ENGINEERING, MATHEMATICS, PHYSICS & HIV/AIDS

Integrated Course Module (Rwanda)
Engineering, Mathematics, Physics & HIV/AIDS

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Preamble

Given the dire situation of HIV/AIDS pandemic in the resource strained countries of sub-Saharan Africa, and the fact that students generally fall into a high-risk group, the UNESCO Regional Bureau for Science & Technology in Africa jointly with the African Women in Science and Engineering organized an in-country training workshop on “Higher Education Science and Curriculum Reform: African Universities Responding to HIV/AIDS” in Nairobi, Kenya, from 17 – 19 April, 2007. The main purpose of the workshop was to train lecturers from Universities as trainers on how to Mainstream and integrate HIV/AIDS into the Engineering and Science courses within their respective universities.

This module is an output of the in-country Training Workshop that targeted Engineering, Physical and Biological Scientists in Rwanda. It summarizes the identification of modules in mathematics, physics and engineering and the potential entry points for integrating HIV/AIDS information. This is a consolidated result of inputs from lecturers from the National University of Rwanda, Kigali Institute of Science and Technology and Kigali Institute of Education; and is based on their curricula in the teaching of Engineering, Mathematics, and Physics.

These sample modules have been developed from the existing modules and course outlines in selected areas of mathematics, physics and engineering. The content of the current teaching units remains the same but there is HIV and AIDS education and HIV related examples. Each teaching unit should be covered in exactly the same time frame as before. The focus of the unit also remains the same. It is anticipated that during the course, the student will not only learn the basic information in mathematics, physics and engineering as prescribed but will also be impacted with some HIV and AIDS knowledge that could influence, the perception, behaviour and contribute in the fight against HIV and AIDS in the universities and the communities at large.
Acknowledgment

This integrated course module has benefited from the input of the lecturers from the following universities in Rwanda: National University of Rwanda, Kigali Institute of Science and Technology (KIST) and Kigali Institute of Education (KIE); and is based on their curricula in the teaching of Engineering, Physics and Mathematics.

The training workshop was facilitated by Prof. Xiaohua Xia, of the University of Pretoria, South Africa. Prof. also compiled information from the training sessions to come up with this country-specific integration module. Technical and editorial input was also received from Professors Mabel Imbuga and Caroline Lang’at Thoruwa of African Women in Science and Engineering (AWSE), and Alice A.Ochanda of UNESCO Nairobi Office.

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AWSE also appreciates secretarial services offered by Mrs. Monica Gammimba.
M101: Analysis

Course description:
The module investigates concepts of single variable functions, limits, continuity, graphs and differential calculus. Also the module deals with concepts of foundations of analysis (sets; logic; proofs, real number system and relations) which have hitherto been approached very intuitively and investigates basic mathematical ideas of definition and proof at an appropriate level of formalism and rigor.

Entry points for HIV integration:

- Exponential function

Objective: rigorous review of the elementary single variable function: exponential function.

- Integration with HIV
  - The short-term (< 4 weeks) viral load response after anti-retroviral therapy can be approximately represented by an exponential decay function of time. The rate of decay is related to the half-life of infected CD4+ T cells;
  - The viral load rebound (viral load blips) after termination of therapy can be approximately represented by an exponential growth function of time. The rate of growth is usually greater than the decay rate as in a).

- Graphical and analytical solutions - plot the viral load response and rebound after initiation of therapy and termination of therapy respectively.

M201: Statistics

Course description:
Descriptive statistics: Data description: introduction to probability theory, random variables, distribution functions, expectation, conditional probability, and conditional expectation; sampling, inference: random
variables and distributions, tests and distributions, tests of significance, test of hypotheses, elementary experimental design, simple regression, and correlation an analysis of variance. Computer Practicals with Microsoft excel.

**Entry points for HIV integration**

- **Collection and presentation of data**
  - Collection of viral load data, in normal scale and log scale
  - Plot the viral load data in log scale

- **Simple linear regression**
  - Linear regression model of the viral load data in log scale

**M202: Ordinary/Partial Differential Equations**

**Course description:**
Ordinary Differential Equations (ODE): existence and uniqueness theorem, definitions of order and degree; first order and first degree equations, exact equations, second order equations with constant and variable coefficients, systems of odes, and series solutions; Legendre and Bessel’s equations;

Partial Differential Equations: Basic concepts, geometrical interpretation, first degree order equations, Monge’s method, Charpit and Lagrange’s method, second order equations of elliptic, hyperbolic and parabolic type, existence and uniqueness of solution of inhomogeneous equations, initial value problems, separation of variables, and solutions by transformation techniques.

**Entry points for HIV integration:**

- **Differential equation modeling:**
  - Modeling of HIV infection as a third order differential equations
  - Reduction of the 3rd order ODE into decoupled 1st order and 2nd order ODE’s after 100% effective reverse transcriptase inhibitor therapy.

- **Solution of linear differential equations**
Solution of the reduced order ODE's, immune system response as a solution of a 1st order ODE, viral response as a solution of a 2nd order ODE.

M301: Mathematical Modelling

Course description:
An introduction to the Mathematics of finance; Investments: Fixed Interest borrowings by Government and other bodies, shares and other equity-type finance; derivatives.
Simple compound Interest Problems: Fixed Interest Securities; Running yields and redemption yields; present value/yield from an ordinary share/property; real rate of interest; index-linked bonds; income tax, capital gains tax and investments. Arbitrage & Forward contracts; Term Structure of Interest Rates: yield (par and to Maturity) spot/ forward rates; duration and convexity; immunization; Stochastic Interest rate models: Mean/Variance of independent and identically distributed annual rates of return; log-normal distribution; probability calculations.

Entry points for HIV integration:
• introduction of the modelling practice of HIV/AIDS
• analysis of the HIV/AIDS model

Suggestion: Extra lecture notes on the modelling of HIV / AIDS should be dispatched to students, and a semester project in groups is encouraged.

M401: Project

Course description:
Research project proposal writing, research methodology, literature survey, research report writing, conducting research on topics of choice.

Entry points for HIV integration:
• literature survey
• conducting research on topics of choice
• report writing
All the above points can be taken as entry points if a choice is made on some research papers on the modelling of HIV/AIDS infection and progression.

PHYSICS

P101: Mechanics I

Course description:
Measurement of physical quantities, dimensional analysis, kinematics. Introduction to inertial and non-inertial frames of reference, dynamics of a particle. Conservation laws: Conservative forces, potential energy, the centre of mass of a system of particles and its motion, centre of gravity, conservation of energy of a system of particles, conservation of linear momentum: collision of two particles in one and two dimensions (elastic and inelastic), motion of a rocket; conservation of angular momentum. Dynamics of a rigid body: Equilibrium of a rigid body, angular momentum of a rigid body and moment of inertia, equation of motion of a rotating body, kinetic energy of rotation, gyroscope, precessional motion of a spinning top. Motion under central forces: Simple harmonic motion, circular motion of particles and bodies, planetary motion and gravity, elliptical and other orbits, Rutherford scattering: scattering of a charged particle by a nucleus.

Entry points for HIV integration
• Measurement of HIV.
  ➢ collection of viral load data, in normal scale and log scale
  ➢ plot the viral load data in log scale
  ➢ discussion of measurement precision and measurement error
• Stability/instability of HIV/AIDS equilibrium.
  ➢ instability of uninfected status
  ➢ stability of infected status
• Sedimentation velocity of red globules in plasma.
P102: Mechanics and Properties of Matter

Course description:


Entry Points for HIV integration

- Laminar flow: Introduction to HIV and AIDS emphasis should be give that HIV and related material are biohazards and must be handled in laboratory. The virus must be handled in bio-safety cabinet which is fitted with laminar flow systems.
- Measurement of HIV
  - collection of viral load data, in normal scale and log scale
  - plot the viral load data in log scale
  - discussion of measurement precision and measurement error
P201: Oscillations and Waves

Course description:

Waves: Elastic waves in a solid rod, phase velocity and characteristic impedance, pressure waves in a gas column, transverse waves in a string, shear wave, travelling waves on an electrical transmission line, transfer of energy and momentum in a wave motion, group velocity. Doppler effect.

Entry points for HIV integration
• Propagation (Spreading) of HIV/AIDS at population level: HIV/AIDS spreading among population is analogous to different types of oscillations: damped oscillations, under-damped oscillations and critical damped oscillations.
• Relationship between energy frequency and wavelength. Use of different wavelengths for determination of absorbance as measure of antibodies with reference to HIV antibodies. Introduction to HIV infection and host response by antibody formation as host protective mechanism. Application of ELISA using different wavelengths to measure antibody response for the purposes of HIV diagnosis.

P301: Introduction to Environmental Science

Course description:
Fundamental concepts and scope of environmental science, Earth’s atmosphere, lithosphere and biosphere, men and nature, technology and population, ecological concepts and ecosystems, environmental quality and management, agriculture, water resources, fisheries, forestry
and wildlife, energy and mineral energy sources, renewable and non renewable resources, environmental degradation, pollution and waste management, environmental impact analysis, remote sensing and environmental monitoring.

Keywords

Environment, ecosystems, pollution, impact analysis

Entry Points for HIV integration

• Effects of condoms on the environment

P401: Nuclear Physics

Course description:
Nuclear properties: The four fundamental interactions: strong, electromagnetic, weak and gravitational; mass, radius, angular momentum, magnetic moment, electric quadrupole moment, parity, determination of mass, mass spectrometer, nuclear constituents, binding energy per nucleon with mass number A, semi-empirical mass formula. Nuclear models and nuclear energy: Shell model, liquid drop model, meson theory of nuclear forces.

Nuclear radiation and their interaction with matter: alpha, beta and gamma decays, Mössbaur effect, nuclear fission, chain reactions, uncontrolled fission and atomic bomb, nuclear reactor, nuclear fusion in stars, hydrogen bomb, problem of controlled fusion. Introduction to accelerators and detectors. Introduction to elementary particles: Properties and classification, conservation laws.

Entry points for HIV integration

• Body cells and decay - is a way of teaching rate of decay and rate of decay in HIV/AIDS as half-life.
• Use of fluorescence to detect HIV in tissue and organs.
• Nuclear model, the binding energy curve fission and fusion and radioactive decay: Use of radionuclide to measure cellular immune response to HIV.
• Use of X-ray in diagnosis of opportunistic infection.
• Use Fluorescence and phosphorescence technique in determination of CD4 counts as measure of HIV and AIDS progression.
P402: Solid State Physics

Course description

Brief review of crystal structures. Wave motion on a homogeneous linear elastic line, (monatomic and diatomic), Brillouin zones, acoustic and optic modes.


Entry points for HIV integration:

- The use of NMR to study the structure of HIV.
P403: Measurement and Instrumentation

Course description:

General: Fundamental concepts and definitions, Measuring errors and their causes, accuracy, precision, significant figures, calculations of static errors, arithmetic mean, standard deviation.

Bridges: Principle of different configurations of designs, errors and their causes, applications of DC-Bridges, AC-Bridges

Cathode ray oscilloscope: Block diagram, CRT, Design and operating principles, Measurement with Oscilloscopes-dc and ac current and voltages, phase, sensitivity, accuracy, frequency and lissajous figures, voltage probes, current probes, and shunts.

Digital measuring instruments and methods: Universal counter/timer (Frequency, time, period, ratio, external signal, etc.). Digital-voltmeters: Rap type DVM, Successive approximation type DVM, Integrating type DVM, etc, Multimeters principles.

Waveform generators and Wave analysers: Function generator, Laboratory Square and triangular waveform generator, Audio signal generator. Audio frequency wave analyser, heterodyne wave analyser, spectrum analyser, Distortion meters, Total harmonic distortion analyser, YIG oscillator.

Electrical measurement of non-electrical quantities: Primary sensing elements-strain,force,displacement,flow,pressure,transducers-active, and digital for various quantities. Strain and stress measurement and force measurements, pressure transducers, LVDT.

Signal conditioning and processing: Filtering, amplification/attenuation, impedance matching, signal buffering and shaping, conditioning networks life-bridge, etc.

Keywords:

Measurement and Instrumentation

Entry Points for HIV integration

- collection of measurement data (of HIV viral load and CD 4 T cells)
- screening of data (of HIV viral load and CD 4 T cells)
- precision and measurement error (of HIV viral load and CD 4 T cells)
E201: Probability and Statistics

Course description:
At the end of the course the student must be able to deal with statistics methods used in engineering fields, he must also know probability applications in engineer life.

Contents: 1. Calculation of average, variance, correlation and linear regression.

2. Calculation of probability;
   a. Permutation
   b. Combination
   c. Bias methods
   d. Chi square methods
   e. Conditional probability

Entry points for HIV integration
- Calculation of average, variance, correlation and linear regression.
  - Calculation of average of people who are HIV/AIDS positive
  - Estimate the number of people who will be affected by HIV/AIDS once they don't take precautions.
  - Show mathematically the distribution of HIV/AIDS in space and in time.

E202: Signals and Systems Theory

Course description:
At the end of this course the student will be able to identify different types of signals, noise using theory of Fourier, Laplace Z- transform and Matlab simulink as software tools.

Contents:
Types of signals, Fourier, Laplace Z- transform theory, Analysis of systems, Theory of noise, function transfer, Correction and compensation systems.
Entry points for HIV integration

- **Correction and compensation systems:** Correction and Compensation of HIV infected people by using anti-retroviral drugs and their engineering design by using feedback methods: PI, PID controller
- **Calculation of transfer function of systems:** Demonstration of human organism behavior facing HIV/AIDS using systems theory.
- **Simulation of the HIV/AIDS dynamics via Simulink:** To reveal the drug effects of low, median and high dosages, as well as multiple combination of two types of drugs: reverse transcriptase inhibitor (RTI) and protease inhibitor (PI).

E301: Automatic Control Systems

**Course description:**
At the end of this course the student will be able to identify systems, to correct them in case they are in unstable state. He will be able also to do automatic control of electrical or electronics systems.

**Contents:**

1. **Introduction to Control System:** Transfer function - Open loop and closed loop system - Feedback system (Positive and Negative feedback and effect of them on system) - Mathematical model of system (electrical and mechanical system, etc.) - Block diagram and signal flow graph, etc. Some numerical problem based on them.

2. **Feedback systems, Characteristics and Performance:** (time and frequency response with stability concept): Sensitivity of control system to parameter variations - Steady state errors - Transient Response - Time domain performance specifications - S plane root location – Concept of Stability (Phase margin and gain margin, etc.) - Hurwits stability criterion – Determination of location in S plane - The Root Locus concept (with parameter design and sensitivity).

3. **Analysis of Control System:** Time domain analysis - State space variables - Signal flow graph state model – Design and Compensation of feedback control system using Phase lag compensation (Derivative control), Phase lead compensation (Integral control), Phase lead and lag compensation (Derivative
Entry points for HIV integration
- Introduction to systems: modelling of HIV/AIDS in three variables, concepts of stable and unstable systems, with their relationships to vaccine study;
- Demonstration of HIV infection and AIDS progression using systems theory.
- Correction and Compensation of systems by feedback methods. PI, PID controller, in relation to HIV therapy design.
- Visualize the reducing of HIV versus antiretroviral treatment using PID controller

E401: Waste Water Treatment and Sewerage

Course description:
The aims of this module are for the students:
- To understand the concepts used in the planning, designing and management of wastewater treatment and sewerage systems.
- To understand principles of aerobic and anaerobic process in water treatment

Contents:
Physical, chemical and biological characteristics of waste water.
Introduction to reactor kinetics.
Anaerobic systems.

Entry points for HIV integration
- Physical, chemical and biological characteristics of waste water.
  ➢ To examine the quality of water to be supplied to people especially those who live with HIV/AIDS.
- Estimation of waste water flow
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