are shown objects, equipment and phenomena, which cannot be shown in the average school and with which the students are unlikely to have had more than very limited experience.

The Third Phase

The third phase, the four years of secondary-school studies, may take place either in the gymnasium (traditional academic type of secondary school), or in technical, or in vocational secondary schools (the latter training skilled workers). In each of these three types of secondary school (except for a few special schools) there is physics instruction during three of the four years. At present the weekly class hours are distributed as follows :

Type of school	Weekly Class-Hours devoted to Physics			
	1st year	2nd year	3rd year	4th year
Gymnasium	-	3	3	4
gymnasium classes with specialized syllabus	-	4	6	6
Technical schools	2	2	3	-
Vocational schools	2	3	3	-
		or		
	-	3	3	2

On the basis of the school reform started in 1960, new plans have been made ; their gradual introduction will begin only in the next school year.

The subject of physics is taught in the form of experimental physics in each of these three types of schools. Actually the modifications in the teaching of physics in the gymnasium brought with itself certain changes in the physics instruction provided in the other two types of schools also. Therefore further statements will apply to physics as taught in the gymnasium, but in most respects hold for the subject of physics in the other two types of school as well.

The teaching of experimental physics in Hungary can look back on traditions of nearly a century. Nevertheless, after World War II practically a new beginning had to be made because in the ruined or severely damaged school buildings left behind after the war, first the objective requirements had to be established, new equipment had to be furnished, to make again possible the type of physics instruction that is based on phenomena, experiments and observation. Parallel with this work of re-development and rebuilding, appeared the new methodological literature. The most outstanding product of this effort is the three-volume work entitled "Collection of Physical Experiments" which was compiled by a team consisting of the foremost Hungarian physics masters.

The year 1955 marked the next step in development, when it was possible to reintroduce laboratory practice for students again. In order to provide improved subject-matter for these practical exercises (measurements) and to encourage the equipment of physics stockrooms along these lines, we published a "Practice Manual".

After World War II written problems have received very great emphasis in physics instruction, and today, particularly in the case of the better students, a great deal is expected in this field. The compilations of problems appended to the textbooks have contributed much to the achievements reached up to date, and so have the "Collection of Secondary-School Physics Problems" and "Problems for Physics Contests I & II", both by Miklós Vermes, and the physics column in the periodical "Secondary School Mathematics". The annual Physics Contests which demand the solution of written problems, and the fact that one written example involving mathematical physics is required of every matriculant at the matriculation examination (the final comprehensive examination which puts the official seal on secondary-school graduation) place special emphasis on the ability to solve problems. Up to the middle of the 1950's the CGS system was almost exclusively used in the problems, but later the curricular demand of bringing school subjects closer to life made it necessary to give priority to the MKS system over the CGS. Today it can be said that the metre-kilogram-second system has become established in school practice ; the teachers have got used to it and learned to appreciate its advantages, and the students find no difficulty in applying it.

During the last twenty years curricular reforms were introduced in 1950 and in 1965. In the syllabus for 1950 the following new demands were emphasized as compared with the requirements of the plan of studies published in 1938 :

(a) stronger emphasis on the scientific approach of physics ;

(b) impressing on students the interrelationship between science and technics, providing the knowledge necessary for the application of the devices of modern technics.

Many ideas and requirements in the 1965 syllabus tally with those in the 1950 plan. Let me point out only the three most important thoughts among those which are stressed :

(a) After the second four years of general school, the young people of 13 and 14 continue their studies in some type of secondary school. Therefore it is important that each one of the three types of secondary school should be integrated with the first two phases, in other words it must not be forgotten that students entering secondary school have not only a certain knowledge of the facts and phenomena of physics, but are even acquainted with the methods of studying the subject. This task of integration must be solved on the basis of the actual experiences of the forthcoming years.

(b) Another major requirement of the new curriculum is to bring the teaching of physics into closer contact with practice, to gain increased validity for the polytechnic principle. The fundamental idea is that the polytechnic principle should be the guiding principle in the method, so that the phenomena, the concepts and laws of physics be introduced and expanded upon through concrete examples and problems taken from the environment, from industry and practical life, and the new knowledge be practised and integrated on the basis of these same examples. In other words, the substance of the striving is that the subject called physics should not only give a grounding in the foundations of the science of physics, but should also teach students to become aware of their environment, to understand it, to grow fond of technics and appreciate their importance.

(c) Until 1964 students evidencing special interest in physics had an outlet for this special inclination only in the physics clubs. The school reform started in 1960, however, made it possible for especially gifted students to make a more penetrating study of physics even within their regular school schedule. These special honours groups in physics are known as "gymnasium classes with specialized syllabus". Actually the tasks of physics instruction are the same in these classes as those in regular gymnasium classes, the extra hours being devoted to the more thorough mastery and integration, manysided practice and application of the regular material through greater emphasis on the solution of problems and making measurements.

ITALIE / ITALY

ACTIVITES DIDACTIQUES DES MUSEES SCIENTIFIQUES (1), Prof. Dr Maria Ferretti (Bologne)

Une aide importante pour l'enseignement scientifique nous vient de plus en plus de l'activité didactique des Museums des différentes sciences. Il y en a un peu partout et parfois leur organisation est excellente, bien que leurs budgets soient toujours trop réduits.

En ce qui concerne les enseignements des sciences physiques et techniques, l'activité la plus efficace est probablement celle du Musée de la Science et de la Technique à Milan. A part les expositions d'appareils ayant une grande importance pour le développement des techniques les plus variées (orfèvrerie, horlogerie, construction de violons, métallurgie, etc...), des sciences physiques (astronomie, métrologie, optique, télécommunications, etc.) ou ayant une valeur historique (reconstruction des projets de Leonardo da Vinci, etc...), l'activité qui intéresse le plus directement l'école est celle du Centre de Physique annexe au Musée. Il est doté d'un bel amphithéâtre, d'un appareillage très riche pour expériences et mesures de physique, et d'une grande salle pour travaux pratiques. Les enseignants de toutes les écoles d'Italie peuvent se rendre à ce Centre avec leurs classes, pour une ou plusieurs leçons expérimentales de physique, pour lesquelles on doit s'inscrire à l'avance, sur quelques sujets particuliers des programmes - généralement les plus difficiles. En plus, près du Centre se trouve une bibliothèque spécialisée, riche de volumes, et des cours de perfectionnement pour enseignants secondaires y ont lieu chaque année. Dans les dix dernières années, un millier d'enseignants environ ont suivi ces cours ; au cours de la seule année 1963-1964 environ 7000 élèves des écoles secondaires ont suivi des leçons expérimentales de physique.

En 1960 le Ministère a pu recueillir, du Centre de Physique de Milan, une longue liste de normes et de suggestions sur l'appareillage des laboratoires de physique des écoles de la Direction classique, qui ont formé la base de la "circulaire 415" actuellement en vigueur contenant les prescriptions pratiques officielles.

En 1963 la Direction du Musée et le Ministère de l'Education Nationale ont coopéré à l'institution d'un "groupe de travail", organisme consultatif, sur les problèmes techniques de l'enseignement de la physique, dont les membres sont des professeurs d'université, des chercheurs, des enseignants, et des Inspecteurs du Ministère.

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1. Très bref passage d'une conférence présentée a Frascati sous le titre "Les organisations des réformes des enseignements scientifiques dans les écoles secondaires d'Italie". Le texte de cette conférence a été publié dans "Politique à suivre en matière d'enseignement scientifique, compte rendu provisoire du Séminaire international de Frascati (6-12 sept. 1965)", édité par le Centre européen de l'Education (Frascati) et le Comité national pour l'Education scientifique (Rome), sous les auspices de l'OCDE.

JAPON / JAPAN

Editor's note. The information given below is taken from a report contributed by the Japanese National Commission for Unesco and drawn up by Professors K. Ishiguro, T. Ishikawa, A. Harasima, Y. Kakiuchi, K. Kohra and S. Koide.(1)

CENTERS AND EXPERIMENTAL GROUPS DEALING WITH CURRICULUM REFORM

In Japan the standard for the school curriculum is set by the Ministry of Education. The present national standard for upper secondary schools has been applied since 1963. Each school forms its curriculum based upon the said standard with consideration of special activities in curriculum, school events and the pupils' actual circumstances. The Ministry of Education is expected to convene the Committee for Course of Study during 1966 in order to improve the national standard of physics teaching. Now it is studying the possibilities of curriculum reform for physics in upper secondary schools in general course (10 experimental schools have been designated).

The interest in the modernization of science teaching in upper secondary schools is becoming more active among teachers and their groups. The main groups dealing with this project and their activities are as follows :

1. Japan Society of Physics Education

It has studied P.S.S.C. since 1961, and started to study the curriculum of physics in upper secondary schools in 1965.

2. Science Education Centres

26 Science Education Centres have been established and 4 Centres are now under construction in Japan. In these centres instructional methods and the curriculum of physics in upper secondary schools is being studied.

3. Teachers' Study Groups

Teachers' Study Groups are engaged in the investigation of physics instruction methods in many prefectures.

AN IMPORTANT REFORM

Recently, physics has become one of the compulsory subjects in high-schools, and we hope this change will considerably facilitate the teaching of physics in universities.

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1. Further information may be obtained from Mr. Katsumi Watanabe, Chief of the Science Section, Japanese Commission for Unesco, Ministry of Education, 4 Kasumigaseki, Sanchome, Chiyoda-ku, Tokyo, Japan.

WE SHOULD TRY TO USE MACHINES TO INSTRUCT STUDENTS

1. A university is no longer established solely for an elite. Today, it is essential that each student should be able to learn at his own pace. Moreover, machines are needed for teaching large classes.

2. There are three types of machines:

(a) Teaching machine : This machine teaches by means of slides and recorded voices, and puts a question to the student. When he answers the question by pushing a key, the machine compares the answer with its programme and carries on with the next suitable picture and instruction.

(b) Sonovision : This is an automatic slide projector with sound. A student can stop the machine whenever he likes and consider by himself. The machine can put a question, but cannot judge the answer.

(c) Tape recorder and textbook : This system combines pictures printed in textbooks with voices from the machine. A student can stop the tape and consider by himself.

3. These machines will be able to impart a knowledge of physics, and professors should devote themselves to teaching the philosophy of physics.

A CURRICULUM FOR INTRODUCTORY COLLEGE PHYSICS

Some necessary considerations in designing a curriculum

Our curriculum should have two principal functions. The first is to give the students a real understanding of science, and the capacity of expanding their knowledge and of enlarging the scope of its application to practical problems, thus enabling them to behave wisely in the scientific and technological medium. This is mainly concerned with the methodological aspects of physics.

Another function for which the curriculum should also be responsible comes from the very fact that any science is science about something. Whenever we talk about science, we have some specific object in mind. When we talk about physics, we probably cannot miss mechanics, electricity and magnetism, as well as thermal and quantum physics, because they are fundamental. In order to make the curriculum entirely different from a mere collection of gadgets, we should select materials which are of fundamental importance and have wider applicability from the whole field of physics, trying to keep the number of topics to a minimum and to deal with them thoroughly.

Another important point is to arrange the course so that the students' learning process may form a complete cycle. This means that they can not only understand the abstract principles through careful studies of what is happening around them, but also that they should realize, through their own eyes, that these principles are not dead orthodoxies, but are still alive in each individual phenomenon. This training should also teach students to correct their behaviour when the tactics they have employed fail to bring success, thus making science even more meaningful and valuable to their life in the cultural as well as in the technological sense. These points of view should also be reflected in the selection of problems and exercises, which must, of course, be carefully linked with the development of the curriculum itself.

A Curriculum Designed for 10 Semester-hours

- For Freshman (1st year)

1. Mechanics

Operational definition of force (spring balance as a measure)
Analytical treatment of motion
    Free fall, uniform circular motion, simple harmonic motion

Concept of momentum and energy (based upon conservation law with especial reference to collision problem)
Analytical solution of simple dynamical problems, with electrical analogy
Harmonic oscillator, Forced oscillation and resonance,
Q-value, Transient phenomena, Mechanical impedance,
Filters, Rotation and precession of a top
Vibration of diatomic molecule
Coupled oscillator
Kepler's law and universal gravitation
Gravitational field and its potential
Rutherford scattering
Wave along the linear lattice
Reflection at boundaries (characteristic impedance)
Standing waves
Modes in wave guides

II. Relativity

Relative motion and inertial force
Galilei-Newtonian Relativity
Michelson-Morley experiment
Lorentz transformation
Invariance of four dimensional distance
Addition of velocities
Acceleration of charged particles (MIT experiment)
Variation of mass with velocity (invariance of momentum conservation law)
Cyclotron vs synchrotron
Mass-energy relation (prediction)
Mass defect and pair creation

III. Electricity and Magnetism

Electrostatic field
Coulomb's law
Gauss' theorem (divergence)
Operational definition of the magnetic field
Electric field of a moving charge
Relativistic interpretation of magnetic field (Kotani-Purcell)
Biot-Savart's law
Vector potential
Electromagnetic induction
Stoker's theorem and curl of the vector field
Displacement current
Electromagnetic wave
Dipole radiation
Electric fields in matter
Magnetic fields in matter

- For Sophomores (2nd year)

IV. Heat and Molecular Motion

Operational definition of temperature and heat
Boyle's law (deduced from rigid sphere molecule model for gas)
Boyle-Charles' law (" ")
Adiabatic expansion (" ")
Carnot's cycle and concept of entropy (phenomenological)
Statistical interpretation of entropy

- Phase space and Liouville's theorem
- Maxwell-Boltzmann distribution
- Specific heat of diatomic molecule gas
- Irreversible process

V. Atoms, Nuclei and Elementary Particles

- Bohr atom and quantum concept
- Waves and particles
- Quantum mechanical theory of hydrogen atom
- Helium atom
- Electron spin
- Eigen state and eigen vector
- Statistical interpretation in quantum physics
- Stark and Zeeman effect
- Interaction of radiation with matter
- Nucleus, its properties and its constituents
- Particles and anti-particles

VI. Molecules and Solids

- X-rays and Crystal structure
- Quantum theory of simple molecules
- Energy bands in solids
- Electric and magnetic polarization in molecules and solids
- Spectroscopy of molecules and solids

UPPER SECONDARY SCHOOL PHYSICS CURRICULUM(1)

It seems appropriate to explain briefly that the lower secondary school education, with an enrollment rate of 99.9%, is compulsory. In the lower secondary school, physics is not taught as an independent subject, but is included in "general science", which is divided into two sections, the first section dealing with physics and chemistry and the second section with biology and earth sciences.

The ratio of the number of class hours of general science to the total of class hours is about 12.8%. The seventh through the ninth graders study general science four hours every week, 35 weeks a year.

The number of class hours allotted to physics is about 25 to 30% of the total class hours of general science.

The upper secondary school, which is non-compulsory, has a general course and/or a vocational course or courses. In 1965, 72.4% of the graduates from the lower secondary schools were admitted to upper secondary schools, which comprise 10th through 12th grades, and about 60% of these students are in the general course.

The students in the general course of the upper secondary school are required to take physics, chemistry, biology and geology before graduation, while the students in the vocational course must take two out of these four subjects.

The number of the required credits for each subject is as follows :

Physics A :	3	Physics B :	5
Chemistry A :	3	Chemistry B :	4
Biology :	4		
Geology :	2		

(B is rather academic and is more advanced in content than A).

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1. See also below : Review of Textbooks, Levels and Trends (upper secondary)

One credit unit represents one hour's study per week, 35 weeks a year.

In principle, biology and geology are taken in the tenth grade in the general course. In the eleventh and twelfth grades, physics and chemistry are taken in parallel with biology and geology.

The standards for the contents of physics A and B are set forth in the Course of Study issued by the Ministry of Education.

The main items in Physics B (standard total number of class hours - 175) are :

force, force exerted on solid,
force exerted on liquid, motion of bodies,
laws of motion, circular motion
simple harmonic oscillation,
mechanical energy, heat,
heat and molecular motion,
wave motion, sound,
light waves,
reflection and refraction of light,
electric and magnetic field,
electric current and resistance,
electric current and magnetic field,
electromagnetic induction,
alternating current and electric oscillation,
electron, atom,
atomic nucleus.

The order in which these items are to be taught to students is not specifically prescribed by the Course of Study.

The contents of the physics course up to the present have been based mainly on the classical concepts of physics. It is generally agreed that the student should receive a comprehensive idea of modern physics (based on the quantum mechanical concept) before finishing the upper secondary school course.

REVIEW OF TEXTBOOKS

General aspects

The current textbooks of physics for upper secondary schools are of two types, Physics (A) and Physics (B). There are about twenty different kinds. In Japan, the textbooks for all the schools from the elementary to the upper secondary school level must be authorized by the government for publication and classroom use. All these twenty textbooks are therefore authorized textbooks, and the maximum price is fixed by the government.

Other physics textbooks of the same level are Japanese versions of the PSSC textbook of USA and that of A.B. Pyoryshkin of USSR. However, they are used only as reference books for students, and are not approved for classroom use.

There are more than forty textbooks of the university level on which no legal restriction is laid for publication or use. These textbooks vary in their volume, level and price, but they can be divided roughly into the following three groups :

(C) for the students majoring in humanities and social sciences (7)
(D) for general use (8)
(E) for students majoring in natural sciences (27)

The marks (C), (D) and (E) are given for convenience sake.

The textbooks of group (D) are to a great extent based on the idea that the contents of "natural science" as a general education subject at universities can be the same for all students, regardless of their majoring subjects.

Group (E) is based on the idea that fundamentals required for professional education are suitable for general education. In other words, these textbooks emphasize the requirements for professional education.

The textbooks of group (E) are divided into two types : the first type includes books with abridged and condensed contents in small volume format like those of group (D), while the second type is of rather voluminous format with richer contents.

The following table shows the volume and price of the textbooks :

Level		Upper Secondary		University			
Group		(A) Physics A	(B) Physics B	(C)	(D)	(E)	
No. of kinds available		10	9	7	8	7	20
Pages	Max.	270	450	280	380	360	1030
	Average	250	420	230	290	300	650
	Min.	230	370	170	240	250	430
Average price (US $)		.36	.60	1.00	1.40	1.40	3.00
Unit		3	5	2	2--3	3	3--4
Type of Student				Lit. course	Lit. & sci. course	Sci., eng. & med. course	Sci. & eng. course

The figures for the kinds and the prices are exact for textbooks for upper secondary schools, but for those for universities the figures indicate approximate numbers and prices.

Levels and Trends (upper secondary)

Contents of textbooks for Physics B are outlined as follows :

- Mechanics

Statics. Composition and resolution of forces, moment of force, center of gravity, static friction, etc.

The textbooks usually deal with the equilibrium of forces acting on a rigid body but do not go into the consideration of the moment of force in terms of vectors.

Motion, Laws of Motion. Velocity and acceleration, mass, Newton's Laws of motion, conservation of mv, universal gravity, etc.

Falling body, projectile circular motion, simple harmonic motion and sometimes Kepler's laws are included as an introduction to or realization of these concepts. In most textbooks, the centrifugal force is explained from the view-point of inertial force in general and very few textbooks refer to the Coriolis'force. Only one of the textbooks refers to the meaning of the inertial mass and gravitational mass.

In dealing wiht the law of motion in quite a few textbooks, the equation $f = \frac{1}{t}(mv)$ is used instead of $f = ma$.

Mechanical Energy. Work, power, potential and kinetic energy, conservation of mechanical energy, etc.

In this area, for example mgh and $\frac{1}{2}kx^2$ are introduced for potential energy but only half of the textbooks refer to $-\frac{GMm}{r}$ (Gravitational potential energy in general)

Other Mechanical Phenomena. Elastic deformations (chiefly on Young's modulus), kinetic friction, resistance of stream, etc.

Rigidity, viscosity, Bernoulli's theorem, etc. are dealt with qualitatively in most of the textbooks. The developing trend is to explain elasticity and plasticity qualitatively from atomic structure of solids.

- Heat and Molecular Motion

Heat. Heat capacity, specific heat, coefficients of thermal expansions, $PV = RT$, vapor pressure, mechanical equivalent of heat and conservation of energy, etc.

Some textbooks refer to Van der Waals equation and the Second Law of thermodynamics.

Molecular Motion. Relation between pressure and temperature of gas and momentum and kinetic energy of gas molecules.

Most of the textbooks deal with the calculation of $\frac{1}{2}\overline{mv^2} = \frac{3}{2}kT$.

- Waves

Wave motion. Transverse and longitudinal waves, $v = \lambda\nu$, interference, diffraction, stationary wave, Huygens' Principle, etc.

On interference and diffraction, quantitative calculation is dealt with.

Sound Waves. Vibration of strings (relation between frequency and tension, length and linear density of the string), standing wave in an air column, beat, etc. are dealt with quantitatively.

Light Waves. Light velocity and its measurement, interference and diffraction of light and examples of these (colors of thin films, diffraction grating, etc.). Polarization of light and dispersion of light are explained qualitatively. Few textbooks refer to Brewster's Law.

Reflection and Refraction of Light. Mainly the formula of thin lenses in addition to principles of the microscope and telescope are dealt with. Photometry and colors are rarely referred to. Only qualitative explanation is given on resolving power. The law of reflection and refraction is usually dealt with under Huygens' Principle and fewer pages are devoted to this subject than in the textbook of PSSC.

- Electricity and Magnetism

Static Field. Coulomb's law, electric field, magnetic field, electric potential, etc.

A few textbooks introduce the concept of Gauss' law. As to the magnetic field, the trend is to describe it by electric current.

Electric Current. Ohm's law, Joule's law, specific electric resistance, D.C. circuit, etc.

An increasing number of textbooks give interpretation of Ohm's law through a qualitative consideration of the behaviour of electrons in metal.

Electric Current and Magnetic Field. Magnetic field of a long wire ($H \propto \frac{i}{r}$, r: distance), magnetic field of a circular wire ($H =\propto \frac{i}{r}$, r : radius), force acting on a current in a magnetic field ($F \propto H : l$, l : length), etc.

An increasing number of textbooks use the MKSA unit system. A few textbooks introduce just B and describe the phenomena without H, as does the PSSC textbook.

Electro-Magnetic Induction. Induced e.m.f. (electro-motive force) by changing magnetic field or by moving a wire across a magnetic field, and self - and mutual inductance as its application.

The principle of the transformer and electric power transmission are also dealt with as important applications. About half of the textbooks explain the induced e.m.f. with Lorentz's force.

Alternating Current and Electric Oscillation. Effective value of A.C., A.C. flowing through a coil or capacitor ($I = \frac{V}{\omega L}$, $I = \omega CV$), resonance circuit ($f = \frac{1}{2\pi \sqrt{LC}}$), electromagnetic waves, etc.

The three-phase current is always mentioned briefly. Most textbooks mention without further explanation the fact that the changing electric field produces a magnetic field, while a few books give a semi-quantitative explanation.

Electrons. e/m of electron (its determination by the deflection of cathode ray), effects of diode, triode, and photo-electric cell, electrons in a solid body (transistor), X-ray, crystal, etc.

Determination of e/m is treated quantitatively in most of the textbooks The effect of a transistor is dealt with only qualitatively and it still is difficult for students to understand the function of the transistor. This point will also be a subject of further studies.

Atoms and Atomic Nucleus. Bohr's quantum hypothesis, electron shell, structure of atom, momentum of a photon, De Broglie's wave ($\lambda = \frac{h}{mv}$), Rutherford scattering, decay of atomic nucleus, elementary particles (proton, neutron, electron and some mesons), Einstein's mass-energy equation ($E = mc^2$), cosmic rays, etc.

These contents of textbooks of modern physics vary from volume to volume and most items are described qualitatively.

SITUATION OF LABORATORIES IN JAPANESE UNIVERSITIES

Generally speaking, the improvement of laboratories has been almost entirely neglected until recently, in strong contrast to the remarkable improvement in the facilities for science education in primary, secondary, and high schools. The subjects and laboratory apparatus, most of which were prepared after the war as a mere continuation of the high school in the old education system, have become, for the most part, old and even outmoded.

Three factors working simultaneously have resulted in a rapid increase in the number of students in the natural sciences over the past few years : First, the increase in the age group entering the third year of the high school (this will reach a maximum next year) ; second, the increased percentage of boys and girls who want to go to a university ; and, third, the increase in the ratio of students in the natural sciences to those in the humanities.

The empirical character of science is often neglected in teaching in Japan. One of the reasons is the difficulty of the entrance examinations for the more famous high schools and universities. In preparation for these, almost all effort is concentrated on calculation, solving given equations, or answering a question with pencil and paper.

Another reason is the fact that the empiricism and pragmatism which are part of the English and American intellectual tradition have not played an important role in the Japanese tradition. Japan was influenced by European idealism, which is similar to Japanese modes of thinking characteristic of the feudal era and the people of Asia.

The conditions or atmosphere for science education outside schools and universities is also poor. For example, we have few science museums corresponding to those in Europe and the United States. Boys and girls have neither time, place nor money to do experiments outside the school, in strong contrast to the fact that they have many inexpensive good books for practising calculation. As a result, most of the students entering universities have no experience in experimentation and are quite timid about doing experiments for themselves.

THE LABORATORY IN THE COLLEGE OF GENERAL EDUCATION. UNIVERSITY OF TOKYO

The laboratory classes of this university meet once every two weeks during the second and third semesters. In other universities, laboratory classes, on the average, meet every week for one semester, usually the second or third, totalling about the same as those of our university. We have laboratory for about four and half hours in the afternoon on all weekdays except Saturday. The period is longer, by two to three hours, than the average length of time spent in laboratory in other universities.

Corresponding to the recent increase in the number of students, the capacity of laboratories has been enlarged as follows :

	Years	Number of students	
		Total	Capacity (average)
(i)	1958-60	1000	120 (100)
(ii)	1961-64	1500	180 (150)
(iii)	1965	1600	220 (200)

Although it had been very difficult to get funds for the improvement of the laboratory, we obtained some funds to take care of increase in the number of students. Making use of this opportunity, we have improved and are continuing to improve our laboratories. The first large-scale improvement was made from 1961 to 1962. In this reform the laboratory courses were not only reduced in number of subjects, but also changed in content. The second reform began last year and is still going on. This arose from the need to meet a serious shortage of teaching staff, the number of which has remained almost constant in spite of the rapid increase in the number of students.

The members of the faculty who teach in the laboratory include a few volunteer professors (one or two), all assistant professors (two or three), and assistants in experimental physics (three to five) ; moreover for the last few years, assistants in theoretical physics and some graduate students have helped the regular members. It is more difficult for all of the teachers to agree in determining laboratory subjects than in determining the curriculum of introductory physics, because the objective of the laboratory is not so clear as that of introductory physics. In order to settle this problem and to push forward our task, we have done the following things :

(i) A committee was organized to carry out long-range planning for the laboratory ;

(ii) All members participated in discussions on each subject especially with regard to the guidance of the students ;

(iii) Two kinds of questionnaires were distributed among the students and teachers ;

(iv) An analysis was made of the elements of each subject which the students could learn, for example, the estimation of error, the kinds of instruments, and methods of measurement.

Here I will mention only one point. Namely, the students and younger teachers, on the average, have little sympathy with the subjects of classical mechanics.

We adopted the following as guiding principles :

(i) The laboratory should be operated independently of the curricula of introductory physics. (To help the students in understanding the lecture, demonstrations and other methods should be utilized).

(ii) Emphasis should be laid on arousing the interest of the students in experimentation, on cultivating the attitude or habit of being ready to conduct experiments.

TEACHING METHOD FOR UPPER SECONDARY SCHOOL PHYSICS

Generally, physics is taught mainly through lectures given and demonstrations made by the teacher. Students usually conduct 10 to 20 kinds of laboratory work a year. Having the college entrance examinations in mind, much time is spent on problem - solving.
There is a contrasting report on an experimental class, where neither lecture was given nor demonstration made. In this experiment students were given study assignments and did the work in groups. Their interest in physics increased and they showed better records than the students in the control class did.(1)

The report says, "Students who like science started liking it from the first year (seventh grade) of the lower secondary school, and many of them continue to be interested in the subject. Students who dislike science acquired this attitude in the eighth or the ninth grade or after entering the upper secondary school. I sometimes wondered if I was standing on the platform in order to make students lose interest in science .... Why was science so unpopular? Did the reason lie with the teachers , or with the students ? Or was it due to some other factors ?"

Thus two classes were formed, where entirely different teaching methods were used.

Teaching Policy for Class A

- Lectures were to be given as thoroughly as time permitted.
- Student's laboratory work and teacher's demonstrations were to be conducted as often as the equipment and time permitted.

Teaching Policy for Class B

- Neither lecture nor demonstration was to be given.
- The contents were to be given to the students in the form of study assignments.
- The students should be led to solve by themselves a series of problems arranged under one and the same theme through such means of collective study as group discussions and group experiments.
- The guiding principle should be that everyone in a group understands, and the students' progress in study was not to be prescribed, except that the deadline expected for the completion of the study of a theme is set in advance.
- As many instruments and materials needed for laboratory work as possible were to be provided in advance, which students were free to use. Students working out experiment methods by themselves were to be appreciated, and they were to be encouraged to make instruments by themselves which might be needed for their laboratory work.

As a result of conducting classes under such policies, "in Class B, the eyes of the students who lost interest in physics became vivid. There was no student who showed no interest in study ..." The students' willingness to study increased, and they became active in class. The records of the examinations showed that the score of students below average went up above that of students of Class A. The average score of the class went up tremendously. An example of the series of problems is as follows :

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1. Kazumitsu Fujishima, An Attempt on the Teaching of General Science, (Rika Gakushu Shido no Hitotsu no Kokoromi), The Journal of the Physics Education Society of Japan, vol. 10,No. 1, 1962, pp. 8-16.

"The study of forces mutually affecting the body and the surface on which the body is "placed :

" - Show by diagram all forces acting on a body mg which is at rest on a plane. "Describe the magnitude of the forces.
" - Show by diagram the force with which the body mg pushes the plane on which it "is placed at rest. Describe the unit and the reason that causes the magnitude of the "force to be mg.
" - Conduct the following experiments to make sure if the items mentioned above "with respect to the nature of the maximum frictional force are true.... (Materials "and methods are given).
" - Devise a method of experiment to find out why a frictional force is produced by "a body rolling on a surface. (Refer to the General Science Experiments manual)."

This method is very close to the programmed learning accompanied by experiments. It is worthy of notice that by this method many students regained their interest in physics and enhanced their understanding of the subject. There is another report on a similar experiment in teaching of physics, which was done mainly through laboratory work. There seem to be many points common to these two experiments, both in methodology and in results, though they differ in details. It is a fact, however, that many of the schools and teachers do not show much interest in the new methodology even when good results and effects are reported.

LABORATORY APPARATUS (SECONDARY SCHOOL)

The great role which the national government is playing in the development of science education lies in the disbursement of subsidies for the purchase of experiment instruments. These subsidies, together with local public expenditures, have been employed to improve and extend the range of experimental apparatus in use in the schools.

The Law for the Development of Science Education was established in 1953. The standard of the scientific facilities of each school was set by this law. The Government plans the budget so that the subsidy will be given to schools whose facilities are not up to the standard. The standard for school science facilities was revised in 1961. In 1965, it was again revised to meet the modern level of science. The facilities for science education of each school are being enriched nationally. The total sum of the Government subsidy adds up to ¥ 8,220,000,000, - in the period from 1954 to 1965. If the amount spent by the patrons of the schools is added, more than ¥ 16,440,000,000, - were used for the improvement of the facilities for science education.

The quantity of instruments and tools bought by the budget in each school is considerable. The study of general science from the facts, therefore, showed excellent results due to enriching facilities and the teachers' efforts to instruct the experimental techniques.

NEW TEACHING AIDS CAPABLE OF MULTIPLYING THE EFFECTIVENESS OF TEACHERS

Inexpensive Laboratory Materials

Instruction in principles and theories have been considered to be the two most important factors in physics teaching in Japan. The demonstration by the teacher has been introduced since the beginning of the 20th century, but it is from about 1918 that individual experiments performed by pupils or students have been made part of the teaching program. These experiments, however, were mostly carried out from the standpoint of verification of laws and theories.

In those days, there were a few pioneers who thought that emphasis in science education should be laid on scientific way of thinking rather than on teaching of established laws and principles. From this standpoint they advocated and practised the device of handmade aids made of inexpensive materials and methods of simple science experiments.

Recently, owing to the rapid advancements in science and technology, the contents of science courses have been reorganized, and consequently the teaching method has made much progress. Individual experiments have become more and more popular in science teaching. Apparatus for experiments and methods of teaching have also been renovated. Especially, the device of physics experiments with inexpensive materials has become more prevalent every year.

Trend in Devising Teaching Aids

There has been much reconsideration of the conventional ideas concerning the traditional science instruments such as a screw micrometer for measuring a small length, a chemical balance for weighing a small mass, and a stop watch for measuring a short time interval. Instead of these fixed ideas, many inexpensive laboratory materials can be introduced ; an optical lever or range finder instead of a screw micrometer, a sensitive balance using a soda straw instead of a chemical balance, and a recording timer made from an AC buzzer instead of a stop watch. Students can design instruments efficient enough for the required accuracy, and devise the methods of investigation for the accuracy of constructed instruments.

There has been a wider application of electronics to science instruments. For instance, we can point out the device of a thermistor thermometer in place of a liquid thermometer. By using an oscilloscope, we can see the tone and interference of the sound with our own eyes, not to mention hearing them with our ears. We can also use a germanium diode or a transistor instead of a thermionic vacuum tube for the teaching of electron or electro-magnetic waves. A low frequency oscillator may be introduced in place of a tuning fork.

The recently developed materials - chiefly large molecular compounds such as vinyl, polyethylene, and plastics - have been introduced into the teaching aids group. This has given rise to methods of simplifying the traditional science instruments. Blister styrol has been used to replace the pith ball of an electric pendulum or the cork of a calorimeter, and a plastic pipe has been used for the cylinder of a pump and the coil of an electromagnet. The high molecular compounds are commonly good insulators, and many applications of this property have been discovered.

The rapidly developing materials for attachment have been used in science handicraft. In the past we used dextrin paste for pasting papers, a soldering method for joining metals, and a fusing method for glass work, and the use of these materials required high technical skill. But now the development of new adhesives (epoxy group) has made the attachment of various materials very easy. In consequence, we can make an optical basin, water tank for projecting use, cylindrical lens, prism, etc., by using the appropriate geometry of vinyl chloride sheets. For their attachment, vinyl paste or other new materials can be used effectively, provided that when the attaching materials are used for metals, it is noted that these materials lose their electrical conductivity.

The trends mentioned above have brought a remarkable change in the size and shape of traditional science aids, and made them easy to handle. In addition to these, the discoveries of cellophane tape, vinyl tape, tape, ferrite and rubber magnets, transistors, thermistors, etc. have contributed greatly to the simplification of the experiments.

Examples of Teaching Aids Recently Discovered

Short time interval recording timers : Suggested by the timer of PSSC Physics, various timers have been devised (1) the type of a clapping electromagnet with an iron armature, (2) the type of a rotating motor with its shaft attached to a disk whose edge has several writing brushes equally distributed and also attached to a rotation counter,

(3) the type of a moving magnetic recording tape driven with various speeds between the poles of an AC electromagnet. The tape is then passed through iron filings.

Wind tunnels : Open types of various wind tunnels, where wind is raised by a fan driven by a motor, have been made and offered for experiments in fluid dynamics. In one type, by setting the proper iris near the wind jet we can obtain the maximum velocity of 8 m/sec, and in another type, we can obtain the perfect parallel flow of wind by using the regulating grid.

A set of three tops : The first top is that whose position of the centre of gravity is variable up and down or right and left by moving the screw which fixes the axis to the top. The second type is one whose axis is able to incline without changing the centre. The third one is the type that looks like an artificial satellite. Spinning these tops, the fundamental motion of the rotating body will be clarified.

A new type of Magdeburg hemispheres : A new type of an exhaust pipe on the place deviating from the centre line of the sphere. The process of exhausting air is simplified without the trouble associated with taking off the handle every time.

Apparatus of sound : Three instruments are put together in this apparatus ; the one illustrating the falling of a body in the vacuum tube, the bell in the vacuum jar, and Kundt's experiment. The main portion of this apparatus consists of a glass tube with a thick wall, 6cm in internal diameter, 100cm in length. According to the purpose of the experiment, various stoppers will be loaded on the two ends. As the sound source, an electronic oscillator is picked up, 200-3,000 c/s in frequency and one watt in average output power. For the vacuum experiment, a tight rubber stopper with an air nozzle and a crystal microphone will be loaded on the opposite end of the glass tube against the sound source. For the experiment of standing waves, a piston will be used together with the cork powder.

A Shive style wave machine : By this machine a synthetic experiment of wave motion such as pulse, damping reflection, superposition, standing wave, and resonance, can be made. The structure of this machine is as follows : many short metal cross pieces are arranged at equal intervals on a central backbone, the centres of the metal pieces are skewered and fixed, then the central backbone is put on the plate by balancing the metal pieces horizontally like a blind. Vertically vibrating one end of these metal pieces, we can cause a wave to form and propagate it gradually. The intervals between the metal pieces are 1.3cm each, each piece being 46cm in length ; the total number of pieces is 70, and the length of the central backbone is 95cm.

An apparatus for producing and projecting water waves : This apparatus is made as follows : the lighting is stroboscopic and it is synchronized with the water wave generator. If this apparatus is fixed to a ripple tank, many students can observe at the same time a stopped image of the various types of waves.

A flexible mirror : It is made mostly from acrylate resin, and can be used as a plane mirror, a concave and a convex cylindrical mirror. Combining two or more, we can carry out the experiment of reflection of many images. This mirror, however, can be substituted by a ferrotype plate of the photograph drier.

Cylindrical lenses : Taking advantage of the thermo-plastic quality of vinyl, we can make various types of cylindrical lens prisms, and liquid blocks by manipulating transparent vinyl chloride plates and attaching them with vinyl paste. In the same way we can make a transparent water tank. While using transparent celluloid plates, we may use the SUMP (Suzuki's Universal Micro-Printing Method) liquid or film cement for attachment. (Main ingredient is acetone or amyl acetate.) We can use experiments of an air lens immersed in a water tank, for the understanding of the refraction coefficient $\mu_{AB} = 1/\mu_{BA}$ between two media A and B. When we use these lenses, filling up the water, we must determine the curvature of the lens considering the difference of refraction coefficient of glass and water. For the mathematical treatment of these lenses, we must treat them as if they were thick lenses.

A rubber magnet : It is put on the market for experimental use in the form of sheets, squares, and rods. It has high electric resistance and small permeability. We can fix it with push nails and bend it easily. We can cut it freely with a knife or a pair of scissors and can attach it to many things and through all these experiments, it does not lose the power of magnetism.

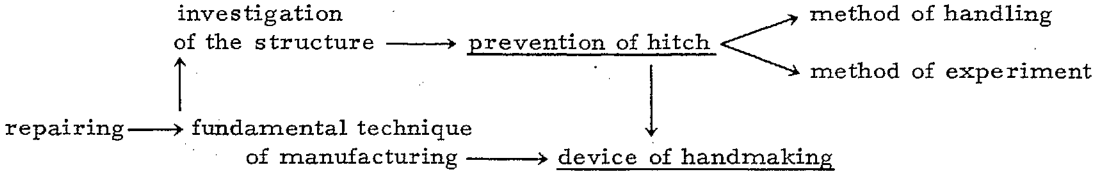
A rod for generation of static electricity : It is a plastic rod made of acrylate resin, and suitable for use being about 20cm in length, 1.2cm in diameter. Using it together with silk cloth and cat skin, we can recognize the pole of the generated electricity, and use it instead of the less effective ebonite or glass rod. In the Van de Graff static high voltage generator which replaced the Wimshurst static electricity generator, many kinds of resins of the acrylic groups are used.

An AC voltage dropper : The resistor made by two electric heater wires of 100v-500W connected in series can be made cheap and easy to handle and can thus have a wide use. We can apply it to the electrolytic rectifier, electromagnet, motor, arc lamp and other low voltage experiments. In this use care must be taken of the heat emission in the resistance wire.

The measurement of e/m : (1) The method of using a cathode ray oscilloscope. This method was reported by M. Hotta and H. Ikehara, both teachers of Yashio upper secondary school, Tokyo-to. They use the deflecting plates of Brownian tube itself as the electric field, and the handmade Helmholtz coils for yielding magnetic field. (Jour. Phys. Edu. Soc. Japan, vol. 12, No.1, pp.28-31). (2) An apparatus is now in the market with the help of which they can estimate the value of e/m by measuring the radius of the circular orbit of electrons produced by the magnetic field of Helmholtz coils. The electrons are shot out from the electron gun in a spherical vacuum tube of 13cm diameter. Using this apparatus, they can measure the value of e/m easily. (3) The method of PSSC Physics is also effective because of the simple apparatus.

Some Studies, Books, and Practices in this Field

1. Short Courses on Techniques for Repairing Science Apparatus, organized by the Ministry of Education (1951-1963), were held for 120 science teachers and supervisors for 4 days every Summer in every district, all the country being divided into 6-9 districts. These courses were held, at first, for the purpose of cultivating the repairing skill of participants, but have developed during the past years and now have the following program :



Here, the meaning of handmaking is not simply to imitate the customary instruments but to put emphasis on the device and aiming at renovations. The details of these courses have been described in the book : Ministry of Education : A Guide Book to the Repairing and Handmaking of Science Apparatus (published Jan. 20, 1963, Tohyoh-kan Publishing Co., Ltd., B-5, 240 pages.)

2. Y. Ikemoto : The Encyclopedia of Experimental Physics (March 31, 1964, Kohdan-sha Co., Ltd., B-5, 712 pages). In this book, over one hundred people who are engaged in scientific research or teaching of experimental physics in universities or secondary schools, are reporting about their valuable devices. Several hundred items, dealing in all areas of experimental physics and convenient for class room or laboratory work, are described clearly and minutely.

3. Kohdan-sha : Picture Book of Experimental Physics (March 31, 1965, Kohdan-sha Co., Ltd., B-5, 324 pages). 437 colour sheets and 143 monochromatic photographs of physical phenomena are given in this book ; an explanation of the mechanical equipment is attached to each photograph. It is intended mainly as guiding materials for experiments in secondary school physics.

4. K. Shinkai, O. Shimada, and K. Hori : Making the Aids for Science Experiments and Fundamental Techniques for Making Them (Feb.2, 1965. Tohyoh-kan Publishing Co., Ltd., A-5, 321 pages). There are some instruments which in spite of their high educational value are not manufactured by makers because of their low commercial values. There are also some whose shapes cannot be predetermined because of the necessity for continuous improvement and which might better be made by the teacher and the students or pupils. In this book these instruments are described. About 200 items for physical and chemical experiments as well as their use and manufacturing are described.

5. R. Okazaki : Physics Experiments by Design and Device (Sept. 1959, Meiji-tosho Publishing Co., Ltd., A-5, 194 pages). It is edited for the purpose of cultivating various scientific abilities, (i.e. how to observe, how to devise, and how to manipulate) and of making us understand the method of use of the device by many practical examples with inexpensive laboratory materials.

6. H. Nakagawa and others : Science Experiments of the World - follow-up test and renovation - (Sept. 1964, Meiji-tosho Publishing Co., Ltd., A-5, 307 pages). From among the science experiments carried out all over the world, many examples are selected because the authors have recognized the importance of those which, though being sometimes limited devices, are useful for our references and for promoting the will to confirm scientific truths. On the other hand items similar to those which are well known in our country are omitted. For the items which, through the confirming experiments, were found to be imperfect, the authors have added explanations for renovation and improvement.

7. Investigations :

Many individual investigations concerning all the above mentioned articles are compiled in the following magazines :

- Journal of the Physics Education Society of Japan. Edited and published by the Society, 2-4 books a year. Started in 1953.
- Bulletin of Society of Japan Science Teaching. Edited and published by the Society, annual issue. Started on Dec. 1, 1959.
- Science Education Monthly. Edited by the Soc. of Japan Science Teaching, published by Tohyoh-kan Publishing Co., Ltd., Started on Sept. 1, 1952.
- Science Class Room. Edited by the Science Education Research Conference, published by Kokudo-sha Co., Ltd., monthly issue.

PROGRAMMED INSTRUCTION

Study by programmed instruction for elementary and lower secondary schools has increased in popularity in Japan in recent years. Many teachers of science education in upper secondary schools are now showing interest in this method and have begun to study it. However, at the present, since a programme covering the whole field of physics has not yet been prepared, and teaching machines are not numerous, the programmed instruction is rarely applied in classroom teaching.

In Japan with the rate of promotion of pupils to upper secondary schools having exceeded 70%, the differences in abilities among pupils is becoming very large, and physics is a compulsory subject in upper secondary schools in the general course. Therefore, the programmed instruction of this subject is expected to be of increasingly great importance as one of the teaching methods which takes into account individual ability.

FILMS, RADIO, AND TELEVISION

Production and utilization of science films

A total of 1, 100 documentary films are produced in Japan every year. 406 (37%) of these are educational films (for school and adult education) ; 125 (12. 3%) teaching aids ; 22, science films for schools (elementary, lower secondary, upper secondary) ; and 33, academic pictures. During the five year period from 1958 to 1962, 232 teaching aids and science films for schools, and 268 industrial educational films were produced ; and in 1963, 37 teaching aids and science films for school, and 27 academic and science films were produced.

However, the number of research and educational films for universities and colleges is quite limited except for those on medical science.

Recently the production of TV films on scientific subjects for general showing in 16mm projectors has greatly increased (for example, the 250 films in the "Science to Enjoy" series and the 45 in the "Primer of Technology").

Distribution of films is made to audio-visual libraries operating in various parts of the country, either by producers themselves or through distributors of educational films to whom producers sell or consign their films.

There are in Japan a total of 850 large and small audio-visual libraries. Some of them are operated by prefectural governments, others by municipalities and still others jointly by groups of schools. The annual budgets appropriated by these bodies range from over 5,000,000 yen (14,000 US dollars) to less than 50,000 yen (140 dollars). Of the national total of such expenditure, 56% is paid by Government and public bodies, 38% by school children, and 6% comes from other sources.

These audio-visual libraries rent films to, and/or conduct itinerant showings at schools and social educational facilities.

In addition, there are a number of other film libraries renting films, such as those maintained by industrial associations (e.g. Rolled Steel Club), banks (e.g. The Bank of Japan's Savings Promotion Committee), newpaper companies (e.g. The Mainichi's "Lessons by IndustrialFilms") and various non-profit organizations (e.g. Japan Science Foundation). The films handled by the above-mentioned bodies include many excellent ones on scientific subjects sponsored by business organizations, and the renting of such films to upper secondary and other educational facilities is increasing.

List of Films for the Teaching of Physics prepared by the Ministry of Education
(selected from the series of "Educational Films for Teaching Science")

Title of Film	Course of study related	Contents	Time (minutes)	Producer	Price (yen)	Date of production
Electric Field and Electric Potential	Electric Field and Magnetic Field	1. Clarification of the concept of "Force" through the understanding of electric field and electric potential 2. Clearing up the concept of "Force Field" by pointing out the properties of an electric field and lines of electric force as demonstrated by various types of experiments, and explaining the relation between electric potentials and work by a mechanical model	25	Nikkei	22,500	Dec. 1963
Force and Motion	Laws of Motion	1. Showing that a body will continue uniform motion unless forces act on it. When forces act on it the body acquires an acceleration proportional to the force and inversely proportional to its own mass 2. Proving experimentally the second law of motion 3. Confirming the above conclusion through some experiments. The second law applies to a wide scope of natural phenomena	20	Iwanami	19,000	Oct. 1963
X-ray	Electron	X-rays are used to analyze the structure of matter because of their very short wave length. Film demonstrates how the structure of crystal is qualitatively analyzed by the X-ray diffraction pattern method.	20	Iwanami	19,000	Jan. 1965

Title of Film	Course of study related	Contents	Time (minutes)	Producer	Price (yen)	Date of Production
Momentum	Laws of Motion	Explaining the principles of momentum, impulse, conservation of momentum, center of gravity and collision, with some examples and experiments, starting with reviews of the first and second law of motion	20	Tōei	19,000	in production
Atomic Structure and Existence of Atomic Nucleus	Atoms and Atomic Nucleus	Explaining Laue's spot and Wilson's cloud chamber as means of proving the existence of the atomic nucleus and its structure, in an easy method, with various types of experiments	20	Nikkei	19,000	in production
Circular Motion	Motion of Bodies	Giving a grasp on the centripetal force quantitatively from experiments on circular motion, using a model car. Giving understanding of centrifugal force and deflecting force, with experiments using dry ice bag and turntable	20	Gakken	19,000	in production

The teaching of science and mathematics through sound and television

At present, NHK is devoting more than half of its programme hours to education and culture : in the sphere of radio, 160 hours per week, that is 61% of the broadcasting time of the First and Second Networks ; and in the sphere of television, 149 hours per week, that is 70% of the transmission time of the General and Educational Services.

Among educational and cultural programmes, the subjects of science and mathematics take eleven and half hours in radio, that is 8% ; and they occupy twenty-five and half hours, that is 17% in television.

The science and mathematics programmes may be divided into the following four groups :

1. Science programmes for Kindergartens, Elementary Schools, Lower and Upper Secondary Schools, 12 types : 25%
2. Science and mathematics programmes for Correspondence Upper Secondary School students : 33%
3. Scientific educational programmes at school broadcast level : 16%
4. Cultural programmes for the propagation of scientific knowledge among the public : 26%.

Today, science has become an indispensable element in our lives. Without the establishment of scientific evidence, nothing at all convinces us. The important role which instruction in science will play in the accomplishments of young people on the threshold of taking up life in society hardly needs pointing out. In Japan, as in other countries, some grown-ups tend to find difficulty in keeping pace with the ever-advancing progress of science and become apprehensive of anything scientific. On the other hand, young men and women are taking an ever deepening interest in science, as revealed in the separate surveys which the Board of Science and Technology and NHK conducted recently. Even such an awesome name as Einstein is heard popping up in the talk of grade-school tots, much to the astonishment of grown-ups. However, such incidents can hardly justify complacency concerning the capacity of the younger generation to bear the burden of the advancement of science in the future years. Here arises a question: young men and women are acquiring a superficial notion of the latest developments of science, but are they acquiring a firm groundwork in science ? We feel keenly the need of implanting the knowledge of basic science in the minds of the young.

To help educational activity in this stage, NHK is transmitting programmes of effective educational value directed to schools and correspondence schools. NHK analyses closely the Course of Study charted by the Ministry of Education, and the syllabi of individual schools and integrates them into the curricula, using systems which are easy for any schools to make use of. In the programmes, school children and students see materials which their schoolrooms have no facilities to conduct. The programmes are produced with the effective use of radio and television techniques and supplement the deficiencies in materials and in demonstrations available in classrooms. Every effort is being made to inculcate in the listening and viewing students the habit of thinking scientifically, to give them a group of fundamental principles and to help them acquire knowledge of the applied phases of science. All this work is closely related to the development of scientific teaching in classrooms.

The educational value of scientific and mathematics programmes is such that the audience percentage in elementary and lower secondary schools is recorded at 70 to 80%. NHK is transmitting programmes which encourage the attitude formed by the basic knowledge acquired in schools and in broadcasts which promote a scientific approach to things and an interest in science.

JOURNALS. See above : "Some Studies, Books and Practices in this Field ;
(7) Investigations.

FILMS IN MAGI-CARTRIDGES

- N.V. Philips, Eindhoven, Holland.

  <u>Physics</u> (in preparation)

  - The unit cell of germanium
  - The crystal lattice of germanium
  - Generation
  - Recombination
  - Acceleration of charge carriers
  - Conduction in pure germanium
  - The formation of N-type crystals
  - The formation of P-type crystals
  - Conduction in N and P crystals
  - The formation of a barrier in a P-N crystal
  - The P-N junction
  - The crystal diode - barrier width
  - The crystal diode - rectification
  - The cathode ray tube
  - Atoms and electrons

ROYAUME UNI DE GRANDE BRETAGNE ET D'IRLANDE DU NORD /
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

THE NUFFIELD PHYSICS PROJECT[1], by Dr John Lewis, Malvern College, England, and associate organizer, Nuffield Physics Project.

In England it is accepted that there is a need to improve the teaching of science in English schools. This work was begun by the Association for Science Education, but it proved beyond the resources of teachers working in their spare time and in 1962 the Nuffield Foundation set aside £250,000 to enable a complete programme in Physics, Chemistry and Biology to be developed. It was decided to begin with a programme suitable for 11 to 16 year old children in grammar schools. This work is now almost complete, it will be published and made generally available in April 1966. Since the start of the project, work has also begun on primary science for younger children and work is now beginning on advanced work for the 16 to 18 age group.

In the Physics project, one of the primary objects was to provide guidance to teachers. It was realized that little was achieved by the mere introduction of new syllabuses : of even greater importance is the way in which the teacher handles the subject matter. It is a relatively easy task to find fault with traditional school work in physics. In developing the new physics programme some basic principles had to be very carefully thought out and these are outlined below.

Principles of the programme

The presentation of any school subject should be devised in such a way that a rounded, consistent and realistic course of a general educational nature should be offered. Children who leave school at the age of sixteen should not automatically be restricted only to a partial course devised with the needs of a specialist, who will continue for another two or more years at school, primarily in mind.

There are two main criticisms of the usual presentation of physics in schools. Firstly, it is dull and makes no conscious attempt to build upon the natural advantage which the science teacher has in the common curiosity of children. Secondly, it is circumscribed and incomplete. It fails, and indeed could hardly be said to attempt, to give children a broad picture of what modern science is about and the way in which scientists think.

It is suggested that the main ideas introduced into a child's education should be few, but sufficiently important that they may be thrown into every combination possible so that the child may make them his own and understand their application in the present circumstances of his actual life. N. Whitehead condemned giving pupils scraps of information and teaching small parts of a large number of subjects, which encourages the passive reception of disconnected ideas.

It has also been said in England that if there is one common complaint by science faculties and examiners about science students, it is that they know but do mt understand. The emphasis in all changes must be on the improvement of the degree of understanding by the

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1. This paper is an adaptation for the "New Trends" of an article by Dr. Lewis, published in the Bulletin of the Institute of Physics and the Physical Society, March 1965.

pupils. Furthermore, it is essential to lay a foundation of simple empirical studies in which pupils become familiar with the more striking phenomena of nature. This study should be permeated, as far as it can be arranged by a spirit of inquiry.

What is the implication of these suggestions ? (a) A physics programme should be complete in itself. (b) It should build on the natural curiosity of the children. (c) It should be relevant to the world outside the classroom. (d) It should give a broad picture of what modern science is about and the way in which scientists think. (e) It should not contain too much material, but a few important ideas which the pupil can make his own. (f) It should strive for understanding. (g) It should foster a spirit of inquiry.

These are precisely the principles which have guided the development of the Nuffield physics programme.

Teaching physics for understanding

Teaching for understanding is a phrase used much in the Nuffield programme. This should not be thought to imply that there has not been teaching for understanding in the past : of course there have been many good and devoted teachers who have striven for it and achieved it. But for a very high proportion of children, physics has been the mere acquisition of factual knowledge, of definitions to be learnt by heart, of formulae to be remembered and of a series of mechanical rules to derive an answer, too often appearing irrelevant to the pupil's interests. There was far too much dependence on dogmatic assertion, whether by the teacher or the textbook, far too little opportunity to get the pupils to think for themselves, to look for evidence and to use their judgment.

The aim in the projects has been "science for all", science as a part of general education. It has been the education of the future citizen that has been considered, the future bank manager, the future nurse, the mothers and fathers of future generations. It is a rather painful and certainly salutary experience to ask one's bank manager whether he did any physics at school and how much he remembers. Traditional courses, and traditional examinations often failed to give understanding or any indication of what lay behind the detailed facts. Although the 11 to 16 year-old course has aimed at general education, it is believed that at the same time this programme for the future citizen is also a very good foundation for the future scientist and engineer. The evidence from the universities is that a sound knowledge of what science is about with an understanding of certain basic principles and topics is a better foundation for the future scientist and engineer than a vast number of ill-digested facts, improperly understood, and a string of formulae into which substitution can give a "correct" answer without understanding the principles involved.

The old proverb "Hear and forget, see and remember, do and understand" is perhaps the clue to how this understanding is to be achieved. Demonstration is considered better than talk and chalk, but in the Nuffield programme it is hoped to get the boy or girl personally involved and by "doing science", instead of hearing about it, to come to understanding. There is a great wealth of new, simple apparatus which enables pupils to gain experience, to make their own investigations and to foster the spirit of inquiry. There is far less talk by the teacher, far less giving the "correct" answer. Questions from pupils are much more often met by further questions to help them find the answer for themselves.

Content of the course

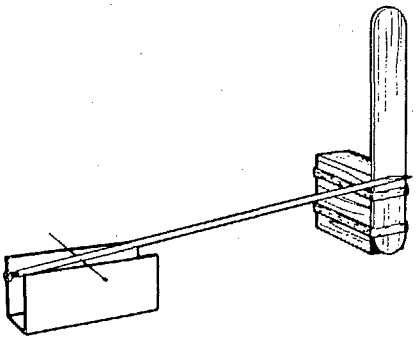
It cannot be too strongly stressed that in all the Nuffield projects there is a conviction that a syllabus, in the sense of a bare list of topics, should never be considered in isolation from the method of teaching. The aim is to develop understanding and this has led to fewer topics being taught than has been customary in recent years. What is included does attempt to form a connected programme, in which something learnt in one place proves useful somewhere else, and something discovered later throws light back on something worked with earlier. In this way it is hoped that pupils will come to feel that physics makes sense, that science is not just a series of statements to be learnt by heart, facts to be accepted for reproduction in an examination or a series of formulae, but a unified fabric of knowledge, linked together and certainly making sense.

In the past a young boy often came to science in his school full of enthusiasm for this new subject, which he associated with atoms and electrons, with rockets and satellites, with radioactivity and so on, and then had this enthusiasm gradually killed by making him find the focal length of a lens by five or six different methods, learn by heart a whole series of definitions or measure the specific heat of copper, brass, zinc, aluminium or lead, merely because one of these may "come up" in the O-level examination. In the Nuffield programme we believe we have a duty to meet the pupil's interest and there has been no hesitation in including a number of "modern" topics.

Because it was considered essential that the programme should be a connected one, it was necessary in deciding on the content to start with the end point. It was considered important that in Year V there should be some feeling for the relationship between experiment and theory, and also some understanding of the part "models" play in scientific thought, how a model is only significant as long as it is useful and how it is only a model. It was also considered desirable to include something on the uncertainties in science to avoid the impression that "science knows all the answers".

To show the relationship between experiment and the development of successful theory some planetary astronomy is included in Year V. This required work earlier in Year V, on motion in a circle, including an experimental derivation of $v^2 R$. This necessitated quantitative work on Newton's laws, a study of momentum changes, of conservation laws, and of kinetic energy in Year IV. This required an empirical approach to force and motion in Year III, including some work on projectiles. The concept of force, however, is first introduced in Years I and II when various forces are encountered as pushes or pulls.

The empirical approach to forces, in which children encounter for themselves forces of various kinds to increase their experience, is typical of the work in the first year of the course. The year begins with a display of many different kinds of materials as part of the need to widen that experience. They start weighing and measuring for themselves. In the past the teacher sometimes began with a formal definition of density, followed by the measurement of its value for sand ; at the end of this so many children could not see "why" this should be done at all. In Year I they are led through the examination of blocks of material (all of a convenient size so that the work is not bogged down in tedious arithmetic) to feeling the need for density. They then weigh liquids and then air. At all stages simple single-pan lever balances are used to avoid the tedium of using chemical balances which, at this stage, merely impede the gaining of experience. Crystals are studied - and grown by the pupils themselves. The first ideas are formed of crystals being made from "piles of atoms". There are various open experiments using magnifying glasses and microscopes. They learn to make careful measurements and to make rough guesses.



Microbalance used individually by pupils in Year I of the course and made from drinking straws and simple apparatus

There is a beginning of statics. The simple microbalance, made by the pupils themselves, is used for precise measurements - a hair is weighed with it - and at the same time begins to inculcate a respect and understanding for apparatus. Springs are investigated, but no longer are the pupils carefully restrained to the region where Hooke's law holds in order to avoid damaging the springs : these are sufficiently cheap and expendable so that they can make a real investigation. Of course it is really the regions where Hooke's law does not hold that are the interesting and significant ones ! Pressure is studied, again empirically, and leads to the first ideas of a kinetic model. Brownian motion supports this and an oil film experiment enables the pupils to make their first atomic measurement. Finally in Year I there is a first introduction to the concept of energy and energy changes ; in all, a year for gaining important experience which is useful later in the course.

Another end point in Year V is radioactivity : the random nature of the process emphasizes the uncertainties involved. The experimental work brings out the statistical nature of readings and helps to discourage expectation of a "correct answer". The work on radioactivity is used in the study of the atom, when atomic models are used to consider the place that models play in science. This work on radioactivity requires earlier a study of electron streams and the effect on them of electric and magnetic fields : the work on motion in a circle again finds a use in estimating e/m.

The work on fields necessitates earlier work on electromagnetism (in both Years IV and III), some electrostatics and some basic work on electric currents in Year II.

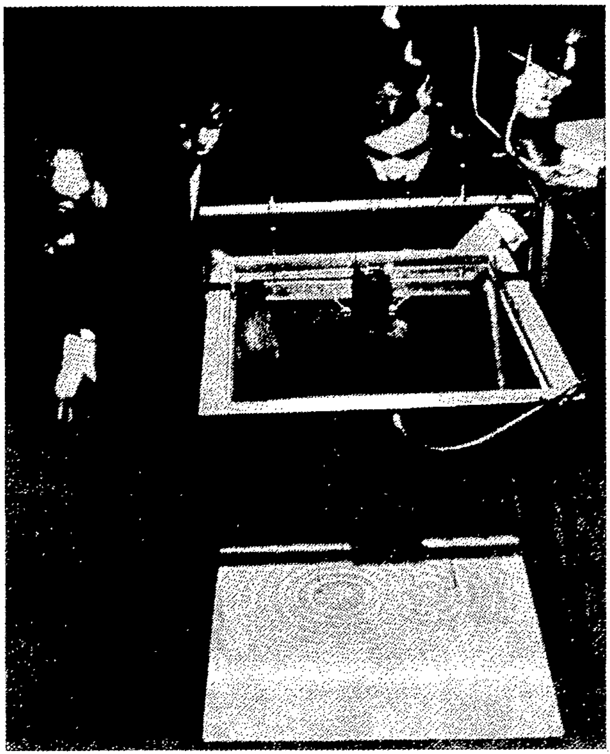
The study of the atom in Year V necessitates another important stream which runs right through the course : the approach to the atomic picture. Year I includes a study of crystals and the idea of piled atoms. The early work on pressure leads on to a molecular model of air, for which evidence comes from Brownian motion in air (an important observation which the project hopes every pupil will make for himself). Some surface tension experiments lead to the first atomic measurement when the pupils themselves make their own estimate of molecular size by spreading an oil drop on a water surface. A cloud chamber and a spark counter conclude Year I with a preliminary foretaste, or appetizer, of nuclear energy. The atomic picture is taken further in Year II with a preliminary look at molecular models of solid, liquid and gas ; attempts are made to interpret the effects of heat. In Year III there is a more detailed look at the molecular model of a gas, Brownian motion is considered again and evidence comes from diffusion and also from Boyle's work on expansion. The work on mechanics enables quantitative work on the kinetic theory to be done in Year IV. There is a calculation of molecular speed and some work on bromine diffusion enables an estimate to be made of molecular diameter.

Wave motion is another important topic introduced experimentally in Year III where there is extensive work by the pupils using ripple tanks. This leads to waves, rays and some ray optics work, again experimentally developed and concentrating on image formation and culminating in optical instruments. The consideration of waves is returned to in Year V with a study of interference and some work on spectra.

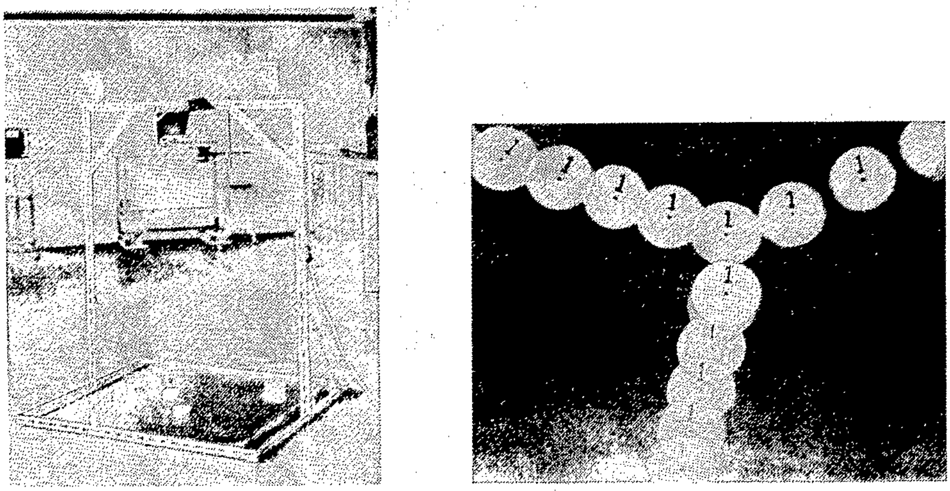
The topics of energy pervades the whole course. It is met first in Year I, returned to year by year, each year being treated with a little more sophistication and becoming quantitative in Year IV. There is a concentration on energy transfers from one form to another.

It should already be apparent from this attempt to outline some of the content that a mere statement of syllabus can do little to give the flavour of the course, though it will doubtless be seen from the above how the topics chosen interlink and interweave between each other, how everything chosen is relevant to the whole.

There are of course many topics omitted from the programme which appear in most traditional courses. There is no Wheatstone bridge, there is far less calorimetry and no experiment finding the specific heat of brass in which the water carried across with the block just compensates for the heat lost on the way over, there is no statics and no direct reference to Archimedes, very little geometrical optics in the traditional sense, no coefficients-of-



Ripple tank for use by pupils, in groups of four, in Year III of the course.



(a)

(b)

Carbon dioxide magnetic pucks used for quantitative work on collision processes.
(a) The pucks moving on a glass sheet with a Polaroid camera set up over them.
(b) Strobed photograph of the pucks colliding.

cubical-expansion-of-mercury-relative-to-glass. Doubtless some will deplore the loss and not wish to teach the Nuffield programme. For others, they will find plenty of exciting new things, which trials have already shown capture the interest of the pupils, who gain from this work something of the fun of a scientific inquiry.

The range of materials

With the main emphasis on the method of teaching, the teachers'guides play a most important role in the programme. These will appear in five volumes, one for each year of the course. There are separate experiment guides, again a volume for each year to assist in the class experiments to be done by the pupils and with the demonstrations by the teacher. There is a great wealth of new apparatus for this experiment work. There will be readers for the pupils to use themselves and volumes of problems for homework and class use. There will be visual aids of various kinds, including 8mm casette film loops.

This material, developed by teachers for teachers, is now being tried out under classroom conditions. One cannot pay too high a tribute to the hundred teachers concerned who are involved in sending detailed weekly feedback. The programme is being modified in the light of this practical experience so that on publication it will all have been tested.

It is hoped that the final material will form a co-ordinated whole to be used by individual teachers as they think best. It should be emphasized that this is no attempt to impose a new orthodoxy. The Nuffield physics project has been doing a piece of research work : the extent to which the work is ultimately used will depend solely on its merits. Some will use the programme as it stands, others may prefer to use parts of it. At least it will be a stimulus for further thought and development among the teaching profession.

Apparatus

The apparatus group in the Nuffield physics project has given consideration to the wide number of problems associated with school physics teaching. When the project began, there were over a hundred experienced teachers working in the various teams who fed in ideas and who made prototype apparatus. Some of these were very ingenious, but did not fit in with the general pattern which evolved. For this reason, they have not been incorporated, though many have been published separately, notably in The School Science Review, and will doubtless prove of great value to individual teachers. Those ideas, however, which fitted the general programme had then to be developed so that they were commercially available, and this work has occupied much of the time of the apparatus group.

There will always be a place in English teaching for good teachers developing their own ideas and building their own apparatus. The last thing that the Nuffield project wishes to do is to discourage them, but the large majority of teachers do not have the necessary skill - or, above all, the necessary time - to make their own equipment and this is the reason for the insistence that the apparatus is commercially available. The project has obligations to all teachers, good and indifferent alike. Thanks to the very active co-operation that has gone on with manufacturers (and a limited number of firms in particular), the necessary apparatus is now available.

With the emphasis in the course on pupils doing experiments themselves, one of the needs was for large quantities of very inexpensive apparatus and this has led to the development of a number of "kits", between thirty and forty of them. The magic number associated with these is thirty-two, which is the maximum number of pupils considered suitable for a Nuffield class. Some kits, for example the microbalance kit, include apparatus cheap enough for pupils to work individually. The electromagnetic kit contains the wherewithal to enable sixteen pairs of pupils to work with it. This kit contains all the necessary parts of over thirty different experiments and, for example, the d.c. motor which the pupils make and use themselves, is cheap enough for them to be able to take home and show their parents. Included with the kits are some general kits, one for each year of the course, which contain a large variety of miscellaneous items which it is necessary for the teacher to have in order to teach the course in the manner intended. Many of the items are things which can be obtained by other means, but one of the troubles of the past has been lack of time on the teacher's part and experiments have often gone by default. It is hoped that manufacturers will continue to supply these general kits to help the teacher in his task.

The project has also considered the design of certain basic equipment suitable for general purposes in a school laboratory : power supplies, amplifiers, scalers with timing facilities incorporated, oscilloscopes, meters and so on. So often in the past, schools had to accept industrial apparatus as being the only type available, but the oscilloscopes and scalers, for example, were not very suitable for schools and were often unnecessarily elaborate. Through collaboration with manufacturers, a great wealth of apparatus is now available. This will of course, be of assistance to all teachers generally, whether or not they adopt the Nuffield programme.

Attention has also been given to basic school apparatus, to the design of retort stands and clamps, to plugs and sockets, to spring balances and balances in general. Far too little attention has ever been given to the right tolerances in, for example, such things as weights and weight hangers. These have often been to a much closer tolerance than the rest of the apparatus justified ; by getting the tolerances right schools can get substantially more for their money. Another good example of the work is variable resistances. The catalogues of all the school apparatus manufacturers are full of an immense range of these. For the average teacher it has usually been a matter of hit-or-miss and he has seldom known which to buy. The Nuffield project has standardized all its experiments on two rheostats (10-15 Ω at 5 A and 330 Ω at 1.2 A). Not only does this help the teacher, but it will also help the manufacturer who can concentrate on this limited range with the result that prices fall substantially because of the greater quantities involved.

In addition to giving detailed specifications on apparatus requirements, the project will ultimately issue a list of recommended apparatus for the assistance of teachers and authorities. This will involve work of assessment, which the project has undertaken to do.

Finally, the project will produce advice and detailed drawings of apparatus to enable enterprising teachers to manufacture their own apparatus in order to reduce costs.

Examinations

However much the teaching is directed away from facts and the reiteration of definitions, however much the concentration is on understanding and a critical approach to the subject, all this will come to nothing if customary examination papers are set with questions which begin, for example, by asking for a formal definition of specific heat, then a description of a standard method of measuring it for copper or brass or lead as the examiner decides (despite the fact that no practising physicist would ever dream of using such a method), followed by a numerical example solved by substitution in a formula learnt by heart. It was essential that there be a public examination in tune with the whole approach.

The project has been fortunate in having a very active examinations group which has been devising new questions and specimen papers suitable for each age of pupil. Perhaps the most encouraging aspect has been the close co-operation with the Department of Education and Science and the G.C.E. Examining Boards, who are arranging for special Nuffield examinations at O-level.

The Nuffield physics project and the engineer

Much has been written in recent years about the English need for more engineers, and the Nuffield project has not forgotten its obligations in this direction. The tendency at the present time is away from early specialization and it is hoped that all children in secondary schools will do a physics course : the Nuffield programme is intended as part of "science for all". It is unlikely that there will ever be any wide adoption of applied science or engineering as an additional subject at O-level. The physics programme must therefore incorporate respect for engineering, for some of its problems and for its achievements.

As was discussed recently in the editorial of Engineering, it is the "how" (the experimental method) rather than the "what" (the prescribed ground to be covered) of Nuffield syllabuses that will influence schoolboy attitudes to technology. "From the outset the schoolboy is encouraged to get to know the feel of the basic materials and to see that getting his hands dirty in the process in no way limits intellectual stimulation."

There are many places where respect for engineering is inculcated in the course. Even in Year I, the simple microbalance does much to stimulate interest in design. The electromagnetic kit, for example, with its emphasis on pupil participation, gets the children doing important work with their hands. The energy conversions kit has the pupils handling dynamos, motors, steam engines and turbines, and the topic of energy which pervades the whole course could be no more fundamental for the future engineer. It is of course important that the simple models used in the classroom should be related to the outside world and discussions are now being held with industry on the production of 8mm film loop casettes relating, for example, the turbines and motors used in the course with the large commercial versions used in engineering.

The reaction of those engineers who have now seen the Nuffield material encourages us in the belief that the work being done in the project will in fact do much to encourage the awareness and the respect for engineering that everyone would like to see.

Questions

There are certain questions that any account of the Nuffield physics project immediately brings to mind, and it seems wise to anticipate some of these.

(i) Will teachers in England have to teach the Nuffield programme ? Of course not. The project has merely been a major research programme, produced by teachers for teachers to use as they wish. Some will adopt it, some will use parts of it, some will prefer to continue with traditional methods. It is offered as a contribution to the many problems that beset science teaching today.

(ii) What about a class textbook, is there not going to be one ? No. In fact a textbook in the conventional sense is not really compatible with the suggested methods, which encourage the pupils to find out for themselves. A conventional textbook gives away all the answers beforehand.

(iii) Is it true that the experiments are no longer accurate ? It is true that in the initial stages there is a great deal of experimental work aiming at giving a growing acquaintance, but there is plenty of quantitative work in later years. If by "accuracy" you mean are the children going to measure the specific heat of brass to several places of decimals, the answer is certainly no. There is more attention given to orders of magnitude and also more attention to the nature of measurement and an assessment of what the real accuracy of a given experiment is. How often in the past children have given the specific heat of copper as 0.09341 merely because their logarithm tables gave it to four decimal places !

(iv) Is the programme better suited to boys than girls ? There are doubtless parts which have greater appeal to boys, the electromagnetic kit, for example, but the needs of girls have been kept in mind and some parts, the ripple tank work, for example, has been especially successful with them.

(v) Do I have to be a teacher of experience before starting such a programme ? Most certainly not. Experienced teachers will be familiar with many things in the guides because these were written deliberately with the inexperienced teacher in mind. In fact some of our best trials have been done by people fresh to teaching without any preconceived ideas.

(vi) Is it easy to teach ? It is certainly fun for the pupils. It is hard work for the teacher though the trials tell us that it is very much easier the second time round !

(vii) How much would the apparatus cost ? This is not an easy question to answer at this stage. First, there has been little or no competition between manufacturers so far. Second, the apparatus has been required in relatively small quantities and large scale production will reduce costs. The cost of the apparatus has been kept low and, in many instances, reduced on conventional costs, but it is important to provide apparatus for pupils to use themselves. It should be remembered that a high proportion of the cost is a once-for-all-payment.

(viii) Are laboratories necessary for teaching Nuffield physics ? The Nuffield course does require the use of a laboratory ; a lecture room is not suitable. The only other requirement is plenty of space for storage.

(ix) What about A-level ? The Nuffield Foundation has already begun to give consideration to the problem of A-level. However, the Nuffield O-level course as it stands would be a perfectly satisfactory basis for either a new Nuffield A-level course when it is produced or for a conventional physics course. In the latter case, there would be certain omissions which would have been covered in the old O-level, but this would be offset by a deeper understanding of certain topics and a knowledge of others which have in the past been confined to A-level.

(x) How soon will the work be finished ? All the material will be published in April 1966 and freely available for use in English schools from September 1966 onwards.

Conclusion

This article has attempted to explain the reasons for the Nuffield physics project and to give some details of it. It is a programme developed for England, but parts of it may interest teachers elsewhere and it is hoped it will be a contribution to the problem of physics teaching throughout the world.

THE NUFFIELD PHYSICS PROJECT : QUESTIONS AND EXAMINATIONS,

by Dr. H.F.Boulind, University of Cambridge Department of Education

Education in the secondary schools of most countries requires and relies upon a system of continuous testing by means of questions to pupils, together with occasional externally-set examinations such as, in England and Wales, the examinations at "Ordinary Level" (for pupils aged about 16) and at "Advanced Level" (for pupils aged about 18). The Nuffield Physics Project is a new, and very complete, scheme for teaching physics to pupils of ages 11 to 16, thus making a course covering five complete years and culminating in an external "Ordinary Level" examination at age 16. The final examination in Year V, and the test questions and examinations set previously, must be in accord with the spirit of the Nuffield Project. If that is not so, then the Project will never get "off the ground" ; it will be "a flop" because pupils must, for the sake of their subsequent careers, obtain satisfactory examination results. Examinations cannot be ignored. Therefore, if the new Project is to succeed, the examinations must not only follow its aims ; they must positively encourage the achievements of those aims. This article is intended to show how questions and examinations are used to further the ideas and ideals of the Physics Project.

Science teachers never have been completely satisfied (and one hopes never will be) with the way in which science is taught. In recent years, however, the need for change in both aims and methods has become particularly pressing. The unsatisfactory nature of school physics teaching in Great Britain was becoming very obvious to many of us just about a decade ago. Briefly, this malaise can be considered under two headings, of which the second is much more important than the first.

1. Out-of-date syllabuses, that is, physics syllabuses containing hardly anything that was not known in the year 1890.

2. Faulty methods of teaching. Many things might be listed under this heading ; perhaps three in particular.
   (a) No encouragement to think. This is not a purely British phenomenon; I am reminded of a Swedish professor who said he had heard a teacher admonish his pupils "If you go on thinking for yourselves how can you expect to cover the syllabus ?"
   (b) Instead, there is great concentration on memorized information for reproduction in examinations - here I remember the remark of an English headmaster who said he was considering urging the exclusion of science from the school curriculum because, he said, "there is no opportunity in science to have opinions and to learn to exercise personal judgement. There is no training but in uncritical commitment to memory".
   (c) The uselessness of much class practical work, which is not investigation or experimentation but which has become the repetitive determination of this, that, or the other well-known constant, such as the specific heat of copper or the refractive index of glass.

Syllabuses can fairly readily be brought up to date, and in England this was done in the first place by the Association for Science Education, working through its committees of school science teachers. Introducing new methods of teaching was another matter however, and one which was quite beyond the resources of the Association, with its committees meeting on occasional Saturdays, and available funds of a few hundred pounds a year. Hence the approach to the Nuffield Foundation, and the request for a British equivalent of the United States "Physical Sciences Study Committee", with a budget measured in hundreds of thousands of pounds, and full-time academic staff. Viewed with hindsight, the principal achievements of the Nuffield Project in Physics would seem to be :

1. A syllabus suited to the sixties (meaning the 1960's.!). As stated above, this is a necessary change, but not the most important or the most difficult to achieve.

2. Emphasis towards the end of the course on the importance of theory in science, and the place of models (meaning both "thought-models" and actually constructed models).

3. Open-ended, heuristic-type investigations by the pupils themselves, providing training not only in science but, more important, in being a scientist. (At its best this means that the pupil not only finds the answers, but finds the questions too.)

4. Good class teaching and demonstration by the teacher - here he is acting as the leader of the class, with pupils and teacher together finding the answers.

5. Suitable class and homework tests and problems.

6. Suitable examinations, both those that are internal to the school, and those that are set by external bodies.

Items 5 and 6 are the subject of the remainder of this article.

Questions and Problems

Five books of problems, one for each year of the course, are available to the "pilot" schools working on the Nuffield Project in Physics. Each pupil is supplied with the book appropriate to the year of the course he is taking. These books will be printed and made available for sale after September 1966. Altogether they comprise about a thousand problems in physics. They closely follow the Nuffield "Teachers'Guides" and, it is hoped, exhibit and encourage the "spirit" of the Nuffield Project. Some examples to illustrate the nature of the problems in these question books will now be given. As regards terminology, Year I means the first year of the scheme, for pupils aged 11+, Year II for pupils aged 12+, Year III 13+, Year IV 14+, and Year V 15+, leading to the externally set and marked "Ordinary Level" examination (O-level for short), which is taken by pupils aged 15 to 16.

Questions of different kinds

1. Some questions are intended to start the pupil wondering about the next subject in the course, or to lead him to preliminary ideas that he may easily discover for himself. For example, two preliminary questions on Astronomy in Year V :

9.1 On a clear cloudless day - or night - the sky above us looks like an inverted hemispherical bowl, with ourselves at the centre : a bright blue bowl by day, or a black bowl by night. Inside this bowl but above us we see objects that clearly belong to the Earth - clouds, and man-made things such as aircraft. Obviously further away, part of the bowl perhaps, are the Sun, the Moon and the stars, including the very interesting objects we call planets.
(a) Certainly to us, on Earth, the Sun is the most important and necessary of these objects - why ?
(b) Moonlight may be useful at night, but the most important thing to us here about the Moon is that it produces tides : what evidence is there that the Moon, rather than the Sun or stars, is chiefly associated with oceanic rise and fall ?
(c) Have the stars any practical usefulness to us at all ? If so, what ?

9.2 Which looks the larger, the Sun or the Moon ? What evidence is there - evidence which men could have known 3000 years ago - that the Sun is further away than the Moon ?

2. Instead of "writing up" copious and often very discursive notes, pupils may instead be asked questions about investigations already performed. Attention may thus be directed to certain outstanding points ; also, leading questions may follow the work through in easy stages, so that the pupil does not initially have to grasp everything at once. Example, a question from Year III.

7.2 You have convex lenses of about 30 cm. and 5 cm. focal length, and a means of mounting them and sliding them up and down on a metal rod. You also have a piece of tissue paper. In order to make a telescope :
(i) Which lens would you take first, and whereabouts on the rod would you mount it ?
(ii) What would you do with the tissue paper ?
(iii) Where would you put the second lens ?
(iv) At what position would you expect to have your eye when looking through the telescope - up against the lens ? - 25 cm. from the lens ? - or where ?

3. Some part of the straightforward work of class teaching can be done by answering questions, e.g., from Year III :

29.5 This is a diagram showing essential parts of a moving coil ammeter.(See next page)
(a) Copy this diagram
(b) Label the following parts, using arrows to show clearly which part each name refers to
the moving coil
the magnets (2)
the controlling springs (2)
the pointer

29.6 Explain the working of the moving coil ammeter you have drawn in answer to question 29.5

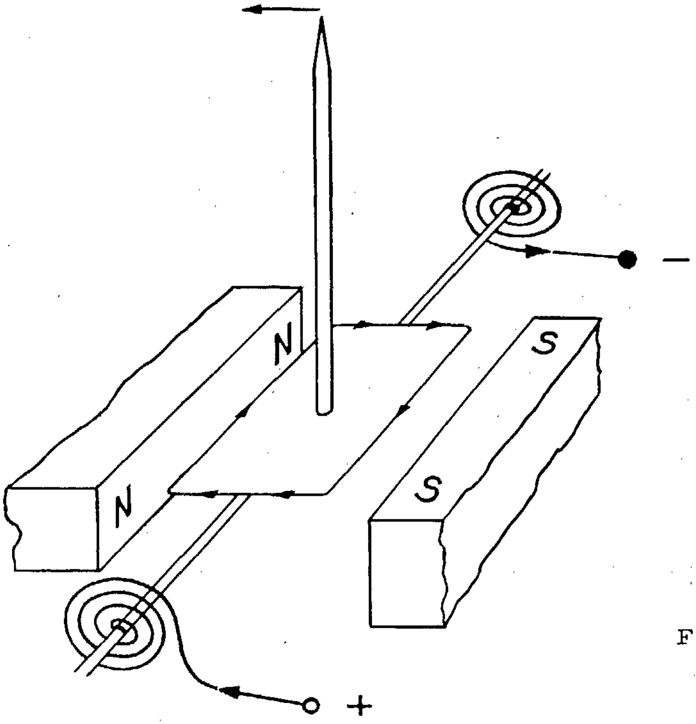


Fig. 29.5

4. Knowledge gained may be to solve new problems, as in the following examples taken from the question book for Year II :

8.9 Try the following experiment : cut a small disc of stiff paper the same size as a penny. Hold the penny horizontally between the thumb and finger of one hand, and hold the paper in the same way with the other hand. Release both at the same time.
(a) Which reaches the floor first ? How do you account for the difference ?
(b) Next put the paper disc on top of the penny and drop both together. What happens now ?
(c) Freddie Jones has done the same experiment, and he says it shows that, if air resistance is removed, paper falls as fast as pennies. The experiment certainly does not disagree with this conclusion, but would you go all the way with him in saying that "it shows that ....." ? If not, write a sentence or two saying why not. What would be a more satisfactory experiment to show the same thing ?

8.10 (a) A man and a parachute together weigh more than a man without one, yet the man with a parachute falls more slowly. Why ?
(b) An aircraft dives vertically with its engines off. It reaches a constant speed (its "terminal velocity") of 350 m.p.h. What two forces are acting on it, and, when it reaches the terminal velocity what can you say about these two forces ?
(c) The aircraft is still diving when the pilot switches on the engines (a "power dive"). What happens now ? Assume the 'plane neither hits the ground, nor comes to pieces.
(d) Why is it likely to come to pieces under this treatment ?

There is no rigid division of questions into the above four types ; usually there is considerable overlap. In any case one seldom consciously sets out to make up a question of a given type ; the above analysis into four headings has been made after the event, by looking through the question books and deciding what it is we have been doing !

Among the less usual questions we have "UNCLE GEORGE" and "FREDDIE JONES". This is what the pupils are told about these two characters.

> " Then there are Uncle George and Freddie Jones. Most of you will think they are awful nuisances. Some of you will think that they ought not to be introduced into anything so solemn as physics questions. They have their uses !
> Uncle George is intelligent and interested, and has time to spare, but he knows very little physics. He certainly didn't do any physics at school ; he was on the classics side, and when he was a boy the classics side did no science. So, you see, he is not an examiner who knows all the answers and is waiting to trip you up. He understands what you say if you tell him simply and shortly, and don't lead him astray with "red herrings". He is also quite willing - perhaps rather too willing ! - to suggest new ideas of his own, sometimes rather "off-beat".
> Freddie is your own age. He is ingenious and moderately sensible, though you can often put him right about things. He also is liable to have off-beat ideas."

You have met Freddie Jones in question 8.9 above. Here is an example of an Uncle George question from Year III. Notice how it puts the pupil into the rôle of the teacher.

> 12.1 (a) Uncle George says, "I've never thought about it before, but I suppose the idea of light being particles, rather like bullets, does explain some things. It explains why light travels in straight lines so that that electric light bulb is where I see it, and not somewhere round a corner. But what else does it explain ?" Write a few sentences telling Uncle George how the particle theory explains (a) reflexion and (b) refraction of light.
> (b) Uncle George then says, "we can have a very bright light or a very dim light, and anything in between. How do particles explain that ? " What is your answer ?

The place of an external examination in the framework of the Nuffield Physics Project.

The purpose of any type of external examination may be stated :

(1) to measure knowledge and understanding and thus to certify the attainment of a certain standard in the subject examined.

As a result, several other ends may be attained, such as,
(a) provision of a landmark in a pupil's study, and an indication of his progress,
(b) provision of a similar check on schools and teachers,
(c) acting as a prognostic test, assisting pupils in choosing their subsequent careers, or subjects of study,
(d) acting as an incentive or spur to encourage diligent study.

Inevitably however, a public examination exerts a controlling effect, not only on the syllabus which is taught, but also on the aims and methods of teaching. Pupils and teachers will study the examination papers and, from this study, decide what is the best method of achieving high marks. In consequence, a second purpose of the examination becomes a paramount importance :

(2) to exhibit to teachers and pupils the aims of the course that is to be followed, and to encourage them to achieve those aims.

Suppose we design a course in which the pupil gains experience of building knowledge on experiment, a course which demonstrates the nature of scientific laws, which illustrates the importance of theory, and establishes scientific thinking as reasoning with carefully chosen data. Suppose we then set questions such as the following :

> " Define coefficient of linear expansion of a solid and describe an experiment to determine its value for a metal rod. What increase in length will occur in a steel girder 100 feet long when its temperature rises from 0 °C to 50 °C (coefficient of linear expansion = 0.000012 per °C) ?"

The result will be that, in following years, pupils will pay little regard to our illustrations of law and theory, to scientific reasoning, and to discovering things for themselves. They will know what they must do ; just learn up everything the month before, the week before, the night before, then reproduce what is wanted, forget it, and in due course collect the certificates. If our aim is "teaching for understanding", if we wish to give each of our pupils the experience of "being a scientist", then these, and not "cheap recall", are what our examination must test. In other words, the examination must lie within the framework of the teaching programme, and it must be relevant to the real aims we have in mind.

Questions of different types

1. A question like the one above, on linear expansion, tests nothing but a candidate's ability to memorize a definition, a standard experimental determination, and a formula, plus the ability to substitute some numbers in the formula. It may be called "cheap recall" and its use in a Nuffield paper is very limited indeed. Candidates will not need to memorize formulae ; they will be given a list of formulae in the questions or at the beginning of the paper.

2. Some questions, or parts of questions, may be of the "expensive recall" type, where several pieces of knowledge may have to be put together and a conclusion drawn, or knowledge applied in circumstances new to the candidate.

3. Questions sometimes ask for intelligent guesswork, and the candidate is then asked to justify his own guesses, or to criticize "Mr. X's" suggestions.

4. A type of question useful for testing understanding is that which puts the candidate into the rôle of the teacher, or of an "advisory scientist". Candidates are used to these in "homework" questions ; they are "Uncle George" type questions.

5. Questions designed to test ability to think scientifically may be set on topics not really within the syllabus at all. Such a question is B1 below : here the candidate is not expected to know anything about anemometers, but the question is useful in testing ability to think about simple things.

Of course, the aims of all these "types" may be incorporated in various parts of a single question. The examiner does not set out to test all these things separately - so many questions of type 2, so many of type 3, etc. He tries to construct what he thinks are "good" questions. The analysis given above is an attempt by one examiner to find out what he has been doing after he has done it !

Two Kinds of Examination Paper

Nuffield physics papers are in process of evolution, and there is no absolute finality about what is written here. Nevertheless we think we are on the right lines. We have an "A", or "Physics I" paper, and a "B" or "Physics II" paper.

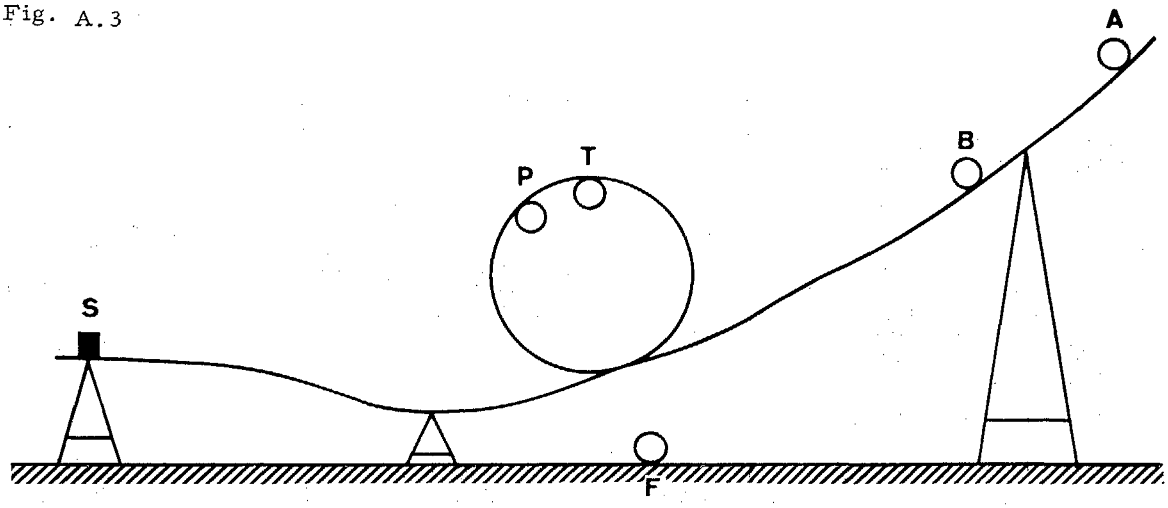
Paper I is intended to give good coverage of the physics syllabus. It consists of short answer questions, with the answers to be written on the question paper. The "short answers" may be single words or several sentences ; they may be short numerical problems, and may require the drawing of diagrams, or the completion of existing diagrams.

Paper II is more descriptive, and, while intended to test a candidate's understanding and ability to think, also tests his ability to express himself upon physical topics.

Two Specimen Questions

These questions are taken, not from an actual 'O'-level paper, but from a preliminary paper set to schools in December 1964. Note that questions of this kind tend to be long, compared with conventional questions, and ample time must be allowed for reading and comprehension. Question A.3 is from Paper I, and B.1 is from Paper II. Since these are not in fact 'O'-level questions, they have not been subjected to the usual "moderating" or "revising" process, but they illustrate the kinds of question that are set.

Fig. A.3



A length of grooved curtain rail is bent into a loop, as shown in Fig. A.3, and supported clear of the floor.
A heavy ball (e.g. a large ball bearing) is released at A, rolls down, "loops the loop", and finally comes to rest against the soft rubber stop S. Friction forces can be ignored.

(a) What two forces are acting on the ball when it is moving past T, and in what direction are they acting ? ....

....

(b) Is the ball falling when it is at T ? ....
(Yes or no).

(c) If "no", why is the ball not falling ?
Or, if "yes", why does it not leave the groove ?

....

....

If the ball is started from B instead of A it is seen to leave the rail at the point P and hit the ground at F.

(d) Draw a pencil line on Fig.A.3 to show a likely path of the ball from P to F.

(e) Why is F not directly below P ? ....

(f) What is the name of the path followed from P to F (circle, straight line, parabola, hyperbola, ellipse, cycloid or something else ? ....

B.1 Uncle George becomes interested in recording details about the weather - he has maximum and minimum thermometers, rain gauges and other things. Now he has made a wind-speed indicator from instructions in a book. He is very pleased.
"It works" he says, "this thing that the wind blows round will go on the roof, and the faster the wind blows, the further the pointer turns over the dial. The dial will be in the house, downstairs. But", he added, "there is no way of knowing what the marks on the dial mean in miles per hour".

"Easy" you say, "just set this up by the side of another wind-speed indicator and then you can mark it from the readings of the other one".
"Don't be silly" he replies, "I haven't got another indicator. If I had, I shouldn't have needed to make this one. The only dial marked in miles per hour that I have is in the speedometer in the car, and I don't see what use that is."
"Wait a minute", you say, "I've an idea ; listen".
You tell him your idea, and next Saturday you and Uncle Goerge go out in his car. It is a bright clear afternoon, with no wind, just what you wanted.

(a) What was your idea ? Explain fully. Say what you do while Uncle George drives and watches the speedometer, and what instructions you give him.
(Note : the proper name for "wind-speed indicator" is "anemometer", and you might use that word because it is shorter to write.)
(b) Uncle George gets out of the car and holds up one finger. He says, "I'm not sure there isn't a slight breeze blowing along the road. It's blowing steadily, that's why you don't notice it".
How would you use the car and anemometer to find out whether he was right ?
(c) If he is right, what changes would you and Uncle George make in what you are doing ? (Answer in one, or two, sentences, but "subtract the wind speed" is not enough - you don't know the wind speed.)

Marking the Examination Papers

Paper A. Short answer questions. Marking is mainly objective but not entirely. The examiner knows the expected "satisfactory" answer to each part of each question, and he gives full marks for it - perhaps 3/3 in a particular case. But there may be a rather better answer, possibly something the examiner never thought of - he then gives 4 marks (out of 3) on that part. This has been a general principle in marking Nuffield papers - to think, not of the best possible answer, but of the "satisfactory" answer for candidates at this level, and give it 100%. Then to mark up or down for answers that are more worthy, or less.

Paper B. Longer answers. The method of marking for the "satisfactory" answer, explained above, is also used here. Marking may be more subjective ; the examiner wishes to get a good general impression of the candidate, rather than award marks for this that and the other detail. Since the questions are almost inevitably broken down into a number of parts, the objective element in the marking is still quite high.

Guidance of Examiners by Teachers

The first Nuffield physics paper, set by the Oxford and Cambridge Schools Examinations Board, was taken in the summer of 1965. In the following September, a meeting was held of examiners and teachers from the schools taking the examination in 1965 & 1966. This was both a post-mortem, in which criticisms of the 1965 papers were considered, and a looking-forward to 1966, in that suggestions for changes were received. Differing styles of the two papers were approved ; in fact it was hoped that Paper II would be even less like Paper I, and would concentrate still more on opinions and discussion. Each teacher sent in one or two specimen questions, to show the type of question he or she thought should be set. These were most useful, and it is hoped that these meetings will become a permanent feature of the examination scheme.

This account covers what has happened in 1965 and 1966, when the number of candidates has been small, and the only real problem was to fit the examination to the Nuffield scheme. Other problems of setting and marking will arise as numbers increase, for example, should Paper I become a paper of "multiple-choice" questions which could be mechanically marked ? Are the questions in Paper II so difficult to devise that only one or two papers can be constructed each year (in spite of the fact that there are eight different Examining Boards in England and Wales alone) ? Answers to questions such as these have still be to found.

Royaume - Uni

THE OVERHEAD PROJECTOR (1), Alan Vincent, Trinity School, Croydon.

Nearly 20 years ago I first saw the Belshazzar, a large box with a light in it, a pillar above it carring a lens. The demonstrator wrote with a wax pencil, and lo ! "the writing on the wall !" I was mildly interested, but I failed then to recognize it as potentially one of the most valuable teaching instruments at the disposal of teachers.

In the time that has elapsed since the first appearance of the overhead projector, the basic design has not changed greatly, though the quality of projection has improved. It is the changing needs of education, and the wide range of processes for making transparencies, which now give the overhead projector a place in the modern classroom. In recent years there have been so many innovations in teaching apparatus that it is difficult to assess the importance of any one new piece of equipment. How does the overhead projector differ from any other kind of visual apparatus ? It does differ, and in ways which I believe to be important.

First, it does not impose restrictions on the teacher. Every other form of projector either demands control of lighting in the classroom, restricting to some extent the use of textbooks, chalkboard and other equipment, or, if it does manage to compete with daylight conditions, it gives a picture which is smaller than one would desire. The overhead projector can give a large picture without calling for any change in classroom conditions.

Second, the overhead projector is a very personal teaching aid. To an extent previously quite unattainable, the teacher can control and choose the images which he presents to the class. He can plan and draw the whole of his material himself, as he does on the chalkboard, or he can make copies of any kind of drawn or printed matter. He can have quality and freedom of choice. The perfection of an engraving by an artist long since dead, or an intricate diagram of the latest nuclear reactor - these are things which can be shown also on slides or filmstrips ; but with the overhead projector they can be shown in a well-lighted classroom, and the teacher can point out features of the projected image while still facing the class and watching their reactions. He can draw on the projected image or add annotations by means of an overlay. The teacher has absolute control of what appears on the screen as regards content and, equally important, as regards timing. He can show as much or as little as he desires at a time. He can cover up, or reveal, any part of the image. He can add or subtract by means of overlays, rapidly or slowly, as the content of the lesson demands. Teaching material which proves effective in use can be preserved as part of a growing collection for future lessons ; what is less successful can be discarded, to be replaced by something different. There is great opportunity for experiment. Within the 10-inch square of the transparency stage found in most of the overhead projectors, the teacher has scope for developing his own style of teaching. While most of the time illustrations may be simple and hand-drawn, the occasional use of a carefully planned and executed series of transparencies which are striking in their impact can give a lift to the whole classroom atmosphere.

Thirdly, the overhead projector has immediacy. From time to time, a class develops spontaneous interest in a particular topic. If the teacher can grasp the opportunity, the resulting learning will be more real to the children. But often there is not time to prepare the visual material needed. An extract from this morning's newspaper, a letter which a child has received from a far-off relative, a picture which answers perfectly the question which a child has asked, can be copied and on the screen for the whole class to see in a matter of seconds with the overhead projector.

No blackout, personal expression for the teacher, immediacy - these are substantial advantages. In the past, teachers could choose and create their teaching material under certain conditions. Either they used the episcope, with the restriction of blackout and

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1. Reprinted from : Education Panorama, Vol. VII, No 1.

interruption to the flow of the lesson, or they gave up much of their leisure to making their own slides and filmstrips. It is true that there is a quantity of published material on slides, filmstrips and films, and this is of great value to teachers, but the methods of a particular teacher and the needs of his classes demand, in addition, more personal control of a large part of the visual material used in teaching.

The writing on the wall : the teacher may write directly on the sheets of transparent material which are projected in enlarged form on the screen over his head.

The overhead projector offers great opportunities, but these will only be realized if teachers are ready to grasp them. It requires much thought and skill to prepare a really effective visual. It is often a salutary experience for a teacher to realize how difficult it is to present an idea or an item of knowledge in visual terms. Conversely, when a teacher has tackled successfully a particular problem, the deeper grasp of essentials which he will have gained will make his teaching more effective.

We have been accustomed in teaching to base our methods largely on the past, accepting the limitations which existed then. Here and there we have absorbed new techniques, but as additions rather than modifications. So much has happened recently to expand the means of communication that it is very necessary to adopt a positive and forward-looking attitude. I suggest that two lines of approach should be followed. First, teachers must ask themselves, "What things do I as a teacher want to do in order to teach more effectively ?" There are bound to be some things which are not yet financially or technically possible, but an awareness of problems may lead towards solutions.

Secondly, teachers must be aware of the progress being made in other fields of communication and ask, "Among all these new developments, are there any which can serve a useful purpose in education ?" I have heard of one school using a juke box to play language records. Why not ? The mammoth automatic projector which shows soundfilms of "pop" singers is used in a Paris museum to project short science films.

There is always a danger of preoccupation with "gadgetry", and in some respects technical advances in teaching aids have gone ahead of the teacher's capacity to use them successfully - but the ultimate problem of using too few teachers to communicate with too large classes is with us the world over, and it is a very urgent one. We cannot afford to ignore or reject any technological advance, though we are rightly cautious and anxious to preserve high academic standards.

The questions I have asked above in a wider sense apply equally to the overhead projector. The first one, "What do I as a teacher want to do ?" must be answered personally by each teacher for himself. The second, "In what way can the overhead projector be of help to me ?" calls for a clear understanding of the nature of the equipment and a study of the possible techniques. Teaching is an art and a craft, and the teacher must accept the need for some technical and manual skill in days when "chalk and talk" alone is no longer sufficient.

Now I shall try to give practical information about the overhead projector and its use, so that teachers can decide what is likely to be of use to them.

In the first place, the particular advantage of the overhead projector lies in its extremely efficient use of available light, and the large aperture through which it passes. We know how the aperture of a camera regulates the amount of light which reaches the film. In the overhead projector the aperture is nearly 100 times as large as in a projector showing a double-frame filmstrip, so the bright parts of the picture can show up effectively on the screen even in competition with daylight. It is the illumination of the unlit screen which must serve for black in projected images, which determines the contrast and, hence, the clearness of the projected picture. So, in placing the screen, it should be where direct daylight strikes it obliquely, rather than directly. This can usually be done without reducing any of the light in the remainder of the room. If there is a very large expanse of window, a single curtain near the projector should be all that is necessary.

Since the projector and the teacher are between the class and the screen, the projector should be low and the teacher seated. In many cases, the projector can conveniently be let into a space in the top of the teacher's desk, or it can be on a low stand or trolley. Twenty-eight inches is a convenient height for the transparency stage.

The screen should be high - the bottom edge four feet six inches from the floor. For a class of 30, it should be five feet square, and it should be tilted forward to avoid distortion of the image. The distance between screen and projector is about eight feet. If these conditions are observed, all of the class will get an unobstructed view of the screen. No pupil should be nearer that 10 feet (two screen widths) or further than 30 feet (six screen widths) from the screen, and seats should not be too far to the side, giving an oblique view of the picture.

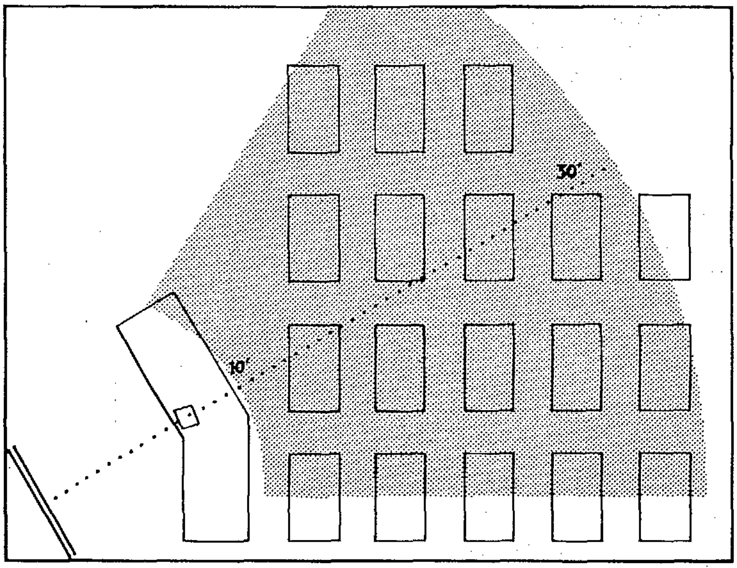
Most projectors have a role of acetate or cellophane on which the teacher can write with wax pencils or pens. There is a great variety of these, and experiment is necessary to decide which are most satisfactory. "Lumacolour" pencils, "Pentel" felt tip pens, and "Rapidograph" and "Acetograph" pens have been found satisfactory, and there are many others which can be tried.

For permanent transparencies, which are hand drawn, India ink or special acetate ink can be used. Care must be taken to keep the surface of the acetate absolutely clean when drawing. Cotton gloves offer the most satisfactory solution.

Many copying processes will produce transparencies for projection. Probably the simplest and quickest is Thermofax, a machine using heat to develop the image by frosting the surface of a prepared plastic sheet. This can be done without chemicals in full daylight. The diffusion transfer process, a reflex copying method, gives very clear copies in black line, with materials made by Gevaert, Agfa and Kodak. These can be used in a variety of copying machines incorporating a light box and developing unit. One of the simplest and cheapest is the Contoura with the Constat developing unit.

For transparencies in colour, diazo film can be used, each film giving an image in one clear colour from a translucent original. Exposure is with a light rich in ultra violet, and developing takes place in ammonia vapour. Diffusion transfer and diazo copying can be done in subdued daylight.

It would take a long time to describe all the techniques which have been tried with the overhead projector - objects shown in silhouette, models cut out in coloured Persfen, simple animation by means of polarized light - the only limit is the ingenuity of the teacher in devising visual methods of communicating ideas. Teachers should be aware of the possibilities, and ready to conduct valid experiments within the field of their own interests and skills. It is the special contribution of the overhead projector to education that it will respond to almost any demands made on it by the teacher. It does not replace the chalkboard, for many teachers do not wish to sit at a machine throughout a lesson, and the teacher's work at the chalkboard has a certain vitality and dramatic value which it would be a pity to lose from the classroom, but the overhead projector, used with skill by a teacher who has really studied its possibilities, is a most powerful aid to teaching and well deserves a place in the classroom.



In this room arrangement for overhead projector viewing, the screen and projector are set an an angle to allow the class to see the image unobstructed. The screen is high off the floor and tilted at the top away from the wall ; this extends the viewing area (shaded portion of sketch) to most of the room.

FILMS IN MAGI-CARTRIDGES[1]

Gateway Educational Films, Ltd. 470-472 Green Lanes, Palmers Green,
London N. 13, England

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1. From Source Directory Educational Single-Concept Films available in Magi-Cartridges, third edition, March 1966, Technicolor Corporation, 1985 Placentia Ave., Costa Mesa, California (U.S.A.), p. 14 - 16

Physical series
- Two sources in phase
- Movement of two sources
- Change of Phase
- Change of Frequency
- At an aperture (Wavelength varied)
- At an Aperture (Fixed wavelength)
- At a straight edge
- At a narrow obstacle
- Vernier scale
- Vernier examples
- Setting up the balance
- Using the balance

Macmillan & Co., Ltd, Little Essex Street, London W.C.2, England

Physics
- Mechanics (Eothen Cinettes)
- Energy and the pendulum
- Momentum and the pendulum
- Uniform linear velocity
- Uniform acceleration
- Force, mass and acceleration
- Motion at right angles
- Motion in a circle - Part 1
- Motion in a circle - Part 2

In preparation :
- Stationary waves
- Bernoulli's theorem

World Wide Pictures, Ltd, 34 Cursitor Street, London E.C.4, England

Physics
- Electronics, Heat and Mechanics :
- Domestic Hot Water system
- The A.C. Dynamo
- The D.C. Dynamo
- The D.C. Motor
- The hydraulic lift, Part 1
- The hydraulic lift, Part 2

PROGRESS REPORT of the Nuffield Foundation Science Teaching Project, published for the Nuffield Foundation by Longmans / Penguin Books.

BULLETIN, The Institute of Physics and the Physical Society (available to members only).

PHYSICS EDUCATION, new journal edited by the Institute of Physics and the Physical Society, 47 Belgrave Square, London W.1, first issue May 1966, six issues per year.

SUEDE / SWEDEN

The efforts made in several countries and regions to improve physics teaching by introducing the PSSC course have been mentioned in the PSSC section of the chapter devoted to the U.S.A.

In Sweden, however, the work of adapting the PSSC course - with which Finland, Iceland and Norway were associated - gave rise to a remarkable effort of modernization which has had repercussions on the American course itself : there has been a "feed-back". It has therefore seemed appropriate to reproduce here in full two studies based on the PSSC course which were carried out in Sweden and the associated countries mentioned above.

THE OECD / SCANDINAVIAN PILOT PROJECT ON PHYSICS TEACHING (1),
Chairman and recorder Dr. Friskopp (2)

The Pilot Project : reasons why the PSSC course was chosen.

In the conventional physics course in Sweden (and probably also in many other countries), our present-day knowledge of physics is presented as facts. Atoms do exist and look like this or that, the conservation laws are profound truths and Ohm's and Boyle's laws are true descriptions of what really happens. To be sure, demonstration and student experiments are made, but the pupils generally understand these to be an illustration of facts and not the basis from which our physical knowledge has been built up.

This attitude is well described by the following statement, found at the very beginning of a recently published foreign physics book : "The physicist endeavours to discover the laws of Nature". In other words, we discover one law after the other, put the laws in a book, and then we know all about physics.

In the PSSC course, on the other hand, the situation is quite different. What the physicist does can, in that course, perhaps be stated thus : "The physicist systematises his observations of how Nature behaves". This totally different approach is very well illustrated all through the course. It follows from this that all our physical knowledge is ultimately based on experiments and that, consequently, our knowledge has the same limitations in accuracy, in space and in time that our experiments have.

Obviously, the most important concept in such a presentation of physics is the physical model, and this has a central position in the whole PSSC course. For instance, in the chapter on atoms in Part I and, more detailed, in the Optics (models of light) it is shown how a model is built up. You must always start with experiments, from these you construct a model

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1. This Pilot Project is one of the results of the international meetings organized by OEEC (Cambridge, 1961) on the teaching of physics using the PSSC course as a basis.
2. This report was drawn up at the conclusion of a meeting on teaching in the technical secondary schools (Tekniske Gymnasiat), held on 7 March 1964.

(or a theory, which is the same thing), which in turn suggests new experiments. These lead to a model again, which may be a slight modification of the first one, or may be something completely new. The chain

experiment model experiment model ....

is infinite. It is important for the pupils to realize that we never arrive at the "truth". Such questions as "What does an atom really look like ?" or "What is really electric charge ?" are naive and pointless from a physical point of view ; they are best left to the philosophers. What we reach in the chain above is a closer and closer description of how Nature behaves. From this also follows that a model is never "right" and never "wrong", it can only be said to be "good" or "bad". The only criterion for a "good" model is that it covers as many different phenomena as possible. In fact, the ultimate goal of physics is to find one model covering all physical phenomena with a degree of accuracy corresponding to that of our measurements, and not to find the "truth". As physicists, the latter does not concern us.

Here in Scandinavia, we have found the approach described above very well presented in the PSSC course. We furthermore think that this approach is of vital importance to a school physics course. To be sure, there are also other important factors - what topics to introduce and in which order they should be presented - but their importance is of the second degree.

Reasons for adaptation

The school system for which the PSSC course is constructed differs from ours, and for that reason a certain adaptation was necessary. The main differences between the situation in USA and in Scandinavian secondary schools, where the new course is tried, are listed below. These differences also hold for several other European countries.

(a) Our pupils have had a previous 3-year cycle of physics at the ages 13/14 - 16/17. This makes it possible to condense or to remove certain parts of the course. References can also be made here and there to this previous cycle.

(b) We have around double the amount of physics periods, which enables us to add some more topics (mainly technological applications).

(c) Our pupils have a better mathematical background, which means that the treatment can be made more mathematical. However, there is a danger in using too much mathematics. It is very simple to plug your problem into a mathematical formula and obtain an answer, which you know must be right as the mathematics used is correct. In this way the feeling for what happens from a physical point of view is usually lost. In the PSSC course it has been necessary to work without mathematics, replacing this with a physical argument. We have found this extremely valuable, and we have kept this line of attack, but supplemented it - in a box or in the text itself - with a more mathematical treatment. By this we gain that the pupils are first given the physical contents of the problem, then are shown the short cut offered by the use of mathematics.

(d) Our pupils take physics for 3 years - age groups 16/17 - 19/20 - and are thus mentally more mature than in USA, where the course is a 1-year one for the age group of 16. We can thus increase the difficulty more steeply and - especially in the latter parts - use more sophisticated arguments and a more mature language.

Changes made

The reasons above could justify quite extensive adaptation of the original PSSC course. Still, our changes are on the whole fairly moderate. The reason for this is that we were afraid that too radical changes would destroy the all-important approach described above. After all, our pilot experiment does not aim at trying out details such as choice of topics or their order, but to investigate the value of the new approach.

The list of changes below refers to the Swedish edition. The Norwegian one is even closer to the original version, due to the fact that the Norwegian physics course is more condensed in time, so their edition had to be ready sooner than ours.

(a) Textbook.

Part I : The chapter on vectors has been moved to Part III. It is a rather difficult chapter, and the vector concept is not really needed until the study of mechanics.

The section on Spectral Analysis has been removed. It is on the whole rather unnecessary (does not support the atomic model of matter to any significant extent) and it is also complicated for the pupils (e.g. no explanation can be given why the substances must be gaseous). Spectra and spectral analysis are treated in Part V instead.

Several sections could have been omitted or condensed because of the lower physics cycle. However, in this experimental edition we have kept such sections, leaving it to the teacher to decide what to omit.

Part II : The chapter on optical instruments has been extended (time for more technical applications !).

In the chapter on the Particle Model, quite a lot of photometry has been added, defining and discussing the SI-units candela, lumen and lux. In the chapter on Wave Motion the concepts "longitudinal waves" and "polarisation" are discussed.

At the end of Part II, the logical step from Young's double slit to the transmission grating has been taken. A section on the polarisation of light has been added.

Part III : The vector chapter, moved here from Part I, has been made more mathematical. Unit vectors are introduced, which simplifies the mathematical treatment in the rest of this part.

The chapter on Angular Momentum, published by the PSSC as an Advanced Topic, has been included. Altogether more mathematics has been introduced, according to the lines mentioned under (c), page 244.

Part IV : The original Part IV has been split into two : Part IV Electricity and Part V Quantum Physics.

The treatment is more mathematical. Chapters on Alternating current, Thermionic tubes (used as rectifiers, amplifiers and oscillators), Radio and Television transmitters and receivers have been added (Technological chapters !).

Part V : To the existing 3 chapters on atomic physics have been added 3 more chapters on nuclear physics, written by two Swedish physicists who spent somewhat more than half a year with the PSSC in Watertown.

The part and the whole course ends by a chapter on Solid state physics. Here is shown how our model of atoms and their combination in crystal lattices enables us to predict and correlate a number of seemingly different properties of solids, such as compressibility, elasticity, hardness, melting point, thermal expansion, thermal and electrical conductivity, etc. As a byproduct we can also give an understandable and substantially correct description of semiconduction and of transistors. This last chapter illustrates very well the aim of physics : to make a model cover many different phenomena.

(b) Laboratory experiments

The positive quality of the original PSSC laboratory experiments is their character of research projects : the aim is mainly to get the experimental basis for models or to test predictions made on the basis of these models. The apparatus is simple, which has the advantage that the physical events are not hidden by complicated black boxes.

On the other hand, the equipment is not very durable, which either makes it expensive, as you have to buy new sets fairly often, or engages a lot of the time of the teacher repairing the things. We have therefore engaged the help of a Swedish firm (Gumperts in Gothenburgh) to construct equipment of a better mechanical quality in some cases.

Further, we think that some experiments should be of a precision type, which is not the case in the PSSC course. It is important to realize what errors are introduced in an experiment, and this cannot be fruitfully discussed, unless the measurements are of a certain precision. Moreover, almost all physics research today consists of precision measurements, and it is reasonable that the pupils are acquainted with such methods.

We have made rough translations of the PSSC laboratory guide. A more definite version will have to wait as we hope that the pilot experiment will supply material for this.

It is to be added that Scandinavian teachers have always used laboratory experiments, performed by the pupils, as an active part of their teaching, and that thus a lot of valuable experience has been gained. The teachers in the pilot classes are therefore given great freedom in choosing suitable experiments.

(c) Films

Some 15 PSSC films have been bought, and they are at present used in their original version in the pilot classes. The films are on the whole much appreciated. Due to lack of time no attempt to adapt them to Scandinavian conditions has yet been made.

Some of the PSSC films are unnecessary, as the corresponding experiment can be performed either as a demonstration or in the laboratory.

We also think that the films are rather long. It is difficult to keep the pupils interested during the show, and too little time is left for discussion after the film.

We are very interested in the 8mm concept films, and we will certainly use them in the future.

(d) Teacher's Guide

A copy of the PSSC Teacher's Guide is available at all pilot schools. Apparently it has been most useful. No translation has been made ; again we feel that our version of a guide will result from the pilot experiment. One item which is missing in the PSSC guide but which we intend to include in our version, is fairly detailed recommendations and descriptions concerning demonstration experiments.

Organization

The pilot experiment started in September 1962 and is scheduled to continue for 5 years. This will give us, we hope, enough statistical material to evaluate the course. The number of schools participating is the following : Norway 10, Sweden 14, Finland 5 and Iceland 1. The total number of classes in all the countries is around 50. Both ordinary secondary schools (Science line) and Technical schools are represented. In Norway and Sweden working groups have been formed which are responsible for the practical arrangements. The pilot experiment is financially supported by the OECD.

Results

We are fully aware that perhaps the greatest difficulty in the whole experiment is the evaluation. In spite of planned tests and cross-tests using "Conventional" classes the ultimate evaluation will probably be mainly subjective, based on questionnaires answered by teachers and by pupils.

In August 1963 a conference was held for all the teachers participating in the project, which by then had been running for one year. Naturally no definite results could be presented after such a short period, especially as the course was as new to the teachers as to the pupils. The following comments were given, however :

(a) Some teachers said that this was <u>the</u> way of teaching physics. Others were more cautious and stated that this was one of probably several good ways of teaching physics. Out of the 40 teachers present, 39 believed it to be a radical improvement on the conventional course, however.

(b) The students get less factual knowledge than in the conventional course. However, this is more than compensated for by a better understanding of what physics is and of physical processes.

(c) The course is excellent for bright pupils but difficult for the poor ones. The latter cannot manage by learning by heart as in the conventional course. This, we feel, is a positive quality of the course : you have to understand, cramming does not work.

(d) Time is a difficulty : only one of the 40 teachers had covered what was planned for the first year. This may improve as the teachers learn what can be skimmed and what must be allotted more time ; on the other hand it is possible that teaching physics well actually requires more periods than we have at our disposal.

(e) Discussions in class are greatly stimulated.

In August this year we will have the next general conference. We are very much looking forward to this, as the results will probably be clearer and more specified this time, the teachers having had one more year to get accustomed to the new approach.

SOME IMPRESSIONS OF THE PSSC PHYSICS COURSE (1) , by Gören Lindahl.

As known, an experiment in the teaching of physics according to the American PSSC course is going on. In Sweden about forty teachers are taking part in this experiment, which was started here in 1962. I have been teaching on the basis of the PSSC course since 1963 and I will try to convey some purely personal impressions of the course gained during the past two and a half years.

What made the PSSC course so attractive to me from the outset was its consistency. It is divided into three large blocks : optics, mechanics and electromagnetism (including atomic physics). In each block the course concentrates on the most important laws and principles and devotes a lot of space to the fundamental laws of physics. The haphazardness of other textbooks is replaced by a clear, logical line of reasoning. Moreover, the PSSC textbook is so comprehensive that students are able to read it without too much aid from the teacher. It was mainly these apparent advantages that made me participate in this educational experiment.

Since then I have discovered other advantages with the course that I consider more essential. There are two aspects in particular which I would like to point out. The one is the epistemological clarity with which new laws are presented and the other is the essential requirement that the students really must understand physics.

The epistemological aspect is the most interesting one. I can understand that the PSSC course tends to repel many who want an answer to the question : "What is the Truth?". At first, many students are irritated at never being told what the definitive truth is. They are victims of the common misconception, that the laws of physics discovered by scientists are true, and that when these laws are changed, then some physicist must have made a mistake previously. The PSSC course presents a different way of looking at it. It shows that reality can be described by means of a model of some kind. This model represents a first approximation and does not need to be especially accurate. It is shown that the first model has certain inherent deficiencies, and another model is presented which is more accurate in some respects, but which also has certain defects. In this manner, by successive approximations the physical reality can be approached more and more closely.

Students do not seem to have any great difficulty in understanding this way of looking at it. This can perhaps best be illustrated by relating a discussion we had in a physics class. We had established that movements and velocity could be added in a certain way (as vectors) and we were going to investigate if the same law was valid for forces. A simple experiment was made therefore with forces of different directions and magnitudes but with the same point of action. We established that the law (the parallelogram of forces) was valid. I asked if there were any objections. Yes, the students were critical on several points. In our exper-

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1. Published in the Swedish paper Skolvärlden (The school world) No.36, Dec.17, 1965.

iment we had only investigated gravitational forces and tensions in pieces of string. The law was not necessarily valid for electric or magnetic forces. Furthermore, the system we had investigated had been at rest. If it had been in motion the law might not apply. Moreover our measurements may not be sufficiently accurate and therefore small deviations from the law may exist undetected by us. Well, what should we do ? Should we start a long series of experiments with different kinds of forces and with systems both at rest and in motion ? No, because we still could not be certain that we had tried all possible cases. But can we then use this law without being absolutely certain of its validity at all time ? Yes, because it is not possible to get any further. This is what we do. We use the law until it becomes evident that it is no longer valid.

The discussion above can also be used to illustrate the other aspect of the PSSC course which I would especially like to point out. It is the requirement that the students really must understand what they are doing. This requirement may seem trivial, but every physics teacher knows the great difficulties this involves. The danger of mechanical application of formulae learnt by heart is always present and threatens to make physics teaching rather meaningless . It is only too easy for the students to learn formulae and to insert in them the values taken directly from the problems. Of course it is of some value that they are at least able to do this. It does not show however that they know any physics, but perhaps that they know some mathematics.

I know how difficult it is for many physics teachers to find problems that really test the students'knowledge of physics. A great advantage of the PSSC textbook is that it contains an abundance of such problems. Some of these can be very irritating even for the teacher because their solution sometimes requires some really careful thought. A single example will be sufficient here to illustrate this : "Can you suggest reasons why no interference is seen when light reflects from the two surfaces of a windowpane ? " In this way the PSSC course makes great demands on the teacher but it is also very instructive. I did not believe it possible to accumulate such a vast number of problems of this type. When both students and teachers get used to this type of problem (the most characteristic feature of which is that they are not a certain type) it becomes possible to use them also in written examinations.

One may fear that the requirements of the course are too severe and that most students may not be able to follow it. The book, however, makes it possible even for weak students to follow it, and does this by means of a very simple method. The exercises included in each chapter start with such simple problems that practically all students can solve them without having read that chapter. The problems serve as an introduction to that particular part of the course. They often have a connection with the natural and unreflected reasoning of the students or, to put it more formally, their pre-scientific knowledge. Once this knowledge is activated, it can be influenced by discussions and demonstrations. This is by no means a trivial statement. On the contrary, I believe that this is a problem which is too readily ignored. Every student (and, indeed, anyone who has not studied mechanics) lives in the world of Aristotelian conceptions as far as the relation between force and motion is concerned. These conceptions are an obstacle to the learning of anything new and different, and what is learnt easily becomes something separate from the students' natural habits of thinking. The acquired knowledge will in other words be rather superficial. When the students pre-scientific thoughts are activated, however, they may be mixed with and influenced by the more scientific ones furnished by the textbook and the teacher. In this way a scientific way of thinking can be incorporated with the students' everyday habits of thinking. This, if anything, should be called firm knowledge.

Taken together these two requirements to understand on the one hand the laws of physics and on the other their logical place from an epistemological point of view constitutes a very attractive aim in the education of young people. PSSC is the complete opposite of authoritarianism. The student shall learn to rely on his own sense of reasoning but at the same time recognize its limitations.

FILMS IN MAGI-CARTRIDGES

Viascan Film (P.D.) (1), Tottvagen 7, Stockholm-Solna, Sweden

Physics (in preparation)

Fall movements
The power equation
Friction
The screw
Archimedes principle Pt 1
Archimedes principle Pt 2

" ELEMENTS " - Devoted to the teaching of mathematics, physics and chemistry in secondary schools. Fredsgatan 4A, Uppsala, Editor Dr. Olaf Eklöf, 4 issues per year.

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1. See : Source Directory Educational Single-Concept Films available in Magi-Cartridges, second edition February 1965, Technicolor Corporation, 1985 Placentia Ave., Costa Mesa, California (USA)

SUISSE / SWITZERLAND

QUELQUES FAITS RECENTS (1)

Lors de ses assemblées générales de Berne, les 6-7 mars et 28-29 mai 1965 à Berne, la Société Suisse des professeurs de mathématique et de physique (2) (SSPMP) a tenu deux séances qui cumulèrent les rôles de cours de perfectionnement, session d'information et séance administrative.

Voici quelques uns des thèmes abordés :

- Structure et concepts de la physique moderne, par M. le Professeur A. Mercier (Berne)
- Symmetrie /Symétrie/, par M. le Professeur Leutwyler (Berne)
- Wechselwirkung, Klassifikation des Elementarteilchen, Parität /Interaction, classification des particules élémentaires, parité/, par M. le Professeur Bebié (Berne)
- Grundlagen der Dimensionstheorie /Base de l'analyse dimentionnelle/, par Dr E. Roth (Berne)
- Ein moderner Aufbau des mathematischen Unterrichts /Une construction moderne de l'enseignement mathématique/, par Dr P. Wolfer (Zurich)
- Neue Konzeption des Physikunterrichtes an der Mittelschule /Une nouvelle conception de l'enseignement de la physique dans les écoles moyennes /, par Dr R. Ruetschi (Winterthur)
- Coordination des enseignements de la mathématique et de la physique, par M. le professeur W. Servais (Morlanwelz, Belgique).

Lors de sa dernière assemblée générale (Winterthur, 25 septembre 1965), la SSPMP a révisé ses statuts, en particulier pour créer deux commissions de physique, l'une alémanique, l'autre romande, pour promouvoir un enseignement de la physique adapté aux exigences de la situation actuelle.

Il conviendra de rapporter sur les divers objectifs de ces commissions lorsqu'il aura été possible de donner une assise financière aux travaux projetés et que des réalisations auront vu le jour.

Lors de cette même assemblée générale, la SSPMP a créé également un Bulletin (voir ci-dessous), assurant un nouveau lien organique entre ses membres.

C'est dire que, cherchant à dépasser les frontières cantonales qui morcellent l'enseignement secondaire en Suisse, les professeurs de physique se mettent à penser en commun leurs problèmes et cherchent à le résoudre, au moins à l'échelon des régions linguistiques.

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1. Note du rédacteur.
2. Président : Dr P. Siegfried Hotz, Collegio Papio, 6612 Ascona.

PHYSIQUE GENERALE, par Jean Rossel, Professeur à la Faculté des sciences de l'Université de Neuchâtel, Directeur de l'Institut de physique, Neuchâtel 1963, Edition du Griffon, 482 p.

BULLETIN de la Société suisse des professeurs de mathématique et de physique, premier numéro de Janvier 1966 (hors commerce).

THE SITUATION IN CZECHOSLOVAKIA (1)

The main characteristic of the present period is not only the still insufficient number of trained physicists for research and the continuously extending scope of research in all branches, but also the growing demands for physicists for the laboratories of industrial enterprises - an outcome of new production technology and the introduction of new kinds of products.

The long-term State plan also demands in the near future a substantial increase in the number of professional physicists for research and, very particularly, for industrial enterprises. The organization of the training of professional physicists is still mainly directed at training research personnel. In this field, too, demands on the quality of the scientific workers are rapidly increasing. All this necessitates the devising of measures permitting us to train increased numbers of physicists for research and industry, and raise the level of their university education simultaneously.

Discussions concerning the most effective methods to achieve this goal in the given situation are going on at universities, the academies of sciences, etc. The Union of Czechoslovak Mathematicians and Physicists, mentioned earlier, also plays an important part in these discussions.

Regarding the raising of the educational level at universities, some principles have already emerged from these talks and will probably soon be put to a practical test. There is, for example, the tendency to lay greater weight on independent studies and, consequently, to reduce the number of obligatory weekly hours in the curricula without, of course, at the same time lowering the standards of knowledge demanded in the examinations. A principal prerequisite for the realization of this suggestion is a greater number of textbooks, not only for the basic physics courses, but also for the special parts of modern physics. There is further the endeavour to let students take part in practical scientific work even earlier than hitherto. Another of the most important problems is the selection and special training of especially talented students. Physicists at present are discussing the possibilities of a new conception of teaching physics, concerning the introductory course at the universities as well as at the general secondary schools. Among other things, a principal rearrangement of the subject matter is considered, in order to introduce modern material and examples as widely as possible from the very beginning of the course.

The large number of physicists to be trained in the near future by our universities represents a problem that provides ample food for deliberation and discussion. It seems as if the practice of training all these physicists by the same methods will have to be abolished. It has been suggested that a two-stage training scheme be substituted for it. One part of the students would study only four years and, after graduating as physicists, would mainly work in industry. Another part - especially gifted graduates of these four-year courses - would continue in their physics studies immediately or at a later date, thus attaining a higher qualification.

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1. Reprinted from "A Survey of the Teaching of Physics at Universities", Unesco, 1966, p. 183-184.

It has become obvious, too, that a considerable improvement in the training of physicists at the universities can hardly be effected without reforming physics instruction in the secondary schools. This involves, in particular, a new conception in teaching physics as far as content and arrangement of the subject matter are concerned, as well as new teaching methods which would considerably enhance the ability of the pupils independently to recognize physical phenomena and laws, and to engage in critical logical thinking.

PROJET DE MODERNISATION DE L'ENSEIGNEMENT DE LA PHYSIQUE EN TCHECOSLOVAQUIE par Prof. M. Valouch.

Au sein de l'Union des mathématiciens et des physiciens tchécoslovaques (Jednota československých matematiků a fysiků), quelques groupes des membres ont commencé à discuter les questions d'une modernisation de l'enseignement des mathématiques et de la physique. Tout d'abord on a étudié les différentes tendances de la modernisation qui existaient déjà à l'étranger. Puis on a commencé à formuler les idées principales concernant le contenu et les méthodes d'enseignement qui pourraient servir comme base d'une profonde réforme répondant à la tradition et aux buts du système d'éducation scolaire en Tchécoslovaquie.

Après quelques discussions et négociations le plan d'une telle réforme est maintenant divisé en deux étapes. Dans la première étape on va préparer surtout une réforme de l'Ecole fondamentale concernant toutes les matières enseignées dans ce type d'école qui est obligatoire pour tous les enfants de 6 à 15 ans. Cette réforme prévoit un changement moins profond des programmes des mathématiques et des sciences naturelles. Une des idées principales de cette réforme est d'effectuer un déplacement de la matière enseignée jusqu'à présent dans les classes supérieures vers des classes plus basses en suite des recherches préliminaires, qui ont montré que les élèves des classes plus basses sont capables d'apprendre en général beaucoup plus qu'on a supposé dans les programmes actuels. En ce qui concerne les sciences naturelles, on veut introduire un enseignement préparatoire à partir de la troisième ou quatrième classe sous forme d'un objet autonome, dans lequel les enfants apprendront les premiers faits et notions de physique, de chimie et de biologie. Dans cet objet on veut éveiller l'attention des enfants autour de l'observation plus profonde de la nature et leur donner les premières idées qualitatives de ce que sont les lois de la nature et les principaux concepts des sciences naturelles. Le commencement d'un cours systématique de physique sera déplacé probablement à la sixième classe au lieu de la septième. L'introduction des parties nouvelles de la physique moderne doit être limitée dans cette étape par l'exigence que les maîtres travaillant à présent dans les écoles puissent enseigner sans grande difficulté d'après les nouveaux programmes. Néanmoins avant l'introduction des nouveaux programmes et livres dans toutes les écoles fondamentales, ce qu'on prévoit pour l'année scolaire de 1970-71, des expériences seront faites dans plusieurs écoles expérimentales. Les travaux concernant cette première étape sont dirigés par l'Institut des recherches pédagogiques du Ministère de l'instruction publique.

En ce qui concerne la deuxième étape de la modernisation de l'enseignement de la physique, qui doit être introduite dans les écoles fondamentales et même dans les écoles du deuxième cycle scolaire (enfants de 16 à 18 ans) un peu plus tard, on est maintenant en train de préparer un projet pilote et de faire des expériences préliminaires dans quelques écoles expérimentales choisies. C'est pourquoi on ne peut pas donner à présent un précis plus détaillé du projet pilote, mais informer seulement sur quelques traits généraux.

Dans l'enseignement de la physique au niveau secondaire (élèves de 12 à 18 ans) toutes les parties de la physique moderne doivent être introduites dans la mesure et par les méthodes appropriées à l'âge des élèves. Pour pouvoir atteindre ce but sans augmenter effectivement l'étendue de la matière à enseigner, il faut élaborer une tout à fait nouvelle structure du contenu des cours dans laquelle la physique moderne, qui est enseignée jusqu'à présent plutôt comme complément de la physique classique, se confondrait d'une certaine façon avec celle-ci. Il est donc nécessaire d'abandonner l'accès historique dans l'enseignement de la physique moderne, auquel on s'accoutumait dans la première moitié de notre siècle non seulement dans les écoles, mais même au niveau universitaire. La situation des sciences physiques dans la seconde moitié du vingtième siècle est favorable à une telle reconstruction profonde.

Le but du projet en question est de donner aux élèves successivement une image aussi complète que possible de la physique d'aujourd'hui sans encombrer trop leur mémoire pour qu'ils puissent connaitre le système des principales relations et les utiliser pratiquement avec l'aide des livres appropriés. On veut essayer d'introduire la notion que toutes les substances sont composées de molécules, le plus tôt possible, et de former ainsi une base pour un accès plus général aux propriétés physiques et chimiques des différentes espèces de substances. Les enfants doivent se familiariser aussi plus tôt avec le mouvement des ondes au sens du transport de l'énergie et encore avant le commencement du cours systématique avec quelques notions fondamentales comme par ex. la force, l'énergie, le travail, etc. d'une façon appropriée à l'âge des enfants, mais assez précise, en prévoyant déjà leur approfondissement et généralisation dans l'enseignement postérieur. Dans la nouvelle structure, les lois générales de conservation doivent jouer le rôle d'un fil reliant toutes les parties de la physique. Les méthodes d'enseignement doivent être basées le plus possible sur des observations et des expériences exécutées par les élèves et évoquer le désir de découvrir et connaitre plus.

Ces quelques exemples montrent seulement une partie des problèmes qu'il faut résoudre en construisant le nouveau programme. C'est pourquoi on a préparé un plan d'expériences assez longues, pendant lesquelles on veut d'abord faire l'épreuve des différentes conceptions partielles dans les écoles expérimentales en comparant leurs efficacités pédagogiques avant de commencer d'écrire les textes complets pour les classes en question. Dans la première période on va se concentrer sur deux sortes de questions : d'un côté, quand et comment peut-on commencer avec l'enseignement des méthodes scientifiques d'observation et avec la formation des concepts fondamentaux par abstraction, et de l'autre côté, jusqu'à quel niveau des connaissances peut-on arriver au bout de l'enseignement secondaire par des méthodes répondant à ce degré en tenant compte d'une différenciation entre des élèves qui s'intéressent spécialement aux sciences naturelles et surtout à la physique et les autres ?

Pour organiser et effectuer le travail sur ce projet de la seconde étape on forme maintenant un Centre pour la modernisation de l'enseignement des mathématiques et de la physique auprès de l'Union des mathématiciens et des physiciens tchécoslovaques, qui sera soutenu par l'Académie des sciences et qui travaillera en collaboration étroite avec l'Institut pédagogique de l'Académie et avec d'autres instituts des mathématiques et de physique de l'Académie et départements aux universités. Ce nouveau centre s'intéresse à l'échange d'informations avec d'autres centres, groupes ou personnes qui travaillent à de pareils problèmes. Adresser toute correspondance à : Professeur M. Valouch, Directeur du Centre, Praha 1, Maltézské nam. 1, Tchécoslovaquie.

ABSTRACTS FROM CZECHOSLOVAK JOURNALS

In Czechoslovakia there are two journals which are concerned mainly with the modernization of physics teaching :

Fyzika ve škole (Physics in school)
Methodological journal edited by the Státní pedagogické nakladatelství (State Pedagogic Publishing House), Praha 1, Ostrovní 6.
A volume of 10 issues per year, about 400 pages. Editor Professor Josef Fuka.
Address of the editor's office : Praha 2, Lazarská 8.

Pokroky matematiky, fyziky a astronomie (Progress of Mathematics, Physics and Astronomy).

Journal published by the Jednota československých matematiků a fyziků (Union of Czechoslovak Mathematicians and Physicists), Praha 1, Maltézské nam. 1

A volume of 6 issues per year, about 380 pages. Editor for Physics Dr. Miloš Matyáš.
Address of the editor's office : Praha 1, Maltézské nam. 1.

Abstracts of articles concerning the modernization of physics teaching :

1. Fuka, Josef : Teaching of Physics at the Fundamental Nine-year Schools and the Secondary General Public Schools.
Fyzika ve škole, 1, 139-146 (1963)

This article is a report delivered by the author at the conference on secondary school physics teaching, which was held from 2 to 4 July 1962 in Prague by the Union of Czechoslovak Mathematicians and Physicists. In this report the author describes the contemporary state of the content and arrangement of physics courses at the general secondary public schools and gives some reasons for their modernization.

2. Kašpar, Emil : Modern Methods and Means for Teaching Physics.
Fyzika ve škole, 1, 239-250 (1963)

This article - like article 1 - is a report delivered at the same conference; it analyses - like the preceding one - the means and methods of teaching.

3. Vanovič, Jan : "New Concepts of Physics in the School".
Fyzika ve škole, 1, 155-189 (1963).

This report delivered at the same conference as articles 1 and 2 deals with the content of physics teaching at the socialist school in the light of problems of modern physics.

4. Fuka, Josef : The Conference on the Modernization of Physics Teaching in Olomouc.
Fyzica ve škole, 2, 283-284 (1964)

This is a report on the conference held from 2 to 4 December 1963 in Olomouc. The report includes also the resolution of the conference.

5. Fuka, Josef : Contribution to the Modernization of Physics Teaching
Pokroky matematiky, fyziky a astronomie, 10, 32-51 (1965).

This is the question of publishing a report delivered at the annual conference of the Czechoslovak physicists in Olomouc in August 1964. The author discusses problems of modernization of physics teaching. He analyses the teaching of physics at the general public schools during the last 19 years and the efforts of the Union of Czechoslovak Mathematicians and Physicists for its improvement. He also outlines plans for research into the content and methods of physics teaching.

6. Rozsíval, Miroslav : Some Comments on the Problems of Modernization in Physics Teaching.
Pokroky matematiky, fyziky a astronomie, 9, 113-116 (1964)

This article is a shortened version of a report presented to the conference described in article 4. The author analyses here the problems of the backwardness of courses in physics compared with the rapid development of physics as a branch of science, and points out some problems in the modernization of physics teaching in Czechoslovakia.

7. Valouch, Miroslav : Efforts for the Modernization of the Teaching of Physics in Foreign Countries.
Pokroky matematiky, fyziky a astronomie, 9, 99-112 (1964)

This is also a summary of a report presented to the conference described in article 4. In this article, the author outlines modernization in the U.S.A. (P.S.S.C.), in West European countries and in the U.S.S.R.

8. Chytilová, Marta : Analysis of the Systems of Instruction in Physics Teaching for the Elementary Nine-year Schools.
Fyzika ve škole, 2, 252-261, 294-300 (1964)

The author analyses the contemporary programme of physics for the elementary nine-year schools from the point of view of the modernization in preparation. She covers physics teaching in classes I - IV and also Physics in classes VII - IX. She also regards contemporary systems of instruction from the standpoint of the elements of physical theories, unities and experimental components, and the solving of problems from the standpoint of technical applications. She analyses the special interests of the pupils in physics and also the relation of physics to the other subjects in the elementary nine-year schools. She states common objections to the contemporary state of physics teaching, and also indicates which problems are in most urgent need of solution, in relation to modernization in the elementary nine-year schools. This report was also given at the conference described in article 4.

9. Fuka, Josef : Conference on Modernization in Physics Teaching.
Pokroky matematiky, fyziky a astronomie, 9, 352-358 (1964)

In this article, the author outlines recommendations put forward at the conferences on the modernization of physics teaching held in December 1963 in Olomouc and in April 1964 in Liblice. The article includes a statement of the resolutions of the conference in Olomouc and surveys the recommendations concerning the arrangement of physics teaching at the elementary public schools being discussed at the conference in Liblice.

10. Chytilová, Marta : Contribution to the Discussion on the Modernization of Content and Methods in Physics Teaching at the Elementary School.
Fyzika ve škole, 3, 389 (1965)

The author gives the reasons resulting in attempts to modernize physics teaching and takes account of content modernization and of teaching methods especially at the elementary nine-year school. She analyses these problems partly in classes I - VI, where the pupils are being introduced to physical ideas, and partly in classes VII - IX, where physical problems are introduced and major proposals for modernization put forward. She outlines also proposals relating to the content of physics teaching in classes VII - IX, accepted in principle at the conference held by the Union of Czechoslovak Mathematicians and Physicists and by the Pedagogical Institute of the Academy of Science in Liblice in October 1964. In conclusion she considers the problems of the modernization of physics teaching methods at the elementary nine-year schools.

11. Kašpar, Emil : The Development of Physical Thinking and Modernization of Physics at School.
Fyzika ve škole, 2, 19 (1964)

The author shows that it is not justified to reduce the problem of modernization only to the problem of content and that the same attention must also be paid to teaching methods. He is also concerned with training in physical thinking. Above all he points out the importance of a correct physical understanding of laws whose mathematical formulation is sometimes very difficult to understand.

UNION DES REPUBLIQUES SOCIALISTES SOVIETIQUES / UNION OF SOVIET SOCIALIST REPUBLICS

THE SITUATION IN U.S.S.R.(1)

The chief aim in training physicists is to give the students a thorough and clear understanding of the fundamental ideas and methods of modern physics on a mathematical basis. This can be achieved only by continuously improving the teaching of physics both in the secondary and in the higher schools.

The main condition for fulfilling this aim is active participation of all members of the physics department in scientific research work. Without this, it is impossible to teach modern physics at advanced level, for the subject is being continually enriched with new scientific data and new methods of scientific research involving the use of very complicated, up-to-date equipment and precision measuring instruments. Only a person directly engaged in scientific research in physics is in a position to give students an understanding of this science.

For this reason, great importance is attached in the USSR to the selection of scientific material for teaching physics in the schools and institutes of higher education, because it is essential to use the modern achievements in physics in the process of teaching the subject. This task is made complicated by the continuous flow of new material, from which the departments in the institutes of higher education must, and do, select scientifically verified material, without too much detail. This is one of the main tasks of the physics departments in the institutes of higher education. On the basis of consolidated scientific work they must select such new data as will meet the needs of the course and introduce these into the syllabus, taking into account the general line of studies provided by the institute in question. It should be noted that this job must be done in conjunction with methodical processing and discussion of the new material in the physics departments. For this reason, the physics courses in institutes of higher education of a particular type are not themselves uniform, although the departments are run on the principle of a general standard syllabus laying down the basic scientific and theoretical line of the physics teaching. The content of the instruction is subject to discussion at inter-institute conferences, leading to the definition of a main line of study, which in the last resort is also helpful in determining the structure of the physics course. Much depends on the character of the physics laboratory, which has to be taken into account in allocating the number of hours devoted to lectures, practical work and laboratory teaching.

As an aid in solving the problem of bringing physics closer to the requirements of practical life, with allowance for the particular type of higher education institute concerned, the regular physics course at many of the institutes is supplemented by subsidiary courses devoted to particular branches of physics to meet the requirements of specialized disciplines.

In a number of branches of higher education there are plans for the further expansion of the physics course ; for example, a decision has been taken to make further improvements in the physics training of students in the medical institutes.

At present, arrangements are being made to develop the experimental part of the course and increase the amount of laboratory work so as to ensure mastery of modern methods of

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1. Reprinted from "A Survey of the Teaching of Physics at Universities", Unesco, 1966.

scientific research in physics in the universities and technical, teacher-training, and medical institutes, taking into account the specific aims of a future practical or scientific research career. Here the teacher-training institutes have a particularly heavy task if they are to train physics teachers capable of involving secondary school pupils in the problems of modern physics, develop in them a capacity for "thinking physically", and give them a taste for taking part in physics societies and laboratories ; this is bound to have a good effect on the teaching of physics in institutes of higher education in the very near future. The goal is to reach a position where it will not be necessary to refer to secondary school material in the higher schools.

The higher schools must give more assistance to the secondary schools. Among other things, it is planned to conduct the physics olympiad in the institutes of higher education on a wider scale (the physics and mathematics olympiad for the European part of the USSR finished at the beginning of 1963). The plan is to draw secondary school pupils who have shown ability in physics into physics societies attached to the institutes of higher education, and also to develop a system whereby such students are individually attached to professors and lecturers at the institutes of higher education.

As a rule, physics lectures for entrants to institutes of higher education in the USSR are accompanied by good visual aids. Because of the great importance of visual aids in teaching physics we are paying more attention to the development of lecture demonstrations. The State University of Moscow and a number of other institutes of higher education have done a good deal to standardize visual aids for use in lectures, and have devised for this purpose special equipment, which has been demonstrated at a special extended conference, attended by representatives of the departments of physics in the institutes of higher education of the USSR. A special design bureau, attached to the Ministry of Higher and Secondary Specialized Education of the USSR, is working on, among other things, instruments (not for batch production) for physical laboratories in the institutes of higher education.

Several films for the teaching of physics have been prepared and are being shown.

In the immediate future the Ministry of Higher and Secondary Education will announce a competition for the best student of physics at an institute of higher education. All these steps must improve the teaching of physics.

In all this, the main purpose is still to ensure that the physics course has a modern content in all branches of higher education. What kind of scientific material should be introduced into the syllabus, how it should be prepared from the point of view of teaching method, what sort of laboratory work should be done in an institute of a particular type, how it should be directed without interfering with the student's independence - these and many others are the questions now facing the departments in the institutes of higher education.

PRE-UNIVERSITY PHYSICS IN THE USSR (1)

In the Soviet secondary schools all teaching subjects, including physics, are compulsory throughout the school, while the time-table and its content throughout the secondary school system are regulated by uniform curricula and syllabuses.

In the eight-year schools physics is taught in the sixth, seventh and eighth forms, and continued in the ninth, tenth and eleventh forms in the eleven-year schools.

Physics in the Soviet secondary school system might be described as a "two-storey" process. In the eight-year schools an elementary physics course is provided in the sixth, seventh and eighth forms, covering, so far as the list of topics is concerned, all the main branches of physics, from mechanics and heat to the elements of atomic physics. This is the

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1. Reprinted from "A Survey", op. cit., p.27-30

first "storey". On leaving the eight-year school the pupil has a complete, if only initial and rudimentary, picture of physics (and also of mathematics).

The physics syllabus for the ninth, tenth and eleventh forms of the eleven-year school is based on the eight-year syllabus and builds, so to say, a second "storey" in each branch of the subject. This syllabus is substantially broader and more thorough than the elementary course, both in the classical and in the modern part, and leads straight to the physics course in the institutes of higher education. Moreover, the most advanced part of the physics course in the eleven-year school partly overlaps, in a number of branches, the first part of the course provided at the institutes of higher education.

The point of this structure is not difficult to see : millions of boys and girls finish their education in the eight- or in the eleven-year school and do not go on to higher education.

Under recent educational reforms and in connexion with the transition from the seven- and ten-year system to the eight- and eleven-year system, all the syllabuses, including the physics syllabus, were revised. The basic idea was twofold : to expand the teaching material illustrating the practical (technical) application of physics and its connexion with the life of the community, on the one hand, and to go deeper into all questions of theory and the phenomenology of physics as a science, on the other. Physics teaching in the secondary schools is thus now geared to the polytechnical approach in education and at the same time to the improvement of theoretical training.

The aims of physics teaching in the USSR are as follows : to give the pupil a knowledge of the fundamentals of physics, ensuring that the polytechnical character thereof is made clear ; to equip the pupil with the theory and practice of working with measuring instruments and laboratory apparatus and of the simplest calculations in physics, which are important for everyday life, and thus to contribute towards his industrial education and training in a trade ; to promote the development of a materialist outlook and of scientific and atheistic convictions, to the development of patriotism, internationalism and respect for labour ; lastly, most important of all, to help develop logical thinking, creative initiative, imagination, the capacity for self-teaching, and for independently solving theoretical and practical problems on the basis of a knowledge of physics and mathematics.

Class work is based on physical experiment in the form of demonstrations, direct laboratory work, and the practical physics work performed in each class at the end of the year in order to illustrate the theoretical material already learned. Forms of self-teaching include solving problems in calculation, drawing graphs, performing experiments and answering set questions, as well as long-term tasks in technical physics, such as making physical instruments or designing very simple technical apparatus in the school workshop.

By agreement with the mathematics teacher, problems with a physical content are solved during the mathematics lesson. This particularly applies to those branches of physics for which the mathematical training of the pupil is not yet adequate : for example, in discussing trigonometric functions or derivatives in the mathematics lessons, problems from the theory of vibrations or kinematics are solved.

Progress is checked by questions in class, by correcting tests done in class or at home and by examinations. A four-mark system is in use in Soviet secondary and higher schools (2, 3, 4 and 5); the mark 2 is regarded as unsatisfactory.

Preparation for school-leaving and matriculation.

Admission to Soviet institutes of higher education is by competitive examination. The examination syllabus depends on the group of special subjects covered by the educational establishment concerned. In all institutes of higher technical education, for example, matriculation entails examinations in mathematics (oral and written), physics (oral), Russian (composition), and one foreign language (oral). The examinations in mathematics and physics are usually held first, since the marks in these two subjects are decisive in the competitive selection. The requirements in mathematics are very high. It is not uncommon for a large percentage of candidates to forfeit the right to take the other examinations because their marks in mathematics are unsatisfactory.

Preparation for the competitive examination is either by self-study or by preparatory courses in the preparatory departments of the institutes of higher education (1). This preparation is short, taking a few months to one year. The teachers are for the most part lecturers in the relevant departments of the institutes of higher education. The competitive examinations and the preparation for them follow special entrance examination syllabuses. In physics, for example, the syllabus (Appendix II DI) coincides roughly with the physics syllabus for the eleven-year schools. Very recently this syllabus was revised and slightly shortened, mainly in regard to the technical applications of physics and material duplicating the basic topics in the physics course of a higher technical school. At the same time, the requirements in regard to the fundamental principles of elementary physics were increased in the majority of institutes of higher education.

In the opinion of the overwhelming majority of physics teachers in higher education the basic requirements for the entrance examination in physics are as follows : the ability to formulate physical concepts, definitions, laws and units of measurement strictly and accurately ; knowledge of the basic quantitative relationships in all branches of the subject ; ability to solve simple problems in physics and reduce the answer to the correct numerical result.

In all this, preference is given to the ability to grasp and to think physically, rather than to the condidates' general store of textbook knowledge.

The examining body is a committee of two. Its marks are final ; there is no appeal and in no circumstances can the mark be altered. In the interest of complete objectivity, the written examination papers are submitted under an assumed symbol, not the candidate's surname.

Before the examinations, which are usually held in August or September in each institute of higher education, a great deal of preparatory work is done under the direction of an Admissions Board appointed by the rector of the academic body concerned. The chairman of this board is the rector himself and its members are professors, lecturers and representatives of the students' and other social organizations.

Admission to higher education is based on State plans which lay down admission quotas and turn-out targets, obligatory on departments and rectors, for a number of years to come. Plans of this kind are drawn up strictly in accordance with the plans for the development of industry and the national economy.

ELABORATION DES PLANS ET ETUDE DES SUJETS PAR THEMES LORS DE L'ENSEIGNEMENT DE LA PHYSIQUE DANS LES CLASSES SUPERIEURES DE L'ECOLE SECONDAIRE , par D. Malobrodski, professeur de physique, Ecole-laboratoire No 1 de l'Académie des Sciences pédagogiques de la Fédération de Russie.

Selon le système des leçons traditionnel, la leçon se déroule, dans la plupart des cas, d'après un schéma rigide comprenant les éléments qui voici : vérification des devoirs, interrogation des élèves, explication des nouveaux sujets, consolidation des connaissances acquises. Or une telle structure de la leçon ne correspond pas dans une pleine mesure à la nécessité de stimuler l'activité cognitive des élèves, limite les possibilités d'organisation du travail individuel en classe.

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1. V.A. Kitaytsev, "Admission to Institutes of Higher Education in the USSR" , published in 1965 in the series "The International Study of University Admission, Access to Higher Education", Vol. II, Paris, Unesco.

Ces derniers temps, certains professeurs de physique renoncent aux leçons à structure stéréotypée. En faisant le point de l'expérience des professeurs de Physique de la R.S.S. d'Ukraine, M. Rosenberg affirme qu'ils usent, dans leur travail, d' un système bien déterminé d'organisation de l'enseignement de la physique, en combinant différents types de leçons dont chacun est caractérisé par une orientation nette et bien définie (donner aux élèves des connaissances nouvelles, leur apprendre à appliquer ces connaissances dans la pratique, récapituler les sujets étudiés, vérifier les connaissances acquises). /A propos du perfectionnement des types et de la structure des leçons de physique, article paru dans la revue "La physique à l'école", Moscou, n.° 3, 1964/.

Néanmoins, même ce système de "plans à long terme" n'élimine pas un des défauts les plus graves de l'enseignement scolaire : morcellement des connaissances, profusion de faits de second ordre. L'élaboration des plans à long terme, qui marque un pas en avant dans le perfectionnement des types et de la structure des leçons, ne prévoit pas l'utilisation des méthodes déductives lors de l'exposition des sujets, ni l'étude des groupes de phénomènes similaires sur la base d'idées et de notions générales. La généralisation des questions étudiées ne se fait qu'aux leçons destinées à consolider les connaissances acquises.

Dans son travail d'enseignement, l'école-laboratoire n° 1 de l'Académie des Sciences pédagogiques de la Fédération de Russie met en pratique un système prévoyant l'élaboration des plans et l'étude des sujets par thèmes, appelé à perfectionner le système des leçons traditionnel.

Quels sont donc les traits essentiels de ce système ?

La leçon demeure la principale forme d'organisation du travail d'enseignement. Pendant la leçon, on use de tous les moyens de travail scolaire (individuel et collectif), de divers procédés et méthodes, pourvu qu'ils soient rationnels du point de vue des sujets étudiés.

Les éléments déterminant la structure de la leçon ne sont pas strictement obligatoires pour chaque leçon, ils ne se répètent pas d'une leçon à l'autre. Mais les éléments catactéristiques du système des leçons en classe, les degrés d'assimilation des connaissances se succèdent dans un ordre bien défini au cours de l'étude du thème dans son ensemble.

On dresse, pour tel ou tel thème du programme, un système de leçons dont la structure et le contenu sont déterminés par le rôle que ces leçons doivent jouer dans le système. Les différentes matières du thème sont exposées dans l'ordre de développement de ces idées essentielles, ce qui permet aux élèves d'acquérir une notion d'ensemble du phénomène ou de la loi donnés.

L'étude du thème se décompose en quatre étapes.

Première étape. Après la récapitulation des données sans lesquelles les élèves ne pourront s'assimiler les nouvelles lois et notions, le professeur explique les nouveaux sujets, en mettant en relief les traits les plus caractéristiques du processus ou du phénomène étudié. Ce sont les expériences, le matériel didactique et l'observation de phénomènes courants qui servent à former dans la conscience des élèves les premières notions nécessaires.

Deuxième étape. Les élèves reproduisent, approfondissent et élargissent les sujets traités, en travaillant en classe seuls, aidés parfois par le professeur. A la deuxième étape, on étudie les sujets plus concrètement, plus en détail ; on élargit et approfondit les notions sur la base desquelles on devra assimiler les lois fondamentales, étudier les processus dans toute la diversité de leurs particularités individuelles. A cette étape, le professeur dresse le plan du travail individuel des élèves, les aide à tirer des conclusions, à faire des généralisations, leur fournit des données complémentaires concernant les sujets étudiés, dirige le travail individuel de certains élèves, répond aux questions qui peuvent surgir pendant le travail, observe le degré d'assimilation des connaissances chez chaque élève, en effectuant ainsi une "rétroaction" avec la classe.

Troisième étape. Les élèves poursuivent l'étude du matériel, ils se l'assimilent au moyen de l'application pratique des connaissances acquises. Ils résolvent des problèmes pratiques, acquièrent des habitudes déterminées. Le professeur leur donne des instructions quant aux travaux pratiques, leur montre les algorithmes de la solution des problèmes, organise des discussions concernant différents procédés de solution des problèmes, aide certains élèves dans leur travail individuel. A la deuxième et à la troisième étapes, il donne aux élèves des notes pour les travaux accomplis, pour une participation active à la discussion du matériel théorique, pour la juste solution des problèmes.

Quatrième étape. Après la généralisation des sujets étudiés, on en fait la récapitulation, parfois les élèves passent une épreuve écrite.

L'établissement de ces quatre étapes découle de la théorie de la connaissance de la dialectique marxiste.

Le processus de connaissance s'effectue tout d'abord en passant du savoir sensible et concret à des abstractions qui cernent l'essence de l'objet. Par exemple, lors de l'étude des lois de la dynamique, on fait des expériences pour montrer aux élèves qu'un corps change d'état seulement sous l'action d'autres corps, et on introduit la notion de force pour caractériser l'action d'un corps sur un autre. Par conséquent, les élèves apprennent que ce n'est que l'interaction des corps qui détermine le changement de leur état mécanique, et non pas leur couleur, leur forme géométrique, etc. La notion de force, c'est une notion abstraite, destinée à généraliser les causes concrètes du changement de l'état d'un corps. A la première étape, les élèves prennent connaissance pour la première fois des traits les plus essentiels du phénomène étudié, sur la base de données concrètes.

Mais le processus de connaissance ne se limite pas à la formation d'abstractions. La science va toujours de l'avant, elle passe des abstractions à des connaissances concrètes qui s'expriment par la connaissance des aspects multiples de l'objet. Après avoir compris que le corps change d'état sous l'action de la force, les élèves doivent étudier, exemples à l'appui, comment change l'état du corps, de quoi relève l'accélération ou la vitesse qu'il acquiert, comment il faut mesurer la force, quelle influence la masse du corps exerce sur le changement de son état.

A la deuxième étape, les notions acquises sont donc approfondies d'une manière plus concrète, plus détaillée.

Seule l'application pratique peut fournir des connaissances solides. C'est à quoi vise la troisième étape.

La généralisation du matériel, qui se fait à la quatrième étape, est nécessaire pour que les élèves puissent bien retenir et s'assimiler les sujets étudiés.

Voyons l'étude du thème "Propriétés des gaz" d'après le nouveau système.

En étudiant ce thème, les élèves continuent de développer leurs connaissances sur certaines valeurs physiques, comme, par exemple, la pression des gaz, la température. On explique les propriétés des gaz à l'aide de la théorie cinétique.

Pour étudier les propriétés des gaz, il faut tout d'abord s'assimiler deux questions essentielles : les processus qui se déroulent dans les gaz et les lois qui régissent ces processus. On traite ce thème moyennant les méthodes statistique et thermodynamique, méthodes fondamentales dont se sert la physique classique pour l'étude de la chaleur. Ces méthodes nous permettent d'établir théoriquement l'interdépendance des paramètres qui définissent l'état du gaz, à partir des lois statistiques et des lois de la mécanique, en se basant sur la théorie cinétique. En effectuant des travaux pratiques, les élèves peuvent vérifier les pronostics de la théorie, ce qui leur permet d'apprécier l'aide que leur apporte la théorie scientifique dans l'étude des phénomènes de la nature.

Comment donc réalise-t-on ces tâches dans la pratique de l'enseignement ?

La majorité des professeurs, qui suivent le programme en vigueur, présentent les lois des gaz uniquement comme le résultat d'expériences, sans les présenter comme découlant de la théorie cinétique. La loi fondamentale des gaz est formulée à partir de lois empiriques à l'issue de l'étude du thème. On a donc peu recours, pour expliquer les propriétés des gaz, à la théorie cinétique et à la loi de la conservation de l'énergie, ce qui constitue un grave défaut.

Dans les classes de physique de l'école-laboratoire n° 1 de l'Académie des Sciences pédagogiques de la Fédération de Russie, les professeurs de physique dressent le plan ci-dessous pour l'enseignement des "Propriétés des gaz" suivant le système de l'élaboration des plans et de l'étude des sujets par thèmes :

Etape	Heures	Contenu des leçons
I	4	Exposé, par le professeur, des questions essentielles du thème 1. Equation fondamentale de la théorie cinétique des gaz 2. Equation caractéristique du gaz parfait 3. Processus qui se déroulent dans les gaz (isotherme, isobare, isochore et adiabatique) 4. Notions sur le fonctionnement du compresseur, des instruments pneumatiques et de la pompe à faire le vide.
II	3	Travail individuel des élèves en classe 1. Loi de Boyle-Mariotte 2. Loi de Gay-Lussac 3. Loi de Charles
III	3	Application des connaissances acquises 1. Travail pratique destiné à vérifier l'équation caractéristique du gaz parfait 2. Solution de problèmes et exercices 3. Solution de problèmes
IV	2	1. Epreuve écrite 2. Leçon de récapitulation.

A la première étape, le professeur expose les notions les plus générales du thème.

A la première leçon, le professeur fait un bref exposé du contenu du thème, indique les problèmes liés à l'étude des propriétés des gaz, parle de l'emploi des gaz dans la technique. Après la causerie d'introduction, le professeur, en s'appuyant sur la théorie cinétique, ainsi que sur les connaissances des élèves en mécanique, déduit l'équation fondamentale de la théorie cinétique des gaz. Il explique le rapport entre la température et l'énergie cinétique moyenne des molécules sans le déduire, et il présente la constante de Boltzmann comme un coefficient de proportionnalité. A cette étape, la notion d'échelle physique des températures est introduite sans éclaircir le sens physique du zéro absolu, en prenant appui sur le seul fait que l'énergie cinétique moyenne ne se réduit pas à zéro à 0 °C. On fait savoir aux élèves que 0 °C correspond à environ 273 °K. Les élèves feront plus ample connaissance de la nouvelle échelle des températures lors de l'étude des lois des gaz. C'est ainsi que, dès la première leçon, les élèves apprennent que la pression du gaz dépend de sa masse volumique et de sa température.

L'objectif de la deuxième leçon est de déduire l'équation caractéristique du gaz parfait à partir de l'équation fondamentale de la théorie cinétique. La constante universelle des gaz est présentée comme le produit de la multiplication de la constante de Boltzmann par le nombre d'Avogadro, et calculée pour un molecule-gramme de gaz dans les conditions normales de température et de pression.

A la troisième leçon, les élèves acquièrent les premières connaissances des processus qui se déroulent dans les gaz et des lois qui les régissent. Il en ressort que les lois des gaz découlent de l'équation caractéristique du gaz parfait. A l'aide du premier principe de la thermodynamique, le professeur interprète les processus isotherme, isobare et isochore du point de vue de l'énergétique.

A la quatrième leçon, on étudie l'utilisation pratique de l'air comprimé, le fonctionnement du compresseur, des instruments pneumatiques et de la pompe à faire le vide. On projette le film "Air comprimé".

A l'issue de la première étape de l'étude du thème, les élèves ont une idée générale des processus qui se déroulent dans les gaz, des lois des gaz et de l'utilisation technique de l'air comprimé.

A la deuxième étape, ces notions deviennent plus concrètes ; les lois des gaz sont étudiées en détail, au moyen du travail individuel pendant lequel les élèves procèdent à la vérification pratique, en laboratoire, des conclusions théoriques. Aux trois leçons de la deuxième étape, les élèves travaillent seuls en étudiant les lois des gaz selon un plan dressé par le professeur. Après la vérification pratique des conclusions théoriques, les connaissances des lois des gaz se précisent, les élèves s'assimilent les méthodes de la recherche scientifique et se rendent compte du rôle de la pratique dans la vérification de la théorie.

Voyons comment le professeur dirige le travail individuel des élèves, en prenant pour exemple l'étude de la loi de Boyle-Mariotte.

D'abord, le professeur récapitule avec les élèves l'équation caractéristique du gaz parfait et l'énoncé de la loi de Boyle-Mariotte. Les élèves doivent vérifier par expérience la constante du produit pV, découlant de l'équation caractéristique du gaz parfait. Le professeur distribue aux élèves des instructions écrites concernant les travaux pratiques et le travail individuel à accomplir après ceux-ci.

Voici un exemple (pour le travail individuel) :

Lisez dans votre manuel le chapitre sur la loi de Boyle-Mariotte et répondez à la question suivante : "Comment la masse volumique d'un gaz dépend-elle de la pression si la température du gaz reste constante et sa masse invariable ?"

Représentation graphique de $p = f(V)$ pour $pV = 12$.

Représentation graphique de $p = f(T)$ et $V = f(T)$.

Lors de la compression du gaz, un travail s'effectue. Pourquoi l'énergie du gaz n'augmente-t-elle pas lors du processus isotherme ?

A qui l'énergie est-elle transmise ?

A l'issue de la leçon, les élèves résolvent seuls des problèmes de calcul sur la pression du gaz enfermé dans un cylindre par un piston.

A la troisième étape, les élèves procèdent à l'application pratique de leurs connaissances. Aussi ne leur donne-t-on pas d'instructions quant au travail en laboratoire destiné à vérifier l'équation caractéristique du gaz parfait ; les élèves doivent résoudre un problème au cours de ce travail. Pour consolider les connaissances sur l'équation caractéristique du gaz parfait, les élèves résolvent des problèmes de calcul. On consolide les connaissances sur les processus qui se déroulent dans les gaz en résolvant des problèmes graphiques et qualitatifs.

L'épreuve écrite comporte un problème de calcul et un problème qualitatif. On distribue d'avance aux élèves les questions pour la leçon de récapitulation.

Lorsqu'il s'agit du thème "Lois des gaz", on étudie l'équation fondamentale de la théorie des gaz à partir de la théorie cinétique déjà connue ; cette équation montre comment, à l'aide des lois de la mécanique, on explique les processus auxquels prennent part beaucoup de particules qui se déplacent d'une manière chaotique. Mais pour d'autres thèmes, par exemple les lois de la cinématique, les lois de la dynamique, le travail et l'énergie, il est nécessaire de s'assimiler d'avance certaines notions, d'apprendre à mesurer certaines valeurs physiques, de s'habituer à se servir des unités de mesure.

Quand on dresse le plan du thème "Travail et énergie", il faut tenir compte de ce qu'on va approfondir des notions essentielles telles que travail et énergie, et étudier la loi de la conservation et de la transformation de l'énergie mécanique. A la fin de l'étude de ce thème, les élèves doivent pouvoir utiliser les notions énergétiques pour expliquer différents phénomènes mécaniques. Pour considérer la notion de travail comme une grandeur caractérisant le changement de l'état d'un corps, il ne suffit pas de revoir avec les élèves la notion de travail ; il faut l'élargir davantage en étudiant le travail d'une force qui fait un angle avec le déplacement, en expliquant la représentation graphique du travail d'une force variable (le ressort tendu), et en rappelant aux élèves la notion de puissance.

Le plan du thème "Travail et énergie" est dressé d'après le schéma ci-dessous :

Etape	Heures	Contenu des leçons
I	5	Préparation à l'étude du matériel 1. Notion de travail. Le travail d'une force qui fait un angle avec le déplacement. Représentation graphique du travail 2. Solution de problèmes 3. Récapitulation de la notion de puissance Exposé,par le professeur, des questions essentielles du thème 4. Etat mécanique du corps. Changement de l'état mécanique. Le travail en tant que grandeur caractérisant le changement de l'état mécanique d'un corps, état défini par ses coordonnées et sa vitesse. L'énergie en tant que grandeur caractérisant l'état mécanique du corps. 5. L'énergie potentielle en tant que fonction de la coordonnée. L'énergie cinétique en tant que fonction de la vitesse. Le caractère relatif de la valeur de l'énergie. La loi de la conservation et de la transformation de l'énergie dans les processus mécaniques.
II	4	Travail individuel des élèves en classe 1. Expression de l'énergie potentielle de pesanteur et de l'énergie d'un corps ayant subi une déformation élastique 2. Expression de l'énergie cinétique 3. L'énergie totale du corps en chute libre 4. Transmission de l'énergie mécanique au moyen d'un choc
III	5	Exercices d'application des connaissances 1. Solution de problèmes 2. Solution de problèmes 3. Application de la loi de la conservation aux mécanismes simples

Etape	Heures	Contenu des leçons
III	5	4. Application de la loi de la conservation aux mécanismes simples 5. Travail en laboratoire : définition du rendement du plan incliné
IV	2	1. Epreuve écrite 2. Leçon de récapitulation

Comme il ressort de ce schéma, les trois premières leçons servent à rappeler aux élèves les notions de travail et de puissance, ainsi qu'à développer ces notions. Au cours de ces leçons, les élèves résolvent des problèmes qui les entraînent à se servir des formules de calcul du travail, de la puissance et leur rappellent les unités de mesure appropriées. Aux deux leçons suivantes, le professeur expose les questions essentielles du thème.

A la deuxième étape, les élèves, en étudiant seuls, à l'aide du manuel, la formule de l'énergie potentielle et cinétique, parviennent à la conclusion que l'énergie totale du corps en chute libre reste constante. Ils apprennent, sur l'exemple de la transmission de l'énergie mécanique au moyen d'un choc, que la force du choc dépend à la fois de la quantité de l'énergie cinétique du corps qui porte le coup et du degré de déformation des corps.

A la troisième étape, les élèves résolvent des problèmes qui les obligent à tenir compte non seulement de la transformation d'une sorte d'énergie mécanique en une autre, mais aussi de la transformation de l'énergie mécanique en énergie interne au moyen du travail résistant. Dans les classes de physique, on peut résoudre des problèmes qui impliquent non seulement la loi de la conservation de l'énergie, mais aussi celle de la conservation de l'impulsion linéaire. La loi de la conservation de l'énergie peut être appliquée à des mécanismes simples dans la solution de problèmes concernant le travail de la vis, de la presse, du plan incliné, tout en tenant compte du rendement. En laboratoire, les élèves déterminent le rendement du plan incliné.

A la quatrième étape, le professeur fait subir aux élèves une épreuve écrite qui comporte des problèmes sur la loi de la conservation et de la transformation de l'énergie. Quant à la leçon de récapitulation, elle est destinée à généraliser les sujets du thème.

L'élaboration du plan du thème "Induction électromagnétique" présente un certain intérêt.

Les questions essentielles de ce thème sont : l'induction électromagnétique, la self-induction et la notion d'énergie du champ magnétique. On explique le phénomène d'induction et de self-induction électromagnétique à l'aide de l'assertion bien connue de la théorie de Maxwell sur la formation, autour d'un flux magnétique variable, d'un champ électrique d'induction tourbillonnaire. La loi de Lenz sur la direction du courant induit et la notion d'énergie du champ magnétique découlent de la loi de la conservation et de la transformation de l'énergie, et sont en rapport avec la transformation de l'énergie de la source du courant, ou bien d'une autre énergie, en l'énergie du champ magnétique.

A la première étape, après l'illustration, à l'aide d'expériences, de l'induction électromagnétique, on expose la notion de force électromotrice d'induction, on examine la loi de Lenz comme découlant de la loi de la conservation et de la transformation de l'énergie. On explique le phénomène de l'induction électromagnétique à partir de la notion de champ électrique induit. Cette notion sert également à expliquer la self-induction lors de la fermeture et de la rupture du circuit.

A la deuxième étape, les élèves apprennent, pendant les expériences en laboratoire, comment la valeur de la force électromotrice (f.e.m.) d'induction dépend de la vitesse de variation du flux magnétique, et aussi par quoi est déterminée la direction du courant induit.

A cette étape, on introduit la notion d'inductance d'un solénoïde lorsqu'on analyse la dépendance de la f.e.m. des propriétés du solénoïde.

A la troisième étape, en résolvant des problèmes qualitatifs, on examine l'application technique de l'induction électromagnétique, on étudie les courants de Foucault.

A la leçon de récapitulation, on généralise les sujets du thème.

Voici le plan pour l' "Induction électromagnétique" :

Etape	Heures	Contenu de la leçon
I	2	Exposé, par le professeur, des questions essentielles du thème. 1. Expériences sur l'induction électromagnétique. La f.e.m. de l'induction. La loi de Lenz 2. Notion de champ électrique induit. Le phénomène de self-induction
II	2	Travail individuel des élèves en classe 1. Expériences en laboratoire sur l'induction électromagnétique 2. Inductance d'un solénoïde. Valeur de la f.e.m. de self-induction. L'énergie du champ magnétique d'un solénoide
III	2	Exercices d'application des connaissances 1. Solution de problèmes (qualitatifs) 2. Solution de problèmes (expérimentaux)
IV	I	Leçon de récapitulation

Les exemples cités montrent que le système de l'élaboration des plans et de l'étude des sujets par thème est particulièrement commode dans les cas où une même idée traverse tout le contenu du thème, ou bien quand on se sert de la méthode déductive. Outre les thèmes sus-mentionnés, on peut citer "Le courant dans les métaux (conducteurs métalliques)", "Le courant dans les gaz", "Le courant dans les électrolytes", "Chaleur et travail", "Moteurs thermiques", etc.

Lors de l'étude du thème "Charges électriques et champ électrique", il faut porter à la connaissance des élèves une multitude de notions, de phénomènes et de rapports entre les grandeurs ; c'est pourquoi il est commode de subdiviser ce thème en quelques sous-thèmes. Pour donner aux élèves une notion générale du champ électrique et de ses propriétés, il faut commencer par une causerie d'introduction ; à la dernière leçon, il faut passer en revue les questions essentielles du thème. On peut faire étudier chaque sous-thème par les étapes mentionnées plus haut.

L'expérience du système d'élaboration des plans et de l'étude du matériel par thèmes, effectuée à l'école-laboratoire n° 1 de l'Académie des Sciences pédagogiques de la Fédération de Russie, a prouvé que cette méthode rend la leçon plus efficace, contribue à former, chez les élèves, une notion d'ensemble des sujets étudiés, les aide à se les assimiler d'une manière consciente.

Cette méthode exige, il est vrai, un certain changement du volume du matériel, l'étude de certaines questions à partir de positions plus actuelles. Grâce à ce nouveau système, les élèves acquièrent des connaissances plus solides, plus profondes.

OLYMPICS ATTRACT YOUTH TO SCIENCE IN THE USSR (1), by M.A. Lavrentiev, Vice-Chairman of the USSR Academy of Science

Ours is an era in which new knowledge is accumulating in all fields. Every major scientific discovery leads to applications that require a high degree of specialization. And the growth of automation, while reducing the need for medium-level personnel, is increasing the demand for creative scientists and engineers.

This situation which is worldwide raises a number of problems, particularly in the technologically-advanced countries : how can young people be encouraged to take up scientific careers ? at what age should training and specialization begin ? and how should science teaching be organized ?

In taking up these problems, it should be kept in mind that man's ability to assimilate knowledge increases much more slowly than the sum total of new data. And this raises the vital problem of the level of general culture and the age at which education should become specialized in order to prepare boys and girls for different careers. We still have no way of selecting at the proper time the occupation that is best suited to the abilities of each student. My experience over nearly half a century has shown that only ten out of 100 boys entering a school of physics and mathematics actually become good mathematicians ; and among girls, the figure is no more than 1 or 2 per cent.

Problems of Selection

Yet it is obvious that the sooner we begin to train teenagers , the more chances they have of becoming creative scientists.

These problems of selecting and educating youth, then of training them as engineers, researchers or industrial planners must be faced in the Soviet Union as in the United States, Britain, France and elsewhere. But whatever the economic system, various schools of thought exist within each country as to the practical solutions that should be adopted.

In the Soviet Union, widely differing views have been expressed on the subject. I would like to describe an interesting experiment carried out in recent years by scientists at the Siberian branch of the USSR Academy of Sciences.

The shortage of qualified specialists in research and technology in Siberia led to the creation of a major scientific centre in the city of Novosibirsk, nearly 3,000 miles from Moscow. Lack of suitable personnel was hampering the development of this immense and rich region where oil, natural gas, coal, iron and gold are plentiful. Siberia also contains the world's biggest supplies of fresh water and hydro-electric plants already in operation or under construction were creating an enormous power potential for industry and science.

The shortage of scientific personnel was particularly acute in Siberia's schools and institutions of higher education. The research institutes, new industries and vast construction jobs were draining the best mathematicians, physicists, chemists and biologists from educational institutions, and the training of the new generation of scientists was in the hands of teachers who were not always in touch with present-day problems.

Quality or Quantity ?

When the University of Novosibirsk was established, a heated debate arose on the question of entrance requirements. Some felt that admission should be limited to youths with a definite scientific bent and some training in science. Others maintained that the doors of the university should be opened wide to high school pupils with top marks so that all vacant places might be filled. There was also a controversy between those who advocated highly specialized scientific training concentrated in laboratories and those who favoured more traditional methods of education.

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1. From "Unesco Features", No 461, July 1965, pp. 10-12.

Since both sides stuck to their guns, a compromise had to be reached. But the results were unsatisfactory : too few students were being admitted and the level of knowledge was too low. Discussion began all over again and led to a new method of selecting students for the university. This plan applied since the 1962-63 school year with excellent results, consists basically in the organization of "Scientific Olympics" and the creation of a specialized boarding school on the Novosibirsk campus.

First Round

Here is how the selection process works. Every year in November or December, the press, radio and television announce the first round of the Siberian Olympics in physics and mathematics and, beginning this year, in chemistry and biology. This round is conducted by correspondence. Ten to fifteen problems in mathematics, physics and chemistry are set and secondary school pupils have a month to send in their answers to Novosibirsk. Among the problems, some are of our eighth-grade level and others at tenth grade. In both sections, certain questions are designed to appeal to the contestants' creative imagination. There is no limit to the number of replies sent in by contestants, for the main purpose of this first round is to awaken an interest in science. During the first Olympics in 1962-63, several hundred teen-agers took part ; this year, we had nearly 10,000 competitors.

Second Round

Candidates who do well in this first round are invited to take part in the second round of the Olympics held in fifteen to twenty regional centres in Siberia, the Soviet Far East and Central Asia. All expenses are paid by the Academy of Sciences. These tests, organized in each centre by three or four representatives of Novosibirsk University, are harder than the first and contestants have to solve the problems in a set time.

Winners of this second round are then invited to spend a whole month on the Novosibirsk campus attending a special summer school. The first year, we had 100 young people ; last summer, 700; and this year, over 1,000. Under the leadership of about 100 young scientists and senior students, the boys and girls visit the institutes and laboratories, and attend lectures given by university professors and researchers. They divide their time between study and leisure - hiking, swimming, boating, etc. This gives the Academy staff an opportunity to establish close contacts with each teen-ager.

Third Round

The third and last round of the Olympics takes place at the end of the month's stay. Problems set are harder than in the previous rounds but most participants are accepted and remain on the campus, some entering the University while others who are still too young are admitted to the special boarding school. Graduates from this school, where courses in physics, chemistry and mathematics are given by leading scientists, are assured of admission to the best scientific institutes.

A NEW SCIENCE CITY IN SIBERIA (1), by Hilary Koprowski, Jacob A. Brody, William J. Hadlow, John F. Hotchin, Richard T. Johnson, Leonard T. Kurland.

Akademgorodok, an interesting new city devoted entirely to science, has been constructed 3000 kilometers east of Moscow at the focal point for the recently organized Siberian Department of the Academy of Sciences of USSR. The city, envisioned as the scientific center for Siberian development, was begun in 1959 and is already nearing completion. It has brought to western Siberia a staff of eminent scientists from all parts of the Soviet Union to direct and encourage Siberian scientific efforts.

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1. Extract of an article published in "Nature", 27 August 1965, pp. 947-949.

The Siberian Department was established as part of an overall plan to make better use of the vast natural resources of this section of the Soviet Union. Territorially, Siberia constitutes more than half of the USSR. Within its geographic boundaries lie 70 percent of the forests of the Soviet Union and a large area of virgin soil and of mineral resources, including coal, oil, and natural gas. Siberia is traversed by several large rivers, including the Irtysh, Yenisey, Lena, and Ob, on which power stations have been built to provide light and heat for its inhabitants.

Akademgorodok(1), freely translated by us as Science City, is situated only 19 kilometers from Novosibirsk, the capital of Siberia, which itself has grown from a workmen's camp on the Trans-Siberian Railway in the second half of the 19th century to a city of more than 1.3 million people. Built along the banks of the Ob River, Novosibirsk was partly settled by Russian farmers who migrated from more crowded areas in search of fertile land. The population of the city grew during the two world wars as workers came to the industries that were springing up in this region. Today, Novosibirsk is an industrial center offering its inhabitants many urban advantages, educational facilities, and cultural opportunities, including theatrical performances, operas, and concerts. The Siberian capital is linked to Akademgorodok by highways and an electric railway system.

The facilities of the Science City are under the direction of the Chief of the Siberian Department of the Academy of Sciences, M.A. Lavrentyev, who serves as the administrative and scientific head of the city and who is also Vice-President of the Academy of Sciences in Moscow. Academician Lavrentyev and his colleagues have supervised the construction of the city since its inception. According to their general plan, the city is divided into three major units : (i) the university and institutes, (ii) apartment houses and single-family houses for the senior scientific staff, and (iii) smaller dwellings used at present for the construction workers.

University and Institutes

The university of Science City, called the University of Novosibirsk, is still in the process of construction ; however, many of the university and institute instructors received part of their education there. The 15 institutes in Akademgorodok are nearly completed. These, together with five institutes in nearby Novosibirsk, offer a diversified program for scientific training. Ten of the 20 institutes are devoted to physics, mathematics, and technology, five to chemistry, three to biology, and one each to geology and economics. Plans are currently under way for a new Institute of Theoretical Medicine. The three institutes of biology are the Biological Institute, for study of Siberian fauna ; the Botanical Garden, for study of Siberian forests ; and the Institute of Genetics and Cytology.

Our Siberian centers responsible to the Siberian Department of the Academy of Sciences are the Forestry Institute in Krasnoyarsk, the Biological Institute of Yakutsk, and the Biological Institute in Vladivostok.

Advanced High School and Future Career

Akademgorodok has a special high school of mathematics, physics, and chemistry for advanced students. Young people from schools throughout Siberia are accepted into this school on the basis of competitive examinations. More than 40,000 children, between the ages of 11 and 14 years, are invited to participate in tests which are sent to schools in even the most remote villages. The students who show the greatest ability are brought to larger centers and are given more difficult examinations. Seven hundred children from this group

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1. The name "Akademgorodok" literally means "Academic Town", but our designation "Science City" seemed more appropriate in view of the scope of its functions.

are invited to spend a summer in Akademgorodok, where they are given additional tests and are interviewed by teachers from the advanced high school. During this summer session the children are further evaluated by individual members of the faculty, and 300 students, are eventually selected to enter the high school.

Following their graduation from the advanced high school, these students are sought by many universities in the Soviet Union, but most remain in the Science City's graduate training program. Besides having a highly qualified teaching staff, the University of Novosibirsk has a close relationship with the institutes. At Akademgorodok, the academic staffs of the institutes and of the university work together ; thus, lectures are given at the university by institute members, and third-and fourth-year university students spend as many as 3 to 6 days a week in one of the institutes, gaining practical experience during college years. No comparable opportunity is available to students in other Soviet centers of scientific education.

The academic and professional titles are separate, as in American universities. The academic ranks are Professor, Docent, and Assistant, which correspond to our Professor, Associate Professor, and Assistant. The scientific ranks, which are not necessarily related to the academic ranks, are Academician, Doctor, and then Candidate. A student attending the university earns a diploma after 5 years of graduate work. To gain the next degree, that of Candidate, he must devote three additional years to study and must defend a thesis. The title of Candidate approximates our Ph.D. degree. To obtain a doctorate, a Candidate must pursue a course requiring from 3 to 20 years of research and study and must defend a second thesis on a more abstruse subject. The various departments elect their own department heads from among the faculty members, generally from among those holding doctorates ; the period of tenure is 4 years. The junior posts are filled by Assistants who have received their diplomas after graduate work or have completed the course for Candidate. At present there are 620 Candidates working at the university or at the institutes, and about half of them received at least part of their training at the University of Novosibirsk.

Road to Excellence

Undoubtedly Akademgorodok's important accomplishment is its educational program designed to develop the human potential of Siberia. The unique, large-scale selection process brings to the Science City gifted students whose abilities otherwise might not have been discovered. These students are expected to engage in independent research at an earlier stage than students in other Soviet science training centers do, and many have published their own work by the time they finish their university training. The cooperative atmosphere, which we witnessed, provided by the close working together of the various educational facilities seemingly gives continuity to the educational process.

Lord Snow has posed the problem of science and government very cogently, and it is our impression that as far as the relationship of the scientists to the government is concerned, the pervading tone in the Science City differs from that of the older academic establishments in the USSR. All members of the delegation felt that the Science City, created in an undeveloped area far from other cultural centers, should be regarded as an interesting experiment which, in concept if perhaps not fully in practice, makes higher education available to individuals whose potentials would otherwise go unrecognized. They felt that these aspects of the experiment may well provide some answers to the educational needs of other societies as well.

FILMS(1)

Leningrad studios for popular science films available from Ministry of Higher and Special Secondary Education (Professional) of the RSFSR.

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1. Two films produced by this service are mentioned in the present publication under "Catalogue de films pour l'enseignement universitaire" (See p. 16)