SCHOOL OF NUCLEAR AND ALLIED SCIENCES

JOINTLY ESTABLISHED BY

UNIVERSITY OF GHANA
AND GHANA ATOMIC
ENERGY COMMISSION

PRESERVING, MAINTAINING AND ENHANCING
NUCLEAR KNOWLEDGE IN GHANA AND AFRICA
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VISION OF THE SCHOOL

To be a leading Graduate School producing high caliber nuclear scientists and engineers to support the health care, industrial, environmental and the socio-economic development of Ghana and Africa.

MISSION OF THE SCHOOL

The School exists for preservation, maintenance and enhancement of nuclear knowledge in Ghana and Africa through the provision of high quality teaching, research, entrepreneurship training, service and development of postgraduate programmes in the nuclear sciences and technology.

INSTITUTIONAL AIM

The programmes which are harmonized to meet international standards by International Atomic Energy Agency (IAEA) provide the essential academic components of the professional training to ensure the contribution of nuclear and radiation science and technology to human welfare and
socio-economic development and their impact on human health, industry, agriculture and environment.

The main objectives of the School, among others, are:

i. To undertake postgraduate programmes in nuclear Sciences and Technology leading to the award of M.Phil and PhD degrees of the University of Ghana.

ii. To popularize nuclear Science and Technology programmes to attract high undergraduates.

iii. To engage in the hosting of AFRA and IAEA regional and inter-regional training courses/workshops, other international conferences/Seminars, and the conduct of research in the peaceful uses of nuclear and biotechnology techniques in Ghana and Africa as a whole.

iv. The research areas to be covered include: Health and Nutrition, Agriculture, Industrial and Environmental sectors as well as Waste Management.

v. To create international links with other Institutions with a tradition in nuclear education and research (such as the Institute for Advanced Studies of the University of Pavia, Italy, Nuclear Training Centre of South Korea, and the World Nuclear University, UK) for exchange of programmes and sharing of experiences.

For further information about the School, please contact:

The Senior Assistant Registrar
School of Nuclear and Allied Sciences
University of Ghana – Atomic Campus
P.O. Box AE 1, Atomic, Accra
Tel: 233-21-400723
Fax: 233-21-400807
Email: snas@gaecgh.org

The SCHOOL OF NUCLEAR AND ALLIED SCIENCES (SNAS) jointly established by the University of Ghana (UG) through the agency of the Faculty of Science and the Ghana Atomic Energy Commission (GAEC) and in co-operation with the International Atomic Energy Agency (IAEA), Vienna, offers accredited Master of Philosophy (M.Phil) and Doctor of Philosophy (PhD) programmes in the following areas of specialization:

1. Applied Nuclear Physics
2. Medical Physics (In collaboration with the School of Allied Health Sciences)
3. Radiation Protection
4. Environmental Protection
5. Nuclear and Radio-chemistry
6. Nuclear Engineering
7. Nuclear Agriculture
8. Radiation Processing
INTERNATIONAL NETWORKING

To strengthen the education and training of students of SNAS, the International Atomic Energy Agency is providing equipment for development of institutional capacity and facilitating networking with renowned nuclear institutions such as the European School of Advanced Studies on Nuclear and Ionizing Radiations Technology, (TNRI) of University of Pavia, Italy, the International Centre of Theoretical Physics, (ICTP), Trieste, Italy and the World Nuclear University, (WNU), UK.

FACILITIES

Laboratories are well-equipped for practical sessions. Major nuclear facilities are available in laboratories and centers of GAEC and at the National Centre for Radiotherapy and Nuclear Medicine at Korle-Bu and Komfo Anokye Teaching Hospitals. Some of the major facilities at GAEC are the Research Reactor and Gamma Irradiator. Various Equipment exist in Non-destructive Testing, Secondary Standard Dosimetry, X-Ray Fluorescence, Solid State Nuclear Track Detection, and Neutron Activation Analysis Laboratories. Fabrication and Machine Shops, Digital Electronics and Nuclear Instrumentation Centre are also available for the design and manufacture of components to support R&D activities.

FACULTY

In addition to the faculty members from Ghana Atomic Energy commission (GAEC), the University of Ghana (UG), the Kwame Nkrumah University of Science and Technology (KNUST) and the University of Cape Coast (UCC), adjunct professors, lecturers and scholars will be recruited from partnership institutions and the International Atomic Energy Agency (IAEA) Member States to lecture and co-supervise PhD Sandwich programmes of the School.

DURATION

The duration of the M.Phil programmes will be for two years. The first year will consist of didactic academic training and the second year will be devoted to practical exposure, individual research projects, seminar presentations and preparation of Thesis. The PhD programmes are normally for three years.

HOW TO APPLY

Application forms can be purchased from the Cash Office at the Registry, University of Ghana, Legon. All enquiries about admissions should be addressed to:

The Director  (Academic Affairs Directorate)
University of Ghana
Registrar’s Office
P. O. Box LG 25
Legon, GHANA
DEPARTMENTS AND PROGRAMMES
OF THE SCHOOL

DEPARTMENT OF APPLIED NUCLEAR AND RADIATION SCIENCES

PROGRAMMES

M.Phil in Applied Nuclear Physics
M.Phil in Radiation Protection
M.Phil in Nuclear Radiochemistry
M.Phil in Nuclear and Environmental Protection

DEPARTMENT OF NUCLEAR AGRICULTURE AND RADIATION PROCESSING

PROGRAMMES

M.Phil in Nuclear Agriculture
  Option 1. Mutation Breeding and Plant Biotechnology
  Option 2. Soil Water and Crop Nutrition

M.Phil in Radiation Processing (to start from 2007/2008 academic year)

DEPARTMENT OF MEDICAL PHYSICS

PROGRAMME

M.Phil in Medical Physics

DEPARTMENT OF NUCLEAR ENGINEERING

PROGRAMME

M.Phil in Nuclear Engineering
  Option 1. Reactor Physics
  Option 2. Reactor Engineering
SCHOOL OF NUCLEAR AND ALLIED SCIENCES

UNIVERSITY OF GHANA AND GHANA ATOMIC ENERGY COMMISSION

APPENDICES FOR PROGRAMMES (COURSE CONTENTS)

(PRESERVING, MAINTAINING AND ENHANCING NUCLEAR KNOWLEDGE IN GHANA AND AFRICA)
COURSE DESCRIPTIONS
OF PROGRAMMES
DEPARTMENT OF APPLIED NUCLEAR AND RADIATION SCIENCES

PROGRAMMES

M.Phil in Applied Nuclear Physics
M.Phil in Radiation Protection
M.Phil in Nuclear Radiochemistry
M.Phil in Nuclear and Environmental Protection
1. MASTER OF PHILOSOPHY (M.PHIL.) IN APPLIED NUCLEAR PHYSICS

ADMISSION REQUIREMENTS

i. The minimum qualification is a good first degree (at least a second class lower division) in any of the following fields: Physics, Chemistry, Chemical Engineering and Engineering Science from any approved University.

ii. In the case of a candidate who does not satisfy the requirement in an appropriate field of study but is otherwise adjudged suitable, other equivalent qualifications with appropriate experience will be considered.

YEAR 1.

CORE COURSES

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<th>COURSE TITLE</th>
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<td>ANPH 601:</td>
<td>Principles of Nuclear Physics</td>
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<tr>
<td>NENG 601:</td>
<td>Basic Reactor Physics</td>
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<td>ANPH 602:</td>
<td>Nuclear Instrumentation and Electronics</td>
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<td>ANPH 604:</td>
<td>Radiation Dosimetry</td>
<td>4</td>
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<td>ANPH 610:</td>
<td>Practical exercises</td>
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<td>NENG 607:</td>
<td>Health Physics and Radiation Protection</td>
<td>3</td>
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<td>NENG 611:</td>
<td>Computational Methods in Engineering</td>
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ELECTIVES

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<tr>
<td>ANPH 603:</td>
<td>X-ray Fluorescence Spectroscopy (XRF)</td>
<td>3</td>
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<td>ANPH 605:</td>
<td>Atomic Absorption Spectroscopy (AAS)</td>
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<td>ANPH 606:</td>
<td>Neutron Activation Analysis (NAA)</td>
<td>4</td>
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<tr>
<td>ANPH 608:</td>
<td>Solid State Nuclear Tract Detection (SSNTD)</td>
<td>4</td>
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<tr>
<td>ANPH 620:</td>
<td>Seminar 1</td>
<td>3</td>
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The 4 electives will consist of both lectures and laboratory work. Candidates are expected to choose any three (3) elective courses.

YEAR 2

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<tr>
<td>ANPH 600</td>
<td>Thesis</td>
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<tr>
<td>ANPH 630</td>
<td>Seminar 2</td>
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The second year is devoted to research project. The research projects may be chosen from the following fields:
COURSE DESCRIPTIONS

ANPH 601: PRINCIPLES OF NUCLEAR PHYSICS (3 Credits)
Radioactive Decay and Decay Processes: Radioactive Equilibrium; Alpha Decay; Beta Decay; Gamma Decay. Interaction of Radiation with Matter: Mechanisms; Elastic Collisions; Non-elastic Collisions; Stopping Power; Energy Losses by Collision; Radiation Loss of Energy.

ANPH 602: NUCLEAR INSTRUMENTATION AND ELECTRONICS (4 Credits)
Power Supplies: Half wave, full wave bridge rectifier circuits; Regulated power supplier using zener diode operational amplifier and 7800 series regulators; High voltage supplier; AC-DC converters; Constant current source; Line conditioners; Switching regulators. Analog Circuit: Discriminations; Inverting and non-inverting amplifiers; Integrators; Signal and pulse generator circuits; Sample and hold circuits; Differentiators and pole cancellation; Complex pole filtering; Base line restoration circuits; Simple spectroscopy amplifier; Selecting an FET; Preamplifier; Noise measurement; Time interval to amplitude conversation; Coaxial cables and delay lines. Digital Circuits: Standard input characteristics and interfacing of logic gates; Special input and outputs of logic gates; Combinational logic; Timing circuits and oscillators; Latches and flip flops; Counters and shift registers; Memories; Design of sequential circuits; Logic analyzers

Rate Meters and Multi-channel Analysis: Pulse stretcher; Wilkinson type analogy to digital converters (ADC); Successive approximation ADC; Flash ADC; Voltage to frequency converters; Rate meters; Scalars; Multi-channel analyzers. Radiation Detectors: Overview of radiation detectors; Charged particles spectroscopy; Scintillation detectors; High resolution gamma detectors; High resolution x-ray detectors; Neutron detection; Coincidence circuits. Special Topics: EURO bin and power supply; High voltage power supply:0-2000 V, negative; Geiger Muller rate meter; Single channel analyzer; Staircase generator; Spectroscopy amplifier; Negative feedback* NIM BIN*

ANPH 604: RADIATION DOSIMETRY (4 Credits)
Radiation and Radiation Fields: Introduction; Radiation sources, Radiation Field’s quantities and units; Interaction of Ionizing Radiation With Matter: Interaction cross sections and coefficient; Interaction of photons with matter; Interaction of neutrons with matter; interaction of charged particles. Theory of Radiation Detection and Measurement: Detection by ionization in gases; Ionization chambers with current measurements; Condenser chambers; Pressure ionization chambers; Extrapolation chambers. Ionization Detectors Counting Pulses: Proportional chambers; GM tubes quenching; Pulse counting scalars and rate meters; Discriminators; Pulse height analysis - coincidence and anti-coincidence.
Detection by Excitation: Scintillation counters; Solid and liquid counting and pulse height analysis; Pulse shape analysis. Other Types of Detectors: Semi-conductor detectors; Photographic emulsions; Thermoluminescent detector; Track detectors; Neutron detectors by (n,a) or (n,p) reactions or by activation. Dosimetry of Radionuclide: Classification of radionuclide; Physical radio nuclide characterization; Radiological control; External exposure; Internal exposure. Radio nuclide and radiation protection date: Emission data and exemption loads; External exposure; Contamination; Internal exposure for workers; Determination of absorbed dose via air karma; Determination of absorbed dose from cavity theory.

**ANPH 606: NEUTRON ACTIVATION ANALYSIS** (4 Credits)
Overview of Nuclear Activation Analysis: General aspects of trace analysis; Methods suitable for trace analysis; Properties of neutron activation analysis; Cross Section in Neutron Activation Analysis: Definition; Practical consideration; Calculations of reaction rates for reactor and accelerator irradiations. Some Application of Neutron Induced Reactions: The cadmium ratio (CR); Neutron spectra; Determination of activation cross sections; Neutron Sources: The nuclear reactors; Neutron from accelerators; Isotopic neutron sources.

Growth and Decay of Radioactivity during and after Irradiation: Laws of radioactive decay; Laws of radioactive daughters; Transformation in a neutron flux. Preparation of Samples and Standards: Preparation of samples; Preparation of standards; Choice of a suitable irradiation facility. Principles of Nuclear Activation Analysis: Overview of nuclear activation analysis-general theory; Advantages and disadvantages of nuclear activation analysis; Interferences in activation analysis. Principles of Neutron Activation Analysis: Overview of Neutron Activation Analysis Procedures; Thermal neutron activation analysis (TNAA); Epithermal neutron activation analysis (ENAA); Fast neutron activation analysis (FNAA); Methods of qualification.

Prompt Gamma Neutron Activation Analysis (PGNAA): Charged particle activation analysis (CPAA); Principles of CPAA; Calculations of CPAA; Application of CPAA; Particle induced gamma ray emission (PIGE). Instrumental Photon Activation Analysis (IPAA): Specialized Activation Analysis Techniques; Derivative Activation Analysis; Cyclic Activation Analysis; Localisation methods in activation analysis. Instrumental Neutron Activation Analysis: General principles; Techniques based on nuclear properties; Analysis of complex decay curves; Coincidence techniques; Spectrum Stripping; Mixed Gamma Spectrometry; Use of computers; Use of special detection systems; Automated Activation Analysis.

Radiochemical Neutron Activation Analysis: Systematic Errors in Activation Analysis; General considerations; Sources of error using the comparator method; Anomalous isotopic abundance; Errors due to different fluxes in samples and standards; Interfering nuclear reactions; Different counting efficiency; Dead time corrections; Other errors. Limits for Qualitative Detection and Quantitative Determination in Activation Analysis: Introduction; Definitions-signal detection; Lower limit of detection of quantitative determination for coincidence counting.

**ANPH 603: X-RAY SPECTROMETRY** (4 Credits)
Dispersive X-Ray Spectroscopy; Semiconductor Detectors for EDXRF; Typical X-Ray Tube Excitation Systems for EDXRF; Applications of Tube-Excited EDXRF.

Spectrum Evaluation: Fundamentals Aspects; Spectrum Processing; Background Evaluation; Simple Net Peak Area Determination; Least Square Fitting using Reference Spectra and Analytical Functions; Monte Carlo Methods; Various Computer Algorithms. Qualification by Infinitely-Thick and Intermediate-Thickness Samples; Correlation between Intensities and Concentration; Factor Influencing the Accuracy of Intensity Measurement; Emission Transmission Method; Absorption Correction Methods using Primary Scattered Radiation; Converting Intensities to Concentration.

Other types of X-Ray Analysis: Radioisotope X-Ray Analysis; Synchrotron Radiation-Induced X-Ray Emission; Total Reflection XRF; Polarised Beam XRF; Particle-Induced X-Ray Emission Analysis; Electron Induced X-Ray Emission Analysis. Sample Preparation: Fundamentals of Sample preparation; Solid Samples; Fused Specimens; Liquid Samples; Biological Samples; Atmospheric Particles; Sample Support Materials. Errors and Limit of Detection: General Sources of Errors; Error Propagations and Computation; Lower Limit of Detection

ANPH 605: ATOMIC ABSORPTION SPECTROSCOPY (4 Credits)
Principles of atomic absorption: Atomic Absorption; Emission and fluorescence. Operation and basic components of an AAS: The basic AA process; Optical system; Electronic system; Spray chamber and nebuliser system, burners and flame types. Calibration techniques: Simple on standard calibration; Calibration by standard addition; Curve due to stray light. General performance: Sensitivities and detection limits; Precision and accuracy; Optimization of operating parameters. Interference effects: Stable compound formation; Ionization matrix effects; Background absorption. Preparation of standard and sample solutions: Aqueous standards and reagents; Non-aqueous solutions; Sample preparation; Solvent extraction.

Sample accessories: Electro thermal atomizers (furnaces); Auto samplers; Mercury cold vapour system; Vapour generation system; Slotted tube atom trap (STAT). Application: Agricultural analysis; Clinical and biochemistry applications; Metallurgy; Oil and petroleum; Siliceous materials; Water and effluents. Methods: Metallurgical – aluminium alloys, copper alloys, iron and steels, lead and tin alloys; Petrochemical – fuel and lubricating oils; Environmental – arsenic and selenium in waters, soils, plants materials, mercury in foods; Clinical – copper and zinc in serum, serum electrolytes, etc.

ANPH 608: SOLID STATE NUCLEAR TRACK DETECTION (4 Credits)
Introduction: Heavy Ion Interaction with Matter: Characteristic of a Track Detector; Nature of the Material; Etching Techniques; Track Evaluation; Sensitivity to Environmental Effects: Thermal; Gases; Radiation; Available Detectors. Applications; Elemental Mapping; Uranium Determination; Fission Track Dating; Geology and geochemistry; Radiography: charged particle and neutron; Dosimetry: radon and neutron

ANPH 610: PRACTICAL EXERCISES (3 Credits)

RECOMMENDED TEXTBOOKS
PRINCIPLES OF PHYSICS
1. Introduction to Atomic and Nuclear Physics. Henry Semat, Chapman & Hall Ltd.

**NEUTRON ACTIVATION ANALYSIS**
1. Neutron Activation Analysis. D. De Soate, R Gijbels and Hoste (1972) Wiley Inter science
2. Practical Aspects of Operating a Neutron Activation Analysis Laboratory IAEA - TECDOC-564 (1990)

**X-RAY FLUORESCENCE SPECTROSCOPY**
4. Total Reflection X-Ray Fluorescence Analysis - Reinhold Klockenkamper
5. X-Ray Spectroscopy in Environmental Sciences - Vlado Valkovic
6. X-Ray Fluorescence Analysis of Environmental Samples - Edited Thomas G. Dzubay.

**SOLID STATE NUCLEAR TRACT DETECTION**

**NUCLEAR INSTRUMENTATION AND ELECTRONICS**
1. The Art of Electronics, Paul Horowitz, Winfield Hill

**RADIATION DOSIMETRY**
3. Physics of Medical Imaging, P. Sprawls, Medical Physics Publishing
10. Introduction to Health Physics Herman Cember, Pergamon Press.

ATOMIC ABSORPTION SPECTROSCOPY

REACTOR PHYSICS
1. Nuclear Reactor Theory. J.R. Lamarsh (1965)
2. An Introduction to Reactor Physics W.S.C. Williams, Oxford Scientific Production

TEACHING STAFF LIST

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Name of Lecturer</th>
<th>Highest qualification, Institution &amp; Year</th>
<th>Status</th>
<th>Status of Appointment</th>
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<tbody>
<tr>
<td>ANPH 601</td>
<td>Principles of Nuclear Physics</td>
<td>Prof. E.K. Agyei</td>
<td>PhD</td>
<td>Assoc. Professor</td>
<td>Part-Time</td>
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<tr>
<td></td>
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<td>Mr. K. Anim-Sampong</td>
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<tr>
<td>ANPH 603</td>
<td>X-Ray Fluorescence Analysis</td>
<td>Prof. G.K. Tetteh,</td>
<td>PhD Univ. Saskat M.Phil., UG (1990)</td>
<td>Professor Snr. Lecturer</td>
<td>Part-Time</td>
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<td>Mr. I.J.K. Aboh</td>
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<td>ANPH 605</td>
<td>Atomic Absorption Spectroscopy</td>
<td>Mr. S.A. Dogbe</td>
<td>M.Sc. Univ. Cransfield</td>
<td>Snr. Lecturer</td>
<td>Full-Time</td>
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<td></td>
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<td>Mr. P.K. Afriyie,</td>
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<td>Mr. E. Boadu</td>
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<tr>
<td>ANPH 604</td>
<td>Radiation Dosimetry</td>
<td>Prof. Emi-Reynolds</td>
<td>M.Sc. KNUST Ph.D. UG, 2005</td>
<td>Assoc. Prof. Snr. Lecturer</td>
<td>Part-Time</td>
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<td></td>
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<td>Dr. E.O. Darko</td>
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<tr>
<td>ANPH 610</td>
<td>Practicals</td>
<td>Mr. B. J. B. Nyarko</td>
<td>M.Phil</td>
<td>Snr. Lecturer</td>
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<td>Mr. O. C. Oppon</td>
<td>MSc.</td>
<td>Snr. Lecturer</td>
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<tr>
<td>ANPH 606</td>
<td>Neutron Activation Analysis</td>
<td>Mr. B.J.B. Nyarko</td>
<td>M.Phil.,UG</td>
<td>Snr. Lecturer</td>
<td>Full-Time</td>
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<tr>
<td>ANPH 608</td>
<td>Solid State Nuclear Tract Detection</td>
<td>Mr. O.C. Oppon</td>
<td>M.Sc., France</td>
<td>Snr. Lecturer</td>
<td>Full-Time</td>
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2. **MASTER OF PHILOSOPHY (M.PHIL) IN RADIATION PROTECTION**

**ADMISSION REQUIREMENTS**

i. The minimum qualification for this programme is a good first degree (at least a second class lower division) in any of the following fields: **Physics, Chemistry, Biology and Engineering** from any approved University.

ii. A candidate who does not satisfy the requirement in an appropriate field of study as above but is otherwise adjudged suitable by virtue of appropriate experience will be considered.

**YEAR 1**

<table>
<thead>
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<th>COURSE CODE</th>
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<tr>
<td>RADP 601:</td>
<td>Review of Fundamentals</td>
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<td>RADP 603:</td>
<td>Radiation Quantities and Measurements</td>
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<td>RADP 605:</td>
<td>Biological Effects of Ionizing Radiations</td>
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<td>RADP 609:</td>
<td>External and Internal Exposure and dose Assessment</td>
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<td>RADP 611:</td>
<td>Sources and Protection Against Non-Ionizing Radiation.</td>
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<td>RADP 619:</td>
<td>Intervention for the Protection of the Public in Situations of Chronic and Acute Emergency Exposure</td>
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<td>RADP 617:</td>
<td>Demonstrations (During Inter-semester break)</td>
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<td>RADP 602:</td>
<td>Occupational Radiation Protection</td>
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<td>RADP 604:</td>
<td>Medical Exposure in Diagnostic Radiology Radiotherapy and Nuclear Medicine</td>
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<td>Exposure of the Public due to Practices and Environmental Protection</td>
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<td>RADP 614:</td>
<td>Technical Visits and Case Studies</td>
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<td>RADP 616:</td>
<td>Regulatory Framework For control of Radiation Sources</td>
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<td>RADP 610:</td>
<td>Seminar 1</td>
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**YEAR 2**

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<tr>
<td>RADP 620:</td>
<td>Seminar 2</td>
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<tr>
<td>RADP 600:</td>
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Total Credits in year 1: 35
Total Credits in year 2: 33

COURSE DESCRIPTIONS

RADP 601: REVIEW OF FUNDAMENTALS (3 Credits)
Introduction: Overview of the training course: aim, learning objectives, content and schedule
Introduction to radiation protection and the safety of radiation sources. Basic nuclear physics.
Introduction to atomic structure: Neutrons, protons and electrons; periodic table; atomic mass,
isotopes of element; excitation, ionization; binding energy; accelerated particles; characteristic X
rays, bremsstrahlung; auger electrons, internal conversion; energies. Radioactivity; Nuclear
stability; unstable nuclei; radionuclides; modes of disintegration alpha, beta, gamma; types of
spectra; positron; electron capture; table of radionuclides; activity; law of radioactive decay; half-
life; decay constant; mean life; activity, units; decay chains and equilibrium. Nuclear reactions
Types of reactions; induced radioactivity; fission and fusion (energy considerations); cross section;
energetics of reactions.

Basic mathematics: Differentiation/integration; decay equations (exponential functions); first order
ordinary linear differential equations with a constant; Statistics; Accuracy; precision; reliability;
student T test; Chi square; probability theory; random variables; distributions: different types (log-
normal, binomial, Poisson, Gaussian); scatter diagram; mean, mode, median; standard deviation;
standard error; confidence levels; regression; correlation; practical application to counting; curve
fitting by least square methods. Charged particle radiation: Heavy particles (alpha, proton nuclei)
Energy transfer mechanisms, ionization, scattering nuclear interaction; range–energy relationship;
Bragg curve; stopping power; shielding; Beta particles; Mechanisms of energy transfer;
relationships; bremsstrahlung; Cerenkov radiation; shielding.

Uncharged radiation: X and gamma rays; Photoelectric effect; Compton scattering; pair production;
secondary photon production; linear mass attenuation coefficient; exponential attenuation; effect of
Z on absorbing medium; buildup correction; shielding. Neutrons; Interaction; scattering; absorption;
energy categories; neutron activation; radioactive capture (n, p), (n, γ); moderation; shielding;
Induced radioactivity: by charged and uncharged particles. Natural radiation: Terrestrial
radionuclides: Uranium (235U and 238U), 232Th, 40K; important radionuclides in 238U and 232Th decay
chains (Ra, Rn emanation, etc.); NORM; Cosmic radiation: types of cosmic radiation; variation
with latitude and altitude. Human made radioactive sources: Radioactive sources: beta, alpha,
gamma and X ray sources; isotopic neutron sources; sealed sources; unsealed sources and isotope
generators; source enclosures; fallout; general safety of radiation sources; production of
radioisotopes; Nuclear reactors: review of fission and fusion reactions; moderation of neutrons;
neutrons, multiplication factor, criticality; basic elements of a nuclear reactor; types of reactors;
research reactors; nuclear fuel cycle installations; Consumer products

RADP 603: RADIATION QUANTITIES AND MEASUREMENTS (2 Credits)
Radiometric quantities and interaction coefficients: Radiation field; fluence (rate); energy fluence
(rate); cross section; mass attenuation coefficient; mass stopping power. Dosimetric quantities:
Exposure (rate); kerma (rate); energy imparted; absorbed dose (rate); linear energy transfer (LET),
linear energy; organ dose. Radiation protection quantities: Equivalent dose (rate); radiation
weighting factor (wR); Effective dose, tissue weighting factor (wT); operational quantities: ambient
dose equivalent; directional dose equivalent; personal dose equivalent; intake; committed dose. Dosimetric calculations: Relationship between fluence, kerma and absorbed dose; air kerma rate constant; calculation of kerma and absorbed dose; Bragg-Gray cavity principle; measurement of absorbed dose with ionization in gas filled cavity; electronic equilibrium; composition of homogeneous cavity; large cavity; small cavity; recombination effects; correction factors for determination of absorbed dose to water in photon and electron beams; Point sources, plane sources, and volume sources; absorption and scattering in air and in the body; attenuation of primary radiation and buildup of secondary radiation; concepts of extended and aligned fields; influence of geometry; Calculation of dose from neutron sources; Microdosimetry; tissue equivalent detectors

Detectors: Gas filled detectors; Ionization chambers with current measurements; condenser chambers; pressure ionization chamber; extrapolation chambers; proportional chambers; GM tubes Scintillation detectors:Solid and liquid scintillators; quenching; Semiconductor detectors; Photographic emulsions; Thermo luminescent detectors; Nuclear track detectors; Neutron detectors Detectors using (n, γ) or (n,p) reactions or activation or others; Imaging detectors; Other detectors: electrets; self-powered detectors; thermally stimulated exoelectron emission (TSEE); radiophoto luminescent detectors (RPLD); Measurement techniques: Efficiency (geometric and intrinsic), background, geometry, statistics; pulse counting scalers and rate meters; discriminators; resolution; pulse height analysis - coincidence and anticoincidence; pulse shape analysis; computer analysis of spectra

RADP 605: BIOLOGICAL EFFECTS OF IONIZING RADIATION (2 Credits)

Basic radiation chemistry: Breakage of chemical bonds by excitation ionization; biologically important elements; direct and indirect effects of radiation: generation of free radicals, interaction with DNA; interaction with proteins and lipids. Effects of radiation on cells: Chromosomes; DNA; point mutations, chromosome breaks, mitosis; mitotic dysfunction, cell death; consequences of cell death; consequences of cell damage, DNA repair; cell sensitivity; radiosensitizers and protectors; chromosome aberrations as biological indicator of dose. Effects of whole body irradiation: General dose-response curve; threshold; severity; acute radiation syndrome; haematopoietic system; gastrointestinal tract; central nervous system. Effects of partial body irradiation: Skin (erythema, ulceration, effect of radiation type and radiation quality); thyroid, lung, eye lens; gonads; threshold doses; effect of fractionation and dose rate; case histories (accidental exposures)

Stochastic effects: Cancer induction and development; sources of data: atomic bomb survivors, dial painters, medical exposures, miners, animal data; Dose-response relationship; absolute and relative risk models; dose and dose rate effectiveness factors; ICRP risk factors, fatal and non-fatal cancers. Stochastic hereditary effects: Elementary genetics; natural mutations; production of gametes and damage to chromosomes (examples); gene mutations; sources of data: man and animals; concept of doubling dose; UNSCEAR and ICRP approach; ICRP risk assumptions: subsequent generations and severity. Radiation effects: Sensitivity at different stages of development; brain development and retardation; induction of leukemia and cancers. Epidemiological studies: Statistical requirements, current types of studies; association and confounding factors, power and precision; prospects and pitfalls. Radiation detriment: Need for an aggregated measure of harm; tissue weighting factor wT, effective dose; dose limits, concept of collective dose; approach adopted by ICRP; comparison of risks from different activities
RADP 607: PRINCIPLES OF RADIATION PROTECTION, THE INTERNATIONAL FRAMEWORK AND NUCLEAR SAFETY (2 Credit)

Conceptual framework: The ICRP Basic Framework (types of exposure, control of radiation sources); brief review of quantities, including collective dose; The System of Radiological Protection in proposed and continuing practices; Justification of a practice; optimization of protection with examples; individual dose limits; Potential exposures; dose and risk constraints System of protection for intervention. Assessment of the effectiveness of the system of protection. International organizations: International Atomic Energy Agency (IAEA): Statutory functions; establishment and implementation of safety standards, legally binding instruments: Conventions International Commission on Radiological Protection (ICRP); International Commission on Radiation Units and Measurements (ICRU); United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR); International Labor Organization (ILO); World Health Organization (WHO); Food and Agriculture Organization of the United Nations (FAO); OECD Nuclear Energy Agency (OECD/NEA); Pan American Health Organization (PAHO); Safety culture of staff at all levels; Priority to safety: policies, procedures; responsibilities; the lines of authority for making decisions; organizational arrangements; communication lines; Safety culture indicators Examples of safety culture

RADP 609: EXTERNAL AND INTERNAL RADIATION EXPOSURE AND DOSE ASSESSMENT (3 Credits)

Dosimetric quantities (review): The radiation weighting factor $w_r$ in terms of unrestricted linear energy transfer in water; equivalent dose; tissue weighting factor $w_T$; effective dose; personal dose equivalent $H_p(0.07)$ and $H_p(10)$; the ambient dose equivalent $H^*(d)$ and the directional dose equivalent ($H^*'(d)$); The monitoring programmes for individual dose assessment; Design of monitoring programmes; Personal dosimetry; Assessments of effective dose in various external exposure conditions: practical approximations; Integrating personal dosimeters (TLD, film, condenser chambers, etc.) calibrated for personal dose equivalent; use of electronic personal dosimeters; performance requirements for personal dosimeters; Whole body, extremities and skin dosimetry; Routine, special, accidental exposure assessment; Analysis of uncertainties: Type A) inhomogeneity of detector sensitivity readings due to limited sensitivity and background, variability of detector readings at zero dose; Type B) energy dependence, directional dependence, non-linearity of the response, fading due to temperature and humidity, effects due to exposure to light, or to other types of ionizing radiation, mechanical shock, calibration errors, variation in local natural background

Monitoring programme for the work place: Routine, task related and special monitoring; fixed and portable monitors; monitoring for work planning purposes; monitoring to detect changes in the working environment; monitoring systems for radiation fields, for surfaces, noble gases; use of ambient dose equivalent and directional dose equivalent; dose rate meters for receptor free conditions calibrated for ambient and directional quantities. Interpretation of measurements: Recording levels; evaluation of doses to whole body, extremities and skin; calculation of the effective dose caused by external exposure; routine, task related and special monitoring. Calibration: Primary and secondary standards; sources used for calibration; calibration; Routine testing of equipment, performance testing, type testing. Quality assurance: Quality assurance procedures. Modes of intake: Inhalation (particle sizes, AMAD, determination of size distribution of aerosols), ingestion and absorption through skin or wounds; influence of specific activity and physicochemical state: retention in tissues, complexation, polymerization, etc; Special case of
tritiated water and vapor: intake through skin of splashed water and of vapor and respiratory intake; Intakes of radionuclides by workers; intakes of radionuclides by members of the public.

Monitoring programme: Monitoring programme for exposure due to the intake of radionuclides Monitoring programme: need, design of a routine monitoring programme, methods of measurement, frequency of monitoring, reference levels, special monitoring; Workplace monitoring: surface, air; the concept of DAC; Direct methods for personal monitoring: principles; measurement geometry: whole body, thyroid, lung; methods of detection; measurement procedures; Indirect methods for personal monitoring: biological samples (urine, faeces, breath, blood, nose blows, tissue sample); normalization of samples; physical samples (air samples, surface samples); handling methods; methods of analysis (radiochemical separation, detection). Biokinetic models used by ICRP:

Quantitative aspects of intake; uptake into blood and transport to various organs; deposition in organs; Modeling by compartment models; relationships between compartments as one basis for specifying monitoring procedures; retention and elimination; exponential compartments, biological half-life and effective half-life; Non-exponential retention; body model ICRP (standard man); gut model; lung model; age dependent models; entry through wounds and intact skin; Performance requirements for detection systems in internal dosimetry; Calculation of committed effective dose Committed effective dose; committed effective dose per unit of intake; committed effective dose per unit intake in the standard adult and as a function of age; consistency of the measurements with biokinetic models; dosimetric models of ICRP; Calculation of the organ contribution to the effective dose; Primary and secondary limits; Special case of radon and radon progeny; Software for internal dose calculation (characteristics and availability).

Calibration: Calibration of body counters; calibration of the biochemical techniques; intercomparison of radiochemical assays; standards; routine testing of equipment. Quality assurance: Quality assurance procedures

**RADP 611: SOURCES OF AND PROTECTION AGAINST NON-IONIZING RADIATION**

(2 Credits)

Static and ELF Electric fields; Ultraviolet, Visible and Infrared radiation; Lasers, Visual displays Units, Radiofrequency radiation; Mobile phones and base stations; Protection principles; Dosimetry and instrumentation. Nuclear safety: Criticality safety. Research reactor safety. Reactor accidents and lessons learned.

**RADP 617: DEMONSTRATIONS**

(3 Credits)

**DEMONSTRATIONS**

1. Presentation of different types of radiation sources and explanation of their application; natural and human made radionuclides; consumer products.
2. Demonstration of radioactive decay: charts of nuclides, use of books and software for sources of nuclear data.
3. Demonstration of shielding properties of different materials and examples of shielding calculations.
5. Demonstration of absorption of beta radiation within sources of different thickness (‘self-absorption’).
6. Demonstration of each type of portable monitor for alpha, beta, gamma and neutron radiations and explanation of the respective applications; use and consultation of equipment manuals.

7. Determination of background level of radiation.

8. Reading of thermoluminescent dosimeters.


10. Use of computer aided materials for an information system for a regulatory authority (for example, the IAEA Regulatory Authority Information System (RAIS)).

11. Use of thermoluminescence dosimetry and film dosimetry for personal dose assessment.

12. Demonstration of practical monitoring systems for areas, surfaces and air.

13. Use of personal protective equipment.


**RADP 619: INTERVENTION FOR THE PROTECTION OF THE PUBLIC IN SITUATIONS OF CHRONIC AND ACUTE EMERGENCY EXPOSURE**

(2 Credits)

Principles for intervention: Chronic exposure situations: types - radon, residual contamination, etc.; remedial action plans; action levels; Nuclear and radiological accidents: nuclear reactor accident; accident with radiation sources, accident outside the country with transboundary effects; nuclear powered satellites and re-entry; history of past accidents; lessons learned. Emergency response Concepts and objectives of emergency response; principles of intervention, including intervention levels; protective actions and operational intervention levels; emergency response strategies; generic response organization. Emergency preparedness: Concepts and objectives of emergency preparedness; emergency planning categories; planning areas and zones; planning levels and responsibilities; planning elements for emergency preparedness; integrated planning concepts; personal protective equipment and devices; training; exercises.

Implementation of emergency response plans: Step by step approach to developing and implementing emergency response plans and procedures; identification and assignment of critical tasks; concept of operations; national emergency response plan. Checklists of emergency preparedness; considerations for radiological and nuclear accidents: infrastructure elements; functional elements. Assessment of radiological emergency. Accident scenarios; generic response organization in a radiological emergency; emergency management; response at the scene: co-ordination of organizations involved; initial response; radiological response: source recovery; decontamination; removal of radioactive wastes; dose assessment overview: external and internal; lessons learned from Goiânia accident.

Assessment of nuclear emergency: Events leading to a release from the core; releases from the core and to the environment; exposure pathways; protective actions; revision of operational intervention levels; lessons learned from reactor accidents (Three Mile Island, Chernobyl). Emergency monitoring overview. Objectives; generic monitoring organization and strategy; small and large scale accidents; staff qualification; instrumentation; basic survey method during an emergency; quality assurance. Field radiation and contamination monitoring: Objectives; basic methods and techniques (plume survey; ground deposition survey; environmental dosimetry; source monitoring; surface contamination survey; aerial survey); field sampling: objectives; methods and techniques (sampling of air; soil; milk; human food; pasture; sediment) measurement techniques; gamma spectrometry (laboratory and in situ); gross alpha and beta measurements; radiochemical analysis.

Radiation protection of monitoring teams:
Objectives; personal protection guides; personal monitoring; simple decontamination techniques. Basic data evaluation: Methods; field monitoring data evaluation; radionuclide concentration data evaluation; mapping; link to operational intervention levels. Medical management: Responsibilities and management of medical intervention; the triage of victims; diagnosis and treatment; training of those involved in medical management of the victims (medical, paramedical staff); psychological effects. Communication: Communication with the public and other parties, including regulatory authority in neighboring countries; objectives of communication with the public; spokesperson; preparation of message; communication methods and means; communication schedule; resources; training on communications. International co-operation: Safety conventions and their implementation. IAEA Emergency Response Network (ERNET).

**RADP 602: OCCUPATIONAL RADIATION PROTECTION**  
(3 Credits)

Radiation protection programme: Prior radiological evaluation and safety assessment; scope and structure of the radiation protection programme; responsibility and commitment of registrant, licensees and employers; responsibility of workers and others at the workplace; radiation protection organization; special administrative arrangements; infrastructure; role of the radiation protection officer; role of the qualified expert; lines of communication (internal, between employers, with regulatory authority); safety culture; quality assurance; emergency preparedness. Technical aspects of radiation protection against sealed and unsealed sources: General principles; Time, distance and shielding; minimum number of sources; protection against contamination; house keeping; hierarchy in protective measures – infrastructure (design) and procedures. Safety and security of sources: Physical protection of sources and waste; leak testing, signs and tagging; conditioning; shielding; storage; decommissioning; emergency procedures. Features of facility design: Design feature (considering also scattering effects); ventilation system; shielding calculation; safety interlocks; remote handling equipment; fume hoods; hot cells; glove boxes; changing room; physical barriers; storage facilities; liquid effluent pipeline and decay control; fixed radiation monitors; warning signs; quality assurance; commissioning survey and regulatory review.

Personal protection: Protective clothing; respiratory protection; contamination control; decontamination; Administrative and procedural controls. Classification of areas: Controlled and supervised areas; Policies and procedures; Local rules and supervision; justification of practices and interventions, compliance with dose limits; record keeping and reporting. Optimization of radiation protection: Commitment to optimization; the optimization process; investigation levels; dose constraints; use of decision aiding techniques. Quality assurance: Routine assessment of management and technical performance; audits and review; feedback for improvements. Training: Induction training for new comers; specific safe working procedures; refresher training; communication skills. Monitoring: Purposes of monitoring; Individual monitoring for external and internal exposure; Workplace monitoring; choice of instrumentation and methods; Interpretation of results; record keeping. Health surveillance: Objectives; responsibilities; medical examination of workers; content of training for the physicians; counseling; management of overexposed workers.

Potential exposures: Safety assessment of structures, systems, components and procedures related to protection and safety including modifications of such items. Documentation of safety assessments: Accident prevention, mitigation and management, design provision and quality assurance for
control of potential exposures; investigations of accidents, incidents and abnormal exposures and follow-up with corrective action. Industrial radiography: Overview of industrial radiography; types of exposure devices (gamma radiography sources and containers; X ray radiography equipment; pipe crawler equipment; real time radiography); organizational responsibilities; specific regulatory requirements; basic requirements for safety (design and use of shielded enclosures; site radiography procedures; storage and transport of sources; safety associated with the equipment maintenance); radiation protection programme: protection of workers; protection of the public; emergency preparedness and response; lessons learned from accidental exposure in industrial radiography.

Industrial irradiators and accelerators: Overview of industrial irradiators and accelerators; organizational responsibilities; basic requirements for safety. specific regulatory requirements; safety associated to the equipment; maintenance; radiation protection programme. protection of the workers; emergency preparedness and response; lessons learned from accidental exposure in industrial irradiators and accelerators. Nucleonic gauges: Overview of gauging devices; organizational responsibilities; basic requirements for safety; safety associated to the equipment; radiation protection programme; protection of the workers. Well logging: Overview of well logging devices; organizational responsibilities; basic requirements for safety; radiation protection programme; protection of workers. Radioisotope production plants: Overview of radioisotope production plants; organizational responsibilities; basic requirements for safety. Safety associated to the plant; specific regulatory requirements; radiation protection programme. Control of effluents; protection of workers.

RADP 604: MEDICAL EXPOSURE IN DIAGNOSTIC RADIOLOGY, RADIOTHERAPY AND NUCLEAR MEDICINE. (2 Credits)

General principles: Diagnostic and treatment purposes; registration of professionals; licensees; role of medical practitioner; role of qualified expert in medical physics. Training; Workers to be trained; content of the training programmes; updating of programmes; refresher training. Justification of medical exposures: Identification of alternative techniques; evaluation of the detriment; criteria for the justification of exposure (difference between diagnostic and treatment practices). Design considerations for equipment: Radiation safety; international requirements (standards (IEC, ISO) for radiation generators and radioactive sources). Basic technical characteristics; regular review and maintenance; factors affecting dose to the patient. Determination of a dose to the patient: Specific correction factors for the determination of absorbed dose in water for photon and electron beams; determination of the dose in nuclear medicine, diagnostic radiology and radiotherapy: determination by assessment; determination by measurement; comparison with reference levels

Operational considerations: Optimization of dose distribution in treatment (planning of physical treatment); minimizing exposures of patients (difference between diagnostic and treatment practices); mobile equipment versus fixed equipment; exposure of women in reproductive capacity;
use of organ shielding. Guidance levels for the patients: Guidance levels for the patient specified by professional bodies on the basis of relevant surveys (in diagnostic and radiotherapy); dose constraints (persons exposed for medical research purposes) and comforters; ethical review committee for experiments; activity in patients to be discharged from treatment in nuclear medicine.

Comprehensive specific quality assurance programmes: Pre-use testing; periodic control (physical and clinical parameters); periodic quality audit and review. Calibration of sources and equipment: Traceability to secondary standard dosimetry laboratory (SSDL); quantities used for calibration; criteria used for calibration of different types of equipment (radiotherapy equipment, sealed and unsealed sources); standards.

Records: Identification of the information to be recorded related to the type of medical exposure.

Accidental medical exposures: Identification and investigation of accidental medical exposures; report to the regulatory authority; lessons learned and feedback into operation. Diagnostic radiology: Overview of diagnostic radiology; classification of the equipment: general and specialized radiology, basic requirements for safety; safety associated to the equipment (IEC standards); shielding; radiation protection programme; protection of the workers. Radiotherapy: Overview of radiotherapy. Radiation sources and equipment used in brachytherapy and teletherapy, basic requirements for safety; safety requirements on radiation sources and equipment (IEC and ISO) for radiotherapy; radiation protection programme, protection of the workers. Nuclear medicine: Overview of nuclear medicine. Radionuclides used in nuclear medicine; basic requirements for safety; safety in diagnostic applications (in vivo and in vitro); safety in therapeutic applications; radiation protection programme; protection of the workers

**RADP 606: EXPOSURE OF THE PUBLIC DUE TO PRACTICES AND ENVIRONMENTAL PROTECTION (2 Credits)**

Natural sources of exposure (review). Terrestrial sources (potassium-40, uranium, thorium, radon); exposure to cosmic and cosmogenic radiation; geographic variation. Responsibilities: Responsibilities of licensees and registrants; regulatory authorities; regulations; inspection; monitoring; reporting; adequate records; emergency planning; communication with the public; physical protection and the safe use of sources; registry and periodic physical inventory of sources; control and disposal of spent sources; control of visitors. Safe transport: Regulatory terminology; basic safety concepts: materials and packages; activity limits and material restrictions; package limits and typical contents; material requirements, package requirements and design; material and package test procedures; controls and communications; labels, transport index; fissile material; consignor’s and carrier’s responsibilities; emergency planning and preparedness; national competent authorities; international model organizations and agreements; international liability and insurance; information services provided by the IAEA; training.

Radioactive waste management: Sources of radioactive waste, waste types, waste classification, waste characterization; Principles of radioactive waste management, basic technical management options: dilute and disperse, concentrate and contain, storage for decay and clearance from control. Waste minimization: Pre-disposal waste management: collection, segregation, treatment, conditioning, secure storage; Control of effluents: approach to regulatory control, establishing authorized discharge levels; Management of disused sealed sources: technical options and safety aspects. Management of waste from decommissioning; Solid waste disposal: disposal options for different waste types, safety principles and technologies for assuring long term safety, safety assessment methods; Management of waste from uranium and thorium; mining and milling.
Management of NORM waste; Cleanup of contaminated areas

Environmental Protection: Environmental assessment: Environmental dispersion and transfer routes; (atmospheric, terrestrial, aquatic), exposure pathways for humans, critical groups, assessment models, individual and collective dose assessment, committed effective dose per unit intake as a function of age.

Environmental monitoring: Monitoring at source: external radiation and liquid; and gaseous effluents, verification of compliance; with discharge limits; Environmental monitoring: atmosphere, water; bodies, foodstuffs, other environmental indicators; verification of compliance with derived environmental; reference levels, survey techniques; Application to different sources: nuclear power plants; waste facilities, including repositories, mining and milling, tailings, contaminated land

Consumer products: Definition; justification; optimization (including type testing); responsibilities of manufacturer and supplier; prior authorization; guidance for users; labeling.

RADP 608: PRACTICAL EXERCISES (3 Credits)

1. Application of the radioactive decay equation; use of some simple mathematical codes.
3. Counting of statistics using a Geiger–Müller or similar counter and radioactive source and verifying the statistical distributions.
4. Determination of maximum energy levels of beta radiation by absorption.
5. Study of attenuation of gamma radiation as a function of thickness and atomic number Z.
6. Determination of characteristics of Geiger–Müller detectors: counting rate versus voltage curve; response to different radiation energies
7. Measurement of beta radiation levels for beta emitter samples and determination of total efficiency.
8. Use of a low background Geiger–Müller system for measurement of low activity beta emitting sources.
10. Use of a low background Geiger–Müller system for measurement of low activity beta emitting sources.
11. Calibration of a gamma scintillation spectrometer in terms of energy and activity.
12. Analysis of a complex gamma spectrum using semiconductor detectors.
13. Making measurements of low activity of tritium and carbon-14 by liquid scintillation counting systems.
15. Identification of unknown radionuclides.
17. Shielding calculations for an X ray facility.
18. Leak testing of sealed sources.
19. Decontamination of surfaces.
20. Measurement of the absorbed dose in the body for a unidirectional exposure to cobalt-60 using a phantom and thermoluminescence dosimetry detectors.
22. Preparation of shipping documents for transport by road and air.
24. Preparation and measurements of environmental samples: air, soil, water and foodstuffs.
25. Measurement of radon in dwellings and comparison with action level.

RADP 614: TECHNICAL VISITS AND CASE STUDIES (3 Credits)

VISITS
1. Calibration of different dosimeters.
2. Visit to industrial radiography facility.
3. Visit to an irradiator or accelerator for industrial or research use.
4. Visit to a department of nuclear medicine of a hospital.
5. Visit to a hospital: departments of radiology, radiotherapy, nuclear medicine: demonstration of procedures and specification of the information to be recorded.
6. Visit to a waste treatment facility and a waste management facility.

CASE STUDIES
1. Interpretation of epidemiological data.
2. Assessment of the risks associated with doses.
3. Description of the elements of the system of radiological protection and of safety culture for any given practice.
4. Principles of protection and safety and national or international experience.
5. Simple evaluation of safety culture for a given organization.
6. Preparation of a conceptual regulatory framework for a country with a defined type and number of radiation sources.
7. Study of the licensing process for an industrial or a medical practice.
8. Conduct of a safety review for a license application for an industrial radiography facility or other type of practice.
10. Development of a routine monitoring programme (internal and external exposures).
11. Interpretation of measurements made with a personal dosimeter.
12. Calculation of internal doses using ICRP models for acute and chronic exposure.
13. Preparation of an organizational chart and highlights of a radiation protection programme in a hospital (radiotherapy, diagnostic radiology or nuclear medicine) and in an industrial facility (industrial radiography or irradiator).
15. Determination of individual dose due to air contamination.
16. Management of personal dose records, dose reduction measures, special monitoring, follow-up measures.
17. Comparison of predicted doses to personnel on the basis of workplace monitoring with the results of individual monitoring in mixed radiation fields.
18. Determination of doses to patients.
19. Optimization of doses to patients in diagnostic radiology.
20. Optimization of doses to patients in nuclear medicine and radiotherapy.
23. Listing of the components of an environmental monitoring programme for a given installation.
24. Interpretation of the results of an environmental monitoring programme.
25. Response to a hypothetical accident: loss of a gamma radiography source.
26. Response to a hypothetical accident: environmental release of a substantial amount of radioactive material.
27. Estimation of the individual doses following an accidental overexposure.
28. Preparation of a syllabus and programme for a training course on radiation protection and the safety for users.

**RADP 616: REGULATORY FRAMEWORK FOR CONTROL OF RADIATION SOURCES**

(2 credits)

Legislative framework: Scope of basic legal framework. Statutory base. Enabling legislation. The regulatory authority: Mandate of regulatory authorities, Responsibilities, Organisation, adequate resources; Training, qualification of staff; Advisory committees and consultants.

**Regulatory system:** The set of regulations (performance and prescriptive). Safety requirements and safety guides System of notification, registration, licensing, and control of radiation sources including criteria for waste storage and disposal, exemptions, clearance. Responsibilities of licensees, registrants and employers. Relationship between regulator and regulated, feedback. National inventory of radiation sources orphan sources, import export transport. Safety assessment, compliance with the safety requirements, inspection, enforcement, training requirements.

Emergency preparedness, investigations of accidents and management of emergencies, dissemination of information on protection and safety and communication with the public. Co-operation between employers (sharing safety information, individual monitoring records..etc.).

**Regulatory assessment:** Methodology to assess the effectiveness: performance indicators, performance criteria, Peer review>

**RECOMMENDED TEXTBOOKS**

1. Radiation quantities and units  ICRU Report No.33
2. Dose quantities for protection Against External radiations NRPB  Vol. 4 No.3
6. Introduction to Health Physic Herman . Cember.
7. Patient dose techniques in Diagnostic Radiology The Institute of Physical Sciences in Medicine Report No. 53
10. UNSCEAR Reports.
20. WHO Publication on Establishing a Dialogue on Risks from Electromagnetic Fields.
22. WHO Publication on Patient Protection in Radiation Protection.
23. ILO Publication in Radiation Protection.

### TEACHING STAFF LIST

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<tr>
<td>RADP 601</td>
<td>Review of Fundamentals</td>
<td>Dr. G. Banini Dr. E. O. Darko Prof. G. Emi-Reynolds Dr. Mary Boadu</td>
<td>PhD (Camb) PhD (UCC) MSc PhD</td>
<td>Sen. Lecturer Sen. Lecturer Assoc. Prof Lecturer</td>
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<tr>
<td>RADP 603</td>
<td>Radiation Quantities and Measurements</td>
<td>Prof. J.J. Fletcher</td>
<td>PhD</td>
<td>Assoc. Prof.</td>
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<td>RADP 605</td>
<td>Biological effects of ionizing radiation</td>
<td>Dr. Mary Boadu</td>
<td>PhD, Univ.Wit.</td>
<td>Lecturer</td>
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<tr>
<td>RADP 607</td>
<td>Principles of Radiation Protection and the International framework</td>
<td>Prof. C. Schandorf</td>
<td>PhD, UG</td>
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<td>RADP 609</td>
<td>External and Internal Exposure and dose Assessment</td>
<td>Prof J.J. Fletcher Dr. E.O Darko</td>
<td>PhD PhD, UCC</td>
<td>Assoc. Prof. Srn. Lecturer</td>
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<td>RADP 611</td>
<td>Sources and Protection Against Non-Ionizing Radiation</td>
<td>Mr. J.K. Amoako</td>
<td>M.Phil</td>
<td>Lecturer</td>
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<td>RADP 602</td>
<td>Occupational Radiation Protection</td>
<td>Prof. C. Schandorf</td>
<td>PhD, UG</td>
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<td>RADP 604</td>
<td>Medical Exposure in Diagnostic radiology Radiotherapy and nuclear Medicine</td>
<td>Prof. C. Schandorf Dr. Mary Boadu</td>
<td>PhD, UG PhD, Univ.Wit.</td>
<td>Assoc. Prof. Lecturer</td>
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<td>RADP 606</td>
<td>Exposure of the Public due to practices</td>
<td>Mr. J. Yeboah</td>
<td>MSc.</td>
<td>Snr. Lecturer</td>
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<td>RADP 608</td>
<td>Practical exercises</td>
<td>Dr. Mary Boadu Mr. J. Yeboah Rev. G. Akoto</td>
<td>PhD, Univ.Wit. MSc.</td>
<td>Lecturer Snr. Lecturer Chief Tech.</td>
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<td>Prof. G. Emi-Reynolds</td>
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<td>Prof. G. Emi-Reynolds, Prof. C. Schandorf</td>
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3. MASTER OF PHILOSOPHY (M.PHIL) IN NUCLEAR AND RADIOCHEMISTRY

ADMISSION REQUIREMENTS

i. The minimum qualification for this programme is a good first degree (at least a second class lower division) in any of the following fields: Chemistry, Chemical Engineering and Engineering and appropriate areas of applied Science from any approved University.

ii. A candidate who does not satisfy the requirement in an appropriate field of study as above but is otherwise adjudged suitable by virtue of appropriate experience will be considered.

YEAR 1.

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<td>Interaction of Radiation with matter</td>
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<td>Chemistry and Analysis of Radionuclides</td>
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YEAR 2.

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Total Credits in year 1: 35
Total Credits in year 2: 33
COURSE DESCRIPTIONS

NURC 601: INTRODUCTION TO NUCLEAR AND RADIO-CHEMISTRY (3 Credits)
Introduction to Nuclear and Radiochemistry: Periodic system, stable and radioactive nuclides; Radioactivity and evolution of Nuclear Theory; Force in Matter and subatomic particles; Nuclides and Natural Decay Chains; Nuclear Chemistry, Radiochemistry and Radiation Chemistry

NURC 603: TYPES AND CHEMISTRY OF RADIOACTIVE DECAY (3 Credits)
Types of Radioactive Decay: Radioactive nuclides; Decay rules; α- particle Decay; β- particle Decay; γ- particle Decay; K-capture/electron capture; Branching Decays and Decay Schemes; Less Common Decay Modes. Nuclear Chemistry and Mass Energy Relationships (Nuclear Structure); Properties of the nucleus, nuclear forces, nuclear particles and decay rules. The nuclear structure, Rutherford’s discovery of the nucleus; Models of the nucleus: the Shell model; Mass-Energy Relationships; Absorption of nuclear particles (excitation and de-excitation) with the emission of particles.

Nuclear reactions: mechanisms and models, theory of decay; Nuclear Reaction : Mechanisms and Models; Theory of decay and Types of Nuclear Reactions; Laws of conservation of energy and momentum, compound nucleus formation, effective nuclear cross-section; Energetics of nuclear reactions; Reaction Mechanisms, direct interaction and compound formation; Special Nuclear Reactions; nuclear fission, nuclear fusion, heavy ion and photonuclear reaction.

Rates of nuclear decay (production of radionuclides): Rates of Nuclear Decay (Production of Radionuclides): Rates of Radioactive Decay; Units of Radioactive Decay; Detailed Mathematics of radioactive decay; Experimental Methods for Determination of Half-Life ( long, medium, short, very short); Estimation of Half-Life from Theory and Systematic; Growth of Radioactive Products in a Decay Chain-parent with a single radioactive daughter and parent; Growth of Radioactive Products in a decay chain and Neutron Flux; Decay energy, equilibrium constant kinetics, isotopic exchange and its mechanisms.

NURC 605: INTERACTION OF RADIATION WITH MATTER (3 Credits)
Interaction/Effect of radiation with Matter; Units of radiation, Roentgen, rad, G-value, sievert etc and Terms; Models of interaction, ion-pair concept; Effect of ionizing radiations on man, concept of permissible dose to individual organs.; Safety in the Radiochemistry laboratory; Good Laboratory Practices in the Radiochemistry Laboratory; Gamma-Ray Interaction, Absorption, Photoelectric effect, Compton Scattering, Pair-production, elastic and inelastic scattering; Linear Energy Transfer; Heavy charged-particle interaction, range, stopping power etc; Beta-particle interaction, range; relationships for beta particles, the feather method, Bremsstrahlung radiation, Cerenkov radiation and beta backscatter; Neutron interaction; General physical effects of radiation on matter; Energy transfer and radiation dose; Radiation effects on metals; Radiation induced synthesis; Special Applications

NURC 607: RADIOISOOTOPE PRODUCTION TECHNIQUES: (2 Credits)
Types of research reactors-Fissionable material, moderating substance, shielding materials, heat exchangers etc; Operation of research reactors, critical size etc and applications of reactors.; Emphasis on production of useful radionuclides using neutron-gamma reactions, ie thermal neutrons; Requirements for radioisotope production: target preparation, determination of neutron flux in reactor, estimation of activities prior to irradiation using decay mathematics, radionuclide purity, half-life determination; Radionuclide purity and radiochemical purity.; Processing of radioisotopes in the laboratory: use of hot-cells separation techniques(solvent-solvent extraction, co-
precipitation, ion exchange, distillation etc, use of hot-atom chemistry to produce short-lived radioisotopes; Production of commercially important radionuclides eg, C-14, P-32, S-35, Na-24, K-39 and I-131. Synthesis of labeled H-3, C-14, P-32, S-35 compounds.

NURC 609: CHEMISTRY AND ANALYSIS OF RADIONUCLIDES (3 Credits)
Chemistry and analysis of radionuclides: Special features in the chemistry of radionuclides; Need for radiochemical separations; Most important radionuclides and their chemical properties; Physical and chemical forms of radionuclides and methods for their speciation; Separation methods for radionuclides; Yield determination in radiochemical analysis; Sampling and pretreatment methods for environmental samples.

NURC 615: RADIOLOGICAL PROTECTION AND NUCLEAR SAFETY (2 Credits)
Uses, benefits of radiation sources and ionizing radiation in medicine, industry, research and teaching; Radiation quantities and units, external and internal radiation exposure, radiation effects and risks; Principles of radiation protection; Occupational radiation protection, good laboratory practices in the radiochemistry laboratory; Principles of nuclear safety as applied to radiation sources and relevant installations. Practical demonstration: measurements of radionuclides in food samples.

NURC 602: DETECTION AND MEASUREMENT OF RADIATION AND RADIOISOTOPE METROLOGY (2 Credits)
Instrumentation and Ion beam Analysis: Definitions of Operating characteristics; Gas-filled Detectors; Solid Scintillation Detectors; Liquid Scintillation Detectors; Solid-state Semi-conductor Detectors; Non-electronic Detection Systems; Special Neutron Detector; GM Counters, Liquid scintillation counters etc; Particle induced X-ray emission (PIXE), including XRF; Rutherford backscattering spectrometry; Mossbauer spectrometry; Hot atom Chemistry

NURC 604: NUCLEAR ACTIVATION ANALYSIS AND ALLIED ANALYTICAL TECHNIQUES (3 Credits)
Nuclear Activation Analysis (NAA): Principles of Activation analysis; Neutron Activation analysis (NAA), eg Instrumental NAA, Epithermal NAA, Radiochemical NAA, Preconcentration NAA; Prompt-Gamma Neutron Activation analysis; Charged-Particle Activation analysis, principles and applications; Particle induced gamma-ray emission (PIGE); Instrumental Photon-Activation analysis (IPAA); Special Activation Analysis Techniques; Derivative Activation Analysis, Cyclic activation analysis, secondary particle activation analysis, coincidence and anti-coincidence techniques in activation analysis; Ionization methods in activation analysis; QA/QC in nuclear activation analysis. AAS, ICPMS, HPLC…etc.

NURC 606: RADIATION CHEMISTRY AND DOSIMETRY (2 Credits)
Radiation Chemistry and Dosimetry: Terms and units; Radiation chemistry of water and aqueous solutions-radiolytic products of water, radiation-chemical yield (G-value), radical scavenger concept; Ionization measurements; Chemical dosimetry systems (Fricke dosimeter, aqueous ceric sulphate dosimeter); Industrial applications of ionizing radiations; in the preservation of foodstuffs, vegetables, sterilization of medical supplies, sterilization of insects and also in radiation therapy; Pulse radiolysis, use of linear accelerator, van de Graaf accelerator, Febetron to produce pulse of high energy; Cyclotron- principles and applications; Solid state dosimetry systems eg polymethyl methacrylate (PMMA)
NURC 608: NUCLEAR DATING METHODS (2 Credits)
Nuclear Dating Methods: General Principles of Nuclear dating; Radiocarbon dating; Tritium dating; U-Pb and Th-Pb Methods; Rb-Sr and K-Ar Methods; Pleochroic Halos; Fission tracks; Special Methods.

NURC 610: ISOTOPE GEOCHEMISTRY AND ISOTOPE GEOLOGY (2 Credits)
Isotope Geochemistry/Isotope Geology: Introduction to Isotope geochemistry/isotope geology; Kinds of isotopes; Application of staple and radiogenic isotopes to geology; Applications of stable and radiogenic isotopes to hydrogeology; Experimental isotope geochemistry.

NURC 612: MANAGEMENT OF RADIOACTIVE WASTE (2 Credits)
Management of Radioactive Waste: Radiation protection; Health Physics; Waste management; Waste minimization; Treatment of waste; Conditioning of waste; Waste disposal.

NURC 614: PRACTICALS ON RADIONUCLIDE ANALYSIS (3 Credits)

NURC 616: RADIOTRACER METHODS (2 Credits)
Radiotracer Methods in Chemistry: General Aspects of radiotracer application-assumptions, factors in the choice of a radiotracer, advantages and disadvantages of radiotracer use; Isotope Dilution analysis and Direct Isotope Dilution Analysis; Theory and Applications, as well as simple calculations on IDA.; Tracers in the study of Chemical Processes, eg equilibrium processes, studies of reaction mechanisms, rates of chemical reactions etc.; Nuclear Medicine and Pharmacy: general aspects of radiopharmaceutical use, nuclear properties of indicator nuclides in vivo diagnostic procedures, in vitro diagnostic testing (Radioimmunoassay and Enzyme Linked Immuno-sorbent Assay), therapeutic uses of radiation etc; General application of radioisotopes in Agriculture eg. Uptake of P-32 or use of C-14 in elucidating the mechanism behind the photosynthesis process. Also in industry to detect leakages in pipes, in determining mixing efficiency, residence times in storage tanks etc.

RECOMMENDED TEXTBOOKS
## Teaching Staff List

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Name of Lecturer</th>
<th>Highest Qualification Institution &amp; Year</th>
<th>Status</th>
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<tbody>
<tr>
<td>NURC 601</td>
<td>Introduction to Nuclear and Radiochemistry</td>
<td>C.B.J. Semanhyia</td>
<td>M.Sc., Univ. Salford</td>
<td>Snr. Lecturer</td>
<td>Full-Time</td>
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<tr>
<td>NURC 603</td>
<td>Types and Chemistry of Radioactive Decay</td>
<td>A.A. Golow</td>
<td>Ph.D., Univ. Exeter</td>
<td>Assoc. Prof.</td>
<td>Full-Time</td>
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<tr>
<td>NURC 607</td>
<td>Radioisotope Production Techniques</td>
<td>Khalid Ahmad</td>
<td>M.Sc., Univ. Salford</td>
<td>Snr. Lecturer</td>
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<td>NURC 605</td>
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<td>Khalid Ahmad</td>
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<tr>
<td>NURC 615</td>
<td>Radiobiological Protection and Nuclear Safety</td>
<td>C. Schandorf</td>
<td>PhD</td>
<td>Assoc. Prof.</td>
<td>Full-Time</td>
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<tr>
<td>NURC 609</td>
<td>Chemistry and Analysis of Radionuclides</td>
<td>A. Chatt Yaw Serfor- Armah B.J.B. Nyarko</td>
<td>Ph.D., Univ. Toronto M.Phil, UG., M.Phil, UG.,</td>
<td>Professor Assoc. Prof Snr. Lecturer</td>
<td>Visiting Scholar Full-Time Full-Time</td>
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<tr>
<td>NURC 602</td>
<td>Detection and Measurement of Radiation and Radioisotope Metrology</td>
<td>A. Chatt PhD Toronto</td>
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<td>Professor</td>
<td>Visiting</td>
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<td>NURC 604</td>
<td>Nuclear Activation Analysis and Allied Analytical Techniques</td>
<td>A Chatt Y. Sefor-Armah</td>
<td>PhD (Toronto) M.Phil (UG)</td>
<td>Professor Assoc. Prof.</td>
<td>Visiting Full-Time</td>
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<td>NURC 616</td>
<td>Radiotracer Methods</td>
<td>I. K. Wilson E. Areyetey A. Golow</td>
<td>PhD MSc (Salford) PhD (Exeter)</td>
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<td>A. S. Dogbe A Golow</td>
<td>MSc (Cransfield) PhD (Exeter)</td>
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<td>Nuclear Dating Method</td>
<td>S. Osae</td>
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<td>NURC 610</td>
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<td>NURC 612</td>
<td>Management of Radioactive Waste</td>
<td>J. J. Fletcher E. T. Glover</td>
<td>PhD MSc</td>
<td>Ass. Prof Lecturer</td>
<td>Part-Time Full-Time</td>
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<td>NURC 614</td>
<td>Practicals on Radionuclide Analysis</td>
<td>Prof. A. Golow</td>
<td>PhD</td>
<td>Assoc. Prof.</td>
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4. MASTER OF PHILOSOPHY (M.PHIL) IN NUCLEAR AND ENVIRONMENTAL PROTECTION

ADMISSION REQUIREMENTS

i. The minimum qualification for this programme is a good first degree (at least a second class lower division) in any of the following fields: Chemistry, Physics, Biochemistry, Agricultural Science or Geology from any approved University.

ii. A candidate who does not satisfy the requirement in an appropriate field of study as above but is otherwise adjudged suitable by virtue of appropriate experience will be considered.

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<td>Hazardous Chemicals</td>
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<td>ENVP 605</td>
<td>Human Toxicology</td>
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<td>ENVP 611</td>
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YEAR 2

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Total Credits in year 1: 31
Total Credits in year 2: 33

COURSE DESCRIPTIONS

ENVP 601: INTRODUCTION TO NUCLEAR AND RADIO-CHEMISTRY (2 Credits)
Introduction to Radiochemistry; Types of Radioactive Decay; Nuclear Chemistry and Mass Energy Relationships (Nuclear Structure); Nuclear Reaction – Mechanisms and Models; Rates of Nuclear Decay (Production of Radionuclides); Interaction of radiation with Matter; Radiation Dosimetry.
ENVP 603:  HAZARDOUS CHEMICALS  (3 Credits)
Naturally Occurring Chemicals in the Environment: Sources of toxicants; Naturally occurring elements in the environment; Fluoride, Arsenic, Lead, cadmium, Radon. Industrial Sources of Chemicals. Minamata and environmental toxicity of mercury; Sources of mercury; Symptoms of methyl mercury poisoning; Treatment of Poisoning; Textile manufacturing industry; Sources, exposure and effects; Asbestos and other fibers; Petroleum, Solvents. Agricultural sources of chemicals; Pesticides Classification and formulations; Uses of Pesticides, Contamination of air, soil, and water due to pesticides; Exposure of humans to pesticides; Veterinary Pharmaceuticals and Growth Regulators; Environmental Contamination with Veterinary Pharmaceuticals; Persistent Organic Pollutants (POPs);

Dioxins and Furans: Chemical structure and characteristics; Historical introduction; Sources and formation; Sources and inventory development; Chemical properties; Environmental properties; Human Exposure and expression of toxicity; Polychlorinated biphenyls (PCBs); Chemical properties; Distribution; Health and Environmental Effects; Investigation of historical sources of PCBs; Stockholm Convention. Urban sources of chemical contamination; Natural sources of air pollution; Fossil fuels as source of air pollution; Ozone as source of air pollution; Variation in air pollution; Liquid and solid wastes; Accidental releases of toxic chemicals

ENVP 605:  HUMAN TOXICOLOGY  (3 Credits)
Introduction; Dermal route of exposure; Inhalation route of exposure; Ingestion route of exposure; Food; Water, Multi-media exposure, Exposure to chemical mixtures, Adverse Effects of Chemicals on Humans, Introduction, Effects on the respiratory system, How the respiratory system works; How chemicals affect the respiratory system; Respiratory diseases caused by chemicals; Effects on the liver; Effects on the kidneys; Effects on the nervous system; How the nervous system works; How chemicals affect the nervous system; Immunotoxicity; Reproductive toxicity of chemicals; Cancer-causing chemicals

ENVP 607:  ENVIRONMENTAL TOXICOLOGY  (2 Credits)
Chemicals and the aquatic environment; Chemicals and freshwater ecosystems; Effects on terrestrial ecosystems; Global environmental impacts of chemicals; Acid rain; Sources of SO\textsubscript{2} and NO\textsubscript{X}; Reaction important in formation of acid rain; Effects of acid rain; Solutions to acid rain; Stratospheric ozone depletion; Effects of ozone depletion; Causes of ozone depletion; The Montreal Protocol; Tropospheric oxidants; Climate change and the greenhouse effect

ENVP 609:  ENVIRONMENTALLY SOUND MANAGEMENT OF TOXIC CHEMICALS  (3 Credits)
Introduction; Prevention; Control Technologies; Regulations, incentives and standards; Pesticides- a regulatory definition; Pesticides control and Management in Ghana (Act 528, 1996); Registration; Labeling; Education, training and workers protection; Transportation, storage and disposal; Integrated pest Management (IPM); Licensing

ENVP 611:  TOOLS FOR BASIC LABORATORY OPERATIONS  (1 Credits)
Quality assurance/Quality control. Good Laboratory Practices

ENVP 602:  RADIOACTIVE AND URBAN WASTE MANAGEMENT  (3 Credits)
Management of Wastes (Sludge, solid, hospital); Radioactive waste management
ENVP 604: ENVIRONMENTAL IMPACT ASSESSMENT (3 Credits)
Introduction to Environmental Management and Local/Global Environmental Issues; Presentation and discussion of global and local environmental issues including urbanization, greenhouse gases, ozone depleting substances, the need for sustainable development. Summarize existing information on the environment, their interrelationships with the environmental compartments (air, water, soil and biota), the importance of local management and sustainable development.

Ghana Environmental Policy and Institutional Arrangements; Presentation of the existing Ghana environmental management instruments and regulations; Water and drinking water management Water quantity and quality, acceptable levels of water pollution, determination of safety levels, management of river pollution. Drinking water: usage, standards, guidelines, linkages between water supply and sanitation; To introduce the general problems of water management and the existing approaches for improved management of water resources. To introduce the general aspects of sanitation and drinking water quality. Ambient air and indoor air pollution management. History, sources, transport, scales of air pollution (indoor, urban, regional, global), air quality criteria and standards, impacts of air pollution on health, monitoring, air pollution management: preventive approaches and end-of-pipe control, control devices.

Solid waste management; Context of solid waste management, environmental problems, resource recovery/recycling, promotion of recycling, private interventions in service delivery, main issues for establishment of a community-based project, an integrated approach to solid waste management planning; Utilization of municipal solid organic waste; Sorting, recycling, composting of organic waste and economics of waste recycling/reuse; Noise Management; Environmental impacts: causes and effects; definitions contents and application fields of some important environmental impact assessment methodologies. EIA process: classification of the environmental effects, the parties in EIA, types of projects requiring EIA, EIA process chart (screening, initial environmental examination, terms of reference, EIS, review, monitoring, evaluation, audit). Preparation and contents of an Environmental Impact Statement (EIS): impact initiator; methods for identification of effects and impacts. Existing legal framework for EIA in Ghana; EIA cases studies: local Ghanaian experiences; Exercises on applications of EIA methodologies.

ENVP 606: MEASUREMENT OF ORGANIC CHEMICAL RESIDUES IN THE ENVIRONMENT (3 Credits)
Chromatography: Chromatography defined, The principles of separation, Chromatogram, Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC); Thin Layer Chromatography (TLC); Mass Spectrometry (MS); History and Basic concepts; Sample introduction; Electron impact ionization (EI); Selected ion monitoring; Detection in field instruments; Time flight detection; Detection of molecular mass; Isotopes.

ENVP 608: MULTI-ELEMENTAL ANALYSIS (3 Credits)
Neutron Activation Analysis and X-Ray Fluorescence spectrometry (XRF); Atomic Absorption Spectrometry (AAS)

ENVP 614: RADIONUCLIDE MEASUREMENTS (2 Credits)
Radiochemistry Instrumentations: Radiotracer Methods; Nuclear Dating Methods; Nuclear Track Detection technique;
RECOMMENDED READINGS
2. Guideline for assessment of indirect and cumulative impacts as well as impact interactions: Environment, Nuclear Safety and Civil Protection, Office for official publications of the European communities, 1999
3. Developing risk management plan for priority chemical Guidance document UNITAR 2001
4. Environmental Monitoring of Pesticide residues Guidelines for the SADC Region Malin Akerblom 1995
7. Pesticides Chemistry and Biochemistry. By Byoung Youl Oh.

TEACHING STAFF LIST

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Name of Lecturer</th>
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<td>Khalid Ahmad</td>
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<td>S.A. Dogbe</td>
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<td>ENVP 603</td>
<td>Hazardous Chemicals</td>
<td>Prof. P.O. Yeboah</td>
<td>Ph.D. UG, M.Phil., UG</td>
<td>Assoc. Prof.</td>
<td>Full-Time</td>
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<td>J. Pwamang</td>
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<td>Snr. Lecturer</td>
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<tr>
<td>ENVP 602</td>
<td>Radioactive and Waste Management</td>
<td>Prof. P. O. Yeboah</td>
<td>PhD (Ghana), M.Sc</td>
<td>Assoc. Prof.</td>
<td>Full-Time</td>
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<tr>
<td></td>
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<td>Mr. E. T. Glover</td>
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<td>Lecturer</td>
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<tr>
<td></td>
<td></td>
<td>Mr. J. B. Pwamang</td>
<td>M.Phil</td>
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<td>ENVP 604</td>
<td>Environmental Impact Assessment</td>
<td>Mr. J. B. Pwamang</td>
<td>PhD (Ghana)</td>
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<td>ENVP 611</td>
<td>Tools for Basic Laboratory Operations</td>
<td>Prof. P. O. Yeboah</td>
<td>PhD (Ghana), M.Phil</td>
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<td>S. A. Kumi</td>
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<td>ENVP 608</td>
<td>Multi-elemental Analysis</td>
<td>Y. Sefor-Armah</td>
<td>M.Phil, MSc</td>
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<td>ENVP 614</td>
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<td>Y. Sefor-Armah</td>
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DEPARTMENT OF NUCLEAR AGRICULTURE
AND RADIATION PROCESSING

PROGRAMMES

M.Phil in Nuclear Agriculture
  Option 1. Mutation Breeding and Plant Biotechnology
  Option 2. Soil Water and Crop Nutrition

M.Phil in Radiation Processing (to start from 2007/2008 academic year)
1. **MASTER OF PHILOSOPHY (MPHIL) IN NUCLEAR AGRICULTURE**

**ADMISSION REQUIREMENTS**

i. The minimum qualification for this programme is a good first degree (at least a second class lower division) in any of the following fields: Biological Sciences, Agricultural Sciences, Veterinary Sciences, Biochemistry, Botany and Zoology, Entomology, Genetics, Molecular Biology, Agronomy, Soil Sciences, Food Sciences, Health Sciences, and Biotechnology from any approved University.

ii. A candidate who does not satisfy the requirement in an appropriate field of study as above but is otherwise adjudged suitable by virtue of appropriate experience will be considered.

The programme offers M.Phil and PhD programmes in the following areas of specialization.

1. **MUTATION BREEDING AND PLANT BIOTECHNOLOGY**
2. **SOIL WATER AND CROP NUTRITION**

**OPTION 1: MUTATION BREEDING AND PLANT BIOTECHNOLOGY**

**YEAR 1.**

**CORE COURSES**

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<td>Research Methods and Scientific Communication</td>
<td>2</td>
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<td>NUAG 605:</td>
<td>Principles of Genetics</td>
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<td>Plant Genomics and Diversity</td>
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**ELECTIVES**

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<td>CROP 641:</td>
<td>Plant Virology and Viral Diseases</td>
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</table>
NUAG 608: Molecular Genetics and Genetic Engineering 3
NUAG 612: Plant Tissue Culture 3
NUAG 614: Post-Harvest Physiology 3

Each student is expected to select a minimum of two elective courses in the year in consultation with an advisory committee. (Not all electives may be available in any year).

CROP 601, CROP 612, CROP 641 and CROP 692 are available in the School of Agriculture

YEAR 2

NUAG 600: Thesis 30
NUAG 620: Seminar 2 3

Total Credits in year 1: 36
Total Credits in year 2 33

OPTION 2: SOIL WATER AND CROP NUTRITION

YEAR 1.

CORE COURSES

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<td>NUAG 618:</td>
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<td>NUAG 624:</td>
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<td>Advanced Soil Physics</td>
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<td>NUAG 630:</td>
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43
Each student is expected to select a minimum of two elective courses in consultation with an advisory committee. (Not all electives may be available in any year).

SOIL 603, SOIL 605, SOIL 614 and CROP 692 are available in the School of Agriculture

YEAR 2

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<td>NUAG 640: Seminar 2</td>
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COURSE DESCRIPTIONS

**NUAG 601: RADIOISOTOPEs, RADIATIONS AND DOSIMETRY** (3 Credits)


**NUAG 602: RADIOBIOLOGY AND RADIATION PROTECTION** (3 Credits)

Types and physical characteristics of ionizing radiations. Penetration mode of ionizing radiations and their interaction with substances. Radiation doses and radioactivity units. Direct and indirect effects of ionizing radiations on cells, molecules, tissues, organs and organisms. Target theory and Hit Principles. The Stochastic theory. Probabilistic model of radiation damage to cell. Methods of estimating the Relative Biological Effectiveness (RBE) of ionizing radiations and its relation to Linear energy transfer(LET). Limits of application of the concept. Responses of cells in different phases of its cycle to irradiation (radio sensitivity, radio resistance, radiation damage and repair, transient effects, delayed effects, lethal effects and forms of cell death), Survival curves and models and their interpretations. Modification of radio sensitivity by environmental factors at irradiation (gases, temperature, humidity, protective agents, synergists, chemicals).


**NUAG 603: RESEARCH METHODS AND SCIENTIFIC COMMUNICATION (2 Credits)**
In year 1, students will be taught how to present scientific information in communication. In addition, students will be taught proposal writing and will be exposed to the use of computer for information management and presentation to audience.

**NUAG 604: MUTAGENESIS AND MUTATION BREEDING (3 Credits)**

**NUAG 605: PRINCIPLES OF GENETICS (2 Credits)**
Mendelian Genetics: Mendel’s discovery and its relevance, Types of crosses, Modified genetic ratios, Gene expression, Cytoplasmic inheritance and maternal influence, Testing genetic ratios; Cytogenetics: Variation in chromosome number, Variation in chromosome structure; Quantitative Genetics: Quantitative inheritance, Distribution and measurement of quantitative traits, Causes of variation in quantitative traits, Heritability, Multiple measurements and repeatability; Selection of quantitatively inherited traits; population Genetics: Gene pool, Gene and genotypic frequencies in populations, Hardy-Weinberg Law and its applications, evolution of populations (changes in gene frequency)

**NUAG 606: CROP PESTS AND VECTOR MANAGEMENT (3 Credits)**
Definition and concepts of crop pests and their vectors; Overview and classification of crop pests (insects, birds, rodents, etc); Economic importance of pests and vectors in crop production (yield losses & transmission of pathogens); Ecology of crop pests, pest populations and forecasting outbreaks. Major pests and vectors of important crops in Ghana and W. Africa. Integrated control of major pests and their vectors. Pesticides –classification, formulations, safe and efficient applications. Equipment calibration and use. Pesticide resistance and residues. Environmental impact assessment of pesticide applications.

**NUAG 607: PLANT GENOMICS AND DIVERSITY (3 Credits)**
NUAG 608: MOLECULAR GENETICS AND GENETIC ENGINEERING (3 Credits)
Gene structure and function: Genetic properties of DNA, Fine structure analysis of the gene, The genetic code, DNA sequencing and gene structure; Molecular nature of the genome: DNA replication, Recombination at the molecular level, Chromosomal DNA in eukaryotes; Gene Expression: Transcription, Translation; Cloning and sequencing; Regulation of gene expression: Control of gene expression in prokaryotes, control of gene expression in eukaryotes, transposable genetic elements. Generation of recombinant DNA. Plasmid vectors; Synthesis of DNA. Construction of DNA library. Analysis of recombinant DNA. Alteration of genes by mutagenesis; expression of foreign proteins in Prokaryotes and Eukaryotes. Applications of DNA technology. Plant transformations.

NUAG 609: PLANT PHYSIOLOGY AND MORPHOGENESIS (3 Credits)

NUAG 611: SOIL FERTILITY AND PLANT NUTRITION (2 Credits)

NUAG 612: PLANT TISSUE CULTURE (3 Credits)
NUAG 614: POST HARVEST PHYSIOLOGY (3 Credits)
Definitions; developmental cycle of plants, dormancy and germination of seeds and storage organs; vegetative and reproductive growth; seed development and fruit ripening; physical, chemical and biological properties of agricultural produce, environmental factors; physiological disorders; physiological effects on horticultural crops of controlled temperatures and supplemental environments or treatments. Low temperature and mineral deficiency disorders; commodity treatment e.g. controlled ripening, and degreening; sprout inhibitors, growth regulators, irradiation, ventilation, waxing, cooling, fungicide application, quality assessment, simple and complex methods including development of abscission layer, visual or appearance; texture firmness, composition; density, impact, force deformation, sonic vibration, ultrasonic techniques and electrical properties; optical properties, near infrared analysis; x-rays and gamma rays; nuclear magnetic resonance, machine vision and aroma.

NUAG 616: NUCLEAR TECHNIQUES IN CROP NUTRITION STUDIES (3 Credits)
Isotopes for crop nutrition studies; Fertilizer recovery: definition and quantification; Measurement of fertilizer recovery: difference method, isotopic method – concept and quantification for N and P fertilizers (using N$^{15}$ and P$^{32/33}$); Biological nitrogen fixation (BNF): concept and different methods of quantification;; Quantification of BNF using N$^{15}$: isotope dilution method, enriched fertilizer method, A-value method; Isotopes in organic residue studies: direct and indirect labeling techniques; Analysis of N$^{15}$ in samples: sample preparation, mass spectrometer, emission spectrometer; Analysis of P$^{32/33}$ in samples: sample preparation, liquid scintillation counter/analyzer.

NUAG 622: SOIL MICROBIAL ECOLOGY AND REMEDIATION (3 Credits)
Major groups of microorganisms occurring in soils: bacteria, fungi, algae, protozoa, viruses, etc; Biotic and abiotic factors affecting soil microbial activity, Identification and enumeration of microorganisms: nucleic acid probes, fluorescent antibodies and viable count; Transformation of N, C, S, P, Fe and Mn; Plant-microbe interactions: lichens, mycorrhizae and azolla; Root nodule bacteria and symbiotic relationship with legumes; Problems of environmental pollution and basic principles of pesticide microbiology; Bioremediation and biotechnological aspects of microbial ecology, management of agricultural soils, composting, landfills/land reclamation etc.

NUAG 624: WATER MANAGEMENT (3 Credits)
Field measurement of soil moisture content: neutron probe – principle, installation of access tubes and calibration, time domain reflectometer (TDR) and Sentek Diviner; Water storage in soils: calculations; Tensiometers: installation and calculations; Potential evapotranspiration: different methods of computation; Actual evapotranspiration: water balance approach, use of potential evapotranspiration and crop coefficients; Simple field lysimeter; Crop water use efficiency; Irrigation: sprinkler irrigation; drip irrigation, fertigation; Irrigation water management: irrigation water requirement, scheduling and management, Erosion: control, use of radio-nuclides in erosion studies

CROP 601: ADVANCED AGRONOMY (3 Credits)
Farming systems in various parts of the world; their development and conditions responsible for their establishment. Large scale mechanized farming systems vs. traditional small scale. Labor-intensive systems characteristic of most developing countries. Methods of building up and maintaining soil fertility – rotations, crop sequences, crop combinations, cover cropping, mulching, green manuring, composting, minimum/zero tillage. Soil and water conservation techniques. Chemical and Bio-fertilizers (uses of Azzola, Mycorrhiza, Rhizobia, etc). Sustainable crop
production – short and long term considerations in establishing annual (arable) and perennial (plantation) crops. Integration of livestock into cropping systems.

CROP 612: CROP IMPROVEMENT (3 Credits)
Historical development, aims, objectives and scope of plant breeding; Origin and evolution of cultivated crops; Reproductive system in plants; Breeding self-pollinated crops; Breeding cross-pollinated crops; Breeding for pest, disease and stress resistance; Mutation breeding; Biotechnology and plant breeding; Genetic Manipulation for crop Improvement; Variety development and varietal release, Plant germplasm resources and conservation.

CROP 637: PLANT VIROLOGY AND VIRAL DISEASES (3 Credits)

CROP 692: BIOMETRY (3 Credits)

SOIL 603: SOIL CHEMISTRY (3 Credits)

SOIL 605: SOIL PHYSICS (3 Credits)
Composition of soils, interaction of soil and water, soil water potentials, potential diagrams and soil water retention; Principles of water movement in soils: Darcy’s Law, distribution of water in soils, infiltration; Soil structure, physical, chemical and biological agents in soil aggregation, soil consistency and strength, effect of soil physical properties on root growth; Management of soil water: water storage in soils, soil water balance, concepts of water extraction by plant roots; Chemical transport in soils: leaching of chemicals (sorbed and non-sorbed) through soils, mass flow and diffusion, irrigation water quality, soil salinity and its control.

SOIL 614: ADVANCED SOIL PHYSICS (3 Credits)
Soil water: water and soil in equilibrium, structure of water forces and energy; Movement of water in soils- saturated: Darcy’s Law and Laplace equation, fundamental concept of unsaturated flow,
differential equations of unsaturated flow and their solutions, diffusivity, infiltration, Philip’s solution for horizontal and vertical infiltration; Onsager’s relation and coupled flow processes; Solute movement in soils; Gaseous diffusion in soils: Fick’s law and the differential equation of gaseous diffusion, transient state diffusion of oxygen in soils; Soil temperature: Fourier’s heat flow law, determination of heat flux in soils, thermal conductivity in soil, simulation of heat, water and solute transport in soils

RECOMMENDED TEXT BOOKS

SOIL PHYSICS AND WATER MANAGEMENT
1. Environmental Soil Physics: Fundamentals, Applications and Environmental Considerations. Daniel Hillel
4. Sprinkle and Trickle Irrigation - Jack Keller and Ron D. Bliesner
5. Irrigation Fundamentals. - George H. Hargreaves and Gary P. Merkley
6. Materials Published by IAEA on Soil Physics and Water Management

NUCLEAR APPLICATIONS IN CROP NUTRITION
1. Materials Published by IAEA on the Use of Isotopes and Nuclear techniques in Crop Nutrition

STATISTICS/BIOMETRY
2. Statistical Procedures for Agricultural Research. K.A. Gomez and A.A. Gomez
3. STATISTICA Software (Latest version)

PLOTTING/GRAPHING PACKAGE
1. SIGMAPLOT (Latest version)

ADVANCED GENETICS /CROP IMPROVEMENT & CONSERVATION
1. Mutation Breeding: Theory and Practical Application - A.M. van Harten
2. DNA Science: A first Course. - David A. Micklos and Greg A. Freyer
6. In vitro Plant Breeding:- Acram Taji
7. Quantitative Genetics, Genomics and Plant Breeding - Manjit S. Kang
8. Quantitative Genetics and Selection in Plant Breeding- G.Wrickle and E. Weber
9. Plant Breeding: Theory and Practice- Edited by V.LO. Chopra
11. Materials Published by IAEA on Mutation Breeding
12. Breeding for Quantitative Traits in Plants – Rex Bernado
13. Plant Molecular Genetics, Genes vii- Benjamin Lewis
14. Fundamentals of Plant Genetics and Breeding- J.R. Welsh
15. Breeding Field Crops- J.M. Poehlman
17. Principles of Plant genetics and Breeding- George Acquaah

PLANT TISSUE CULTURE
1. Plant Propagation by Tissue Culture- E.F. George and P.D. Sherrington
3. Plant Biotechnology: The genetic Manipulation of Plants. Adrian Slater, Nigel Scott and Mark Fowler

MOLECULAR GENETICS AND GENETIC ENGINEERING
2. Molecular Biology. - Robert F. Weaver
TEACHING STAFF LIST

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<th>Highest qualification, Institution &amp; Year</th>
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<td>BIOMETRY</td>
<td>Prof. I. K. Ofori</td>
<td>Ph. D. Sask (CAN); 1995</td>
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<td>Dr. D. K. Asare</td>
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<td>RESEARCH METHODS &amp; SCIENTIFIC COMMUNICATION</td>
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<td>PRINCIPLES OF GENETICS</td>
<td>Dr. H. M. Amoatey</td>
<td>Ph. D. UW(UK); 1991</td>
<td>Sr Lecturer</td>
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<td>NUAG 607</td>
<td>PLANT GENOMICS &amp; DIVERSITY</td>
<td>Dr. E. Owusu-Marfo</td>
<td>D. Eng. TOKYO UNIV; 2001</td>
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<td>Mr. S. Amiteye</td>
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<td>PLANT PHYSIOLOGY &amp; MORPHOGENESIS</td>
<td>Dr. K. E. Danso</td>
<td>Ph. D. UB(UK); 2003</td>
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<td>Dr. M. Abekeoe*</td>
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<td>SOIL 603</td>
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<td>SOIL MICROBIAL ECOLOGY &amp; REMEDIATION</td>
<td>Mr. E.O. Ayeh</td>
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<td>Prof. SK. Adiku*</td>
<td>Ph. D.</td>
<td>Assoc. Prof.</td>
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<td>SOIL 614</td>
<td>ADVANCED SOIL PHYSICS</td>
<td>Prof. K.B. Laryea*</td>
<td>Ph. D.</td>
<td>Professor</td>
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<td>NUAG 624</td>
<td>WATER MANAGEMENT</td>
<td>Dr. D.K. Asare</td>
<td>Ph. D. NMSU (USA); 1995</td>
<td>Snr Lecturer</td>
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</table>
DEPARTMENT OF MEDICAL PHYSICS

PROGRAMME

M.Phil in Medical Physics
MASTER OF PHILOSOPHY (M.PHIL) IN MEDICAL PHYSICS

ADMISSION REQUIREMENTS

i. The minimum qualification for this programme is a good first degree (at least a second class lower division) in Physics from any approved University.

ii. A candidate who does not satisfy the requirement in an appropriate field of study as above but is otherwise adjudged suitable by virtue of appropriate experience will be considered.

YEAR 1.

<table>
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<th>COURSE CODE</th>
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<tr>
<td>MPHY 601</td>
<td>Selected topics in Anatomy, Physiology and Chemistry</td>
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<td>MPHY 603</td>
<td>Computing, Micro-computing, Probability and Statistics</td>
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<td>MPHY 605</td>
<td>Radiation Physics</td>
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<td>MPHY 607</td>
<td>Radiobiology and Radiation Protection</td>
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<td>Electronics, Instrumentation, Signal Analysis, Imaging and Display</td>
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<td>Dosimetry for Photon and Electron Beams</td>
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<td>MPHY 613</td>
<td>Practicals in Radiation Dosimetry</td>
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<td>Practicals in Radiotherapy</td>
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<td>MPHY 602</td>
<td>Ultrasonics, Theory, Instrumentation and Practice</td>
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<td>MPHY 604</td>
<td>NMR Spectroscopy and Imaging</td>
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<td>X-Rays and Diagnostic Radiology</td>
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<td>MPHY 608</td>
<td>Nuclear Medicine</td>
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<td>Radiotherapy</td>
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<td>MPHY 614</td>
<td>Applications of Digital Computers, Lasers in Medicine, Ultraviolet radiation and Hydrophilic Materials</td>
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<td>MPHY 619</td>
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<td>MPHY 613 AND MPHY 615</td>
<td>Inter-Semester break practicals</td>
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Total Credits in year 1: (including practicals) 40

YEAR 2.

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<td>MPHY 616</td>
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<td>MPHY 618</td>
<td>Seminar 2</td>
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Total Credits in year 2: (including practicals) 37
COURSE DESCRIPTIONS

MPHY 601: SELECTED TOPICS IN ANATOMY, PHYSIOLOGY AND CHEMISTRY (3 Credits)

Structure and Function/Haemodynamics: An introductory course on the structure and function of the main organ systems in the body and their role in maintaining homeostasis; Fluid biomechanics and flow properties of blood; The vascular network, viscometry and pulsatile flow; Measurement of blood pressure, flow and volume; Electromagnetic and ultrasonic techniques; Use and technology of extracorporeal circuits. Chemistry: Theoretical instrumentation and applied aspects of basic chromatographic methods as used for the qualitative and quantitative and quantitative analysis of clinical and biological samples; Evaluation of instrumentation supported by practical experience of thin layer, gas and high performance liquid chromatography; Techniques commonly used in Analytical Chemistry with Electrochemical Applications in the Medical and Sociological field; Introduction to theoretical aspects and simple models, which explain the behavioural response of biological cells to external Electromagnetic (EM) fields.

MPHY 602: ULTRASONICS, THEORY INSTRUMENTATION AND PRACTICE (2 Credits)

Ultrasonics: Theory: Physics of ultrasound generation and detection; Ultrasonic wave propagation; Bio-acoustics and their application to clinical ultrasound; Ultrasound Instrumentation and Practice; Physical concepts underlying the design and use of modern ultrasonic equipment, building from elementary principle through to those that are more demanding (The style is largely non-mathematical and descriptive); Basic concepts of medical ultrasonics and ultrasonic characterization of materials; Ultrasound imaging display modes (e.g. A,B, TP and sector scanning),. Image quality (longitudinal lateral and spatial resolution and contrast), beam properties (Fresnel and Fraunhofer beam zones), Doppler scanning; Techniques and typical image artifact.

MPHY 603: COMPUTING, MICROCOMPUTING, PROBABILITY AND STATISTICS. (3 Credits)

Computing and microcomputing: Introduction to key topic including: the CPU, memory subsystems, peripherals and computer interfacing; programming in C++ and VISUAL BASIC Image formatting (e.g. JPEG, BITMAP) and analogue-to-digital conversion (sampling rate and Nyquist criterion); Probability and Applied Statistics

MPHY 604: NMR SPECTROSCOPY AND IMAGING (3 Credits)

NMR Spectroscopy and imaging: Basic physical principles; Magnetization, radiofrequency, Larmor frequency, Larmor frequency; T1 and T2 relaxation, pulse sequences, magnet complex, magnet and cryogens, shim coils, gradient coils, radiofrequency coils; Computer systems; Control and viewing consoles. NMR imaging: Imaging methods; Sequential point measurements; Line methods; Planar methods; 3-D techniques; Pulse sequences used in clinical MRI; Image quality; Image artifacts; Magnet shielding; Relaxation and contrast enhancement in imaging; Water content and relaxation Contrast enhancement agents; Imaging of flow; Chemical shift imaging; Imaging of solids and materials; Solvent suppression; Magnetic resonance dosimetry; Electron Spin Resonance (ESR); Electronic paramagnetism; Classical view of magnetic resonance; Hyperfine interaction; ESR spectrometer; Quantitative ESR; Magnetic Resonance Imaging safety; Static magnetic field; Gradient magnetic fields; Radio-frequency fields; Liquid cryogens or heat dissipation; Metal objects and missiles, magnetic devices
MPHY 605: RADIATION PHYSICS  (2 Credits)
Radiation Physics: Detection and Dosimetry; The interactions of radiations with matter, with particular emphasis on photons; Gamma-ray spectrometry, detection and measurement techniques; Quantitative tomography; Radioactive substances, radiation counting and dosimetry; Use of Sources of Radiation in nuclear medicine, Radiotherapy and radiopharmacy;

MPHY 606: X-RAYS AND DIAGNOSTIC RADIOLOGY  (3 Credits)
Charged Particles and X-Rays: The interaction of charged particles, in particular electrons, with matter; Production of characteristic X-rays and bremsstrahlung; X-Rays and Diagnosis; A description and explanation of commonly used X-Ray equipment; X-ray equipment physical performance and practical application.; Physicist’s role in diagnostic x-ray imaging, particularly the contribution to quality assurance of x-ray equipment and radiation protection; Mammography: Physics and QA; Introduction to mammography as a dedicated X-ray imaging modality and its use in a population-screening programme; Practical Aspects of Ct Scanning; The CT image (how it is created and presented); CT scanner design (first, second, third and fourth generation and spiral scanners) detectors used in CT Scanning; CT imaging performance parameters (noise, resolution, slice thickness and how they are measured), and artifacts in CT; Demonstration of clinical CT system in support of taught sessions.

MPHY 607: RADIOBIOLOGY AND RADIATION PROTECTION  (3 Credits)
Radiobiology: Effects of radiation on biological systems are developed into effects (stochastic and deterministic) on man and reasons for the quantification of risks; Cell, Radiation damage and repair; Survival curves and models; Effects of radiation on cells, molecules, tissues, organs; Sources of ionizing radiation (natural and man-made) and their contribution to absorbed dose to the population; Dosimetry related to Radiation Protection; Concepts, quantities and practical methods of measuring radiation dose are considered including methods for evaluating dose from radioisotopes taken into the body; Consideration of a selection of legal, administrative and practical radiation protection issues; Radiation Protection; The consideration of ‘real life’ situations, which involve radiological protection in R&D, Medicine and Industry; The impact of these situations on workers, the public and environment.

MPHY 608: NUCLEAR MEDICINE  (3 Credits)
Nuclear medicine: Types of radionuclides used in medicine and methods of production; Preparation of labeled materials and radiopharmaceuticals; ‘In vivo’ and sample measurement techniques; Principles of tracer kinetics; Radionuclide imaging, design and QA of cameras and other imaging systems; Gamma-ray emission tomography and positron tomography; Dynamic studies; Whole body counting; Saturation analysis; Clinical applications of radionuclide techniques, tumor localization, organ function, absorption studies, metabolic investigation; Comparison of radionuclide and other tests; Radiation protection and isotope dosimetry; Radiopharmacy.

Radionuclides-review of decay modes and production methods; Preparation of radiopharmaceuticals- Pharmacopoeial requirements; Overview of radiopharmaceuticals-labeling methodologies; Diagnostic radiopharmaceuticals-selection of radionuclide, localization mechanisms, clinical applications, protein and peptide based radiopharmaceuticals; Therapeutic radiopharmaceuticals-selection of radionuclide, relevance of dosimetry studied, clinical applications In vitro studies.
MPHY 609: ELECTRONICS, INSTRUMENTATION SIGNAL ANALYSIS, IMAGING AND DISPLAY (3 Credits)

Electronics Instrumentation: A basic theoretical and experimental course on aspects of device and system electronics; Safety Aspects of Medical Physics; Medical physicists work in a multi-disciplinary environment and need to be aware of the various risks to which they and patients may be exposed; Principles of safe working; Signal Analysis; Introductory course to medical signal processing, which will be relevant to X-ray CT, MRI and ultrasound; Imaging and Display; Medical imaging processes: image acquisition, image display and image perception; Different types of medical imaging are compared in a way that allows both differing and complimentary characteristics to be compared in relation to the state of formal imaging theory; Overview of the relative contribution of different imaging modality, another and to specific medical applications; Methods of image display and hard copy outputs, together with factors affecting visual perception.

MPHY 611: DOSIMETRY FOR KILOVOLTAGE X-RAYS, MEGAVOLTAGE PHOTON AND ELECTRON BEAMS (3 Credits)

Photon interaction mechanisms: Attenuation of photons by matter; Absorption processes; Scattering processes; Total atomic collision cross-section. Electron interaction mechanisms: introduction; Electron-electron collision losses; Radiation losses; Total stopping power; Energy-loss straggling; Elastic nuclear scattering; Application to an electron depth-dose curve; Photon and electron; Interaction coefficients for dosimetry; Fundamental principles of dosimetry; Introduction; Stochastic nature of energy deposition; Definition of Absorbed Dose; Particle Fluence; Energy Fluence; Planner Fluence; Kerma; Relation between Fluence and Kerma; Relation between Kerma and Absorbed Dose; Charged particle equilibrium; Transient charged particle equilibrium; Cavity theory for “large” detector; Relation between Fluence and Dose for electrons; Delta-ray equilibrium; Bragg-gray cavity theory; Spencer-Attix modification of Bragg-Gray theory; General cavity theory; The Fano theorem; Dosimetry standards and their dissemination; Introduction; Low and medium energy x-radiation; Free-air chamber; Standards for 80 KV to 300 KV X-radiation at SSDL; Higher energy x-ray and gamma ray beams; Cavity chamber for measurements of high-energy X-ray beams; Absorbed dose and still higher X-ray energies; Absorbed dose calorimeter for X-ray.

Measurements at Primary Standard laboratory; Working standards for Absorbed Dose calibrations; Conversion of Absorbed Dose from graphite to water; Cavity ionization theory method; Dose ratio method; Comparison of the two methods; X-ray calibration procedure at primary standard laboratory; Dissemination of X-ray standards; Electron beam dosimetry; Existing procedure for electron dosimetry; New Absorbed Dose calibration service for electron chambers. Overview of dose measurement methods: Introduction; Calorimetry; Fricke (ferrous Sulphate) system; Thermoluminescence dosimetry; Semiconductor diodes; Film as a dosimeter; Miscellaneous systems; Ionization chambers: General; Thimble chambers; Measuring systems; Practical measurement corrections; Build-up caps; Choice of dosimetry method;

Dosimetry protocols based on air kerma calibration: Introduction; Background; From AIR KERMA to the No. factor; The factors km and Katt; Bragg-Gray relation; Stopping – power ratios; Perturbation factors: Correction for extended detector; Wall correction factor: Putting the components together; Uncertainties; Dosimetry of electron beams: Introduction; Depth Dose characteristics of electron beams; Energy specification of electron beams; The mean energy at the surface; The most probable energy at the surface; The mean energy at depth: Formalism of electron...
dosimetry protocols; Stopping power ratios; Perturbation factors; Electron protocols; Low energy electrons/plane parallel chambers; Non-water phantoms; Practical measurement correction factors; Protocol development; Uncertainties;

Determination of dose from kilovoltage X-rays: Definition, application, physics; Ionization chamber; Recommended procedures; Low-energy X-rays; Backscatter factors; Medium – energy X-rays; Perturbation factors: Correction to standard ambient conditions: Determination of HVL. Depth – dose and Isodose distributions: Adoption of published data; Measurement of depth – doses and isodoses; Calculation of depth – doses and isodoses

Calibration and QA of Brachytherapy sources: TLD dosimetry; Basic principles; Calibration procedures; Accuracy and precision, Calibration; Practical considerations: Choice of TLD material, Read out; Linearity, Energy and Quality Dependence, Angular dependence, Fading, Background signals, Annealing, Glow curves, Packaging and handling, Quality control, Automatic readers. Practical considerations for in vivo dosimetry: Alternative dosimetry systems, Semiconductor dosimetry: Theory of operation, Diode encapsulation, Temperature effects, Background signals, Radiation damage; Energy dependence, Angular dependence, Calibration, Quality control.

**MPHY 612: RADIOTHERAPY** *(3 Credits)*

Teletherapy: Treatment planning in radiotherapy: Radiotherapy as treatment modality, Considerations for therapy planning; Normal tissue tolerance, Tumor control. Treatment techniques: Introduction, Single field, Opposed fields, Wedge pair and 3 fields, 3-dimensional planning, The planning process, target localization; Patient position, Immobilisation devices, Reference landmarks, Patient machine alignment, Direct making, Simulator, CT, limitations to accuracy, Introduction; Implication for planned target size; Dose measurements, Dose limitations. Simulation techniques and patient positioning: Patient positioning, Special systems, Breast, Cast support system, Cast positions, Cast size, Initial localization, Simple fields, Complicated treatments, Block preparation, Multiple field treatment, Contrast media, Requirements for CT scans, Use of CT treatment planning, CT numbers and windowing, Inhomogeneity corrections based on CT, properties of CT image, Transfer of Ct and MRI images, Coplanar treatment in an inclined plane, Use of CT in radiation therapy, Requirements of CT for radiation planning, Impact of CT on radiotherapy planning, Value of CT scanning in radiation planning; Effects of CT on outcome of radiotherapy treatment; MRI images for treatment planning: benefits and problems, Introduction nuclear magnetism, Signal measurement, Relaxation times, Pulse sequences, Signal localisation in imaging, Origin of T1 and T2 relaxation, Conventional pulse sequences, Fast (Gradient echo) sequences, hardware employed in MRI, MR in radiotherapy

Photon dose calculations in planning: basic tools: Definitions, Back Scatter Factor, Peak Scatter Factor; Tissue Air ratio, Tissue maximum Ratio, Output Factor, Effects of accelerator geometry, Calculation of central Axis Depth doses, Percentage Depth Dose method, TAR method, Effect of change of SSD, Blocked Beams, Correction for inhomogeneity; Off Axis Calculations: Off axis factors, Position of beam edge, Use of isodose chart, Correction for obliquity and inhomogeneity, Isodose shift method, TMR method, Wedges, Calculations of lead blocks, Asymmetric collimators, Computer dose calculation algorithms: photons, Computer dose calculation algorithm : electrons, Data collection : theory and practice, Treatment plan accuracy, Commercial planning systems, Stereotactic radiotherapy

Brachytherapy: Clinical considerations in Brachytherapy, Surface moulds and interstitial therapy, Intracavitary techniques and dosimetry, After loading equipment and techniques, Unsealed sources
for radionuclide therapy, Megavoltage radiation sources, Equipment and Quality Assurance, Generation and quality control of Kilovoltage X-rays, Production of a clinically useful beam, Quality control of megavoltage photon equipment, Quality control of dose, Quality control of the treatment planning process, Radiation Biology; Radiobiology of tumors, Radiobiology of normal tissues, Biological models in treatment planning, Radiotherapy in its radiobiological context

Imaging and verification: Megavoltage imaging, Image analysis techniques, Verification system, In vivo Dosimetry/ Monte Carlo Simulations, Clinical situations, Practical considerations for in vivo measurements, Total body irradiation, Skin dose measurement, Eye doses, Field matching, Dynamic therapy, Rectal dose measurements, Iridium implant dosimetry, Quality assurance by in vivo measurements, Phantom measurements, Monte Carlo methods: what, why and how?

**MPHY 614: APPLICATIONS OF DIGITAL COMPUTERS, LASERS IN MEDICINE, ULTRAVIOLET RADIATION AND HYDROPHILIC MATERIALS**

(2 Credits)

Computer Applications: Major concepts involved in computing in a medical environment including signal digitization, digital sampling, speed and bandwidth; An overview of networking and communications, and examples of computers for a number of specific clinical applications. Formal reconstruction theory. MTF and ROC Analysis; An introduction into the concepts of modulation transfer function (MTF) and its application in assessing the performance of an imaging system. The role of the observer in a generalized imaging system is considered and so is the use of the receiver operating characteristics (ROC) analysis for evaluating the observer’s performance. Brain function; Basic aspects of brain function; Physical techniques used as probes.

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Name of Lecturer</th>
<th>Highest qualification, Institution &amp; Year</th>
<th>Status</th>
<th>Status of Appointment</th>
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<tr>
<td>MPHY 601</td>
<td>Selected topics in Anatomy Physiology and Chemistry</td>
<td>Dr. John Kutor</td>
<td>Ph.D., Zhejiang Univ., 2004</td>
<td>Lecturer</td>
<td>Part-Time</td>
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<tr>
<td>MPHY 605</td>
<td>Radiation Physics</td>
<td>Prof. J. J. Fletcher</td>
<td>Ph.D</td>
<td>Assoc. Prof.</td>
<td>Part-Time</td>
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<tr>
<td>MPHY 607</td>
<td>Radiobiology and Radiation Protection</td>
<td>Prof. C. Schandorf</td>
<td>Ph.D., UG</td>
<td>Assoc. Prof</td>
<td>Full-Time</td>
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<tr>
<td>MPHY 609</td>
<td>Electronics, Instrumentation, Signal Analysis, Imaging and Display</td>
<td>Mr. Allison Hughes, Prof. J.H. Amuasi</td>
<td>M.Phil., UG, Ph.D, Univ. London, 1982</td>
<td>Lecturer, Professor</td>
<td>Part-Time, Full-Time</td>
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<td>MPHY 611</td>
<td>Dosimetry for Photon and Electron Beams</td>
<td>Mr. E.K. Nani, Mr. E.K. Addison</td>
<td>M.Phil., UG, M.Sc., KNUST, 1993</td>
<td>Lecturer, Lecturer</td>
<td>Full-Time, Part-Time</td>
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<td>Practicals in Radiation Dosimetry</td>
<td>Mr. E.K. Nani, Mr. E.K. Addison</td>
<td>M.Phil., UG, M.Sc., KNUST, 1993</td>
<td>Lecturer, Lecturer</td>
<td>Full-Time, Part-Time</td>
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<td>MPHY 615</td>
<td>Practicals in Radiotherapy</td>
<td>Mr. E.K. Nani, Mr. E.K. Addison</td>
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<td>Lecturer, Lecturer</td>
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<td>MPHY 602</td>
<td>Ultrasonics, Theory, Instrumentation &amp; Practice</td>
<td>Prof. C. Schandorf</td>
<td>Ph.D., UG</td>
<td>Assoc. Prof</td>
<td>Full-Time</td>
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<td>MPHY 604</td>
<td>NMR, Spectroscopy &amp; Imaging</td>
<td>Prof. C. Schandorf</td>
<td>Ph.D., UG</td>
<td>Assoc. Prof</td>
<td>Full-Time</td>
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<td>MPHY 606</td>
<td>X-Rays &amp; Diagnostic Radiology</td>
<td>Prof. J. J. Fletcher, Prof. C. Schandorf</td>
<td>Ph.D, Ph.D, UG.</td>
<td>Assoc. Prof</td>
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<td>MPHY 608</td>
<td>Nuclear Medicine</td>
<td>Prof. A.W.K. Kyere, Dr. I.K. Wilson</td>
<td>Ph.D, Leeds, Ph.D.</td>
<td>Assoc. Prof</td>
<td>Full-Time, Full-Time</td>
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<td>MPHY 612</td>
<td>Radiotherapy</td>
<td>Mr. E.K. Addison, Mr. E.K. Nani</td>
<td>M.Sc., KNUST, 1993, M.Phil., UG</td>
<td>Lecturer, Lecturer</td>
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<td>MPHY 614</td>
<td>Applications of Digital Computers, Lasers, etc.</td>
<td>Dr. J. Kutor</td>
<td>Ph.D., Zhejiang Univ., 2004</td>
<td>Lecturer</td>
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DEPARTMENT OF NUCLEAR ENGINEERING

PROGRAMME

M.Phil in Nuclear Engineering
  Option 1. Reactor Physics
  Option 2. Reactor Engineering
MASTER OF PHILOSOPHY (M.PHIL) NUCLEAR ENGINEERING

ADMISSION REQUIREMENTS

i. The minimum qualification is a good honours degree (at least Second Class Honours Division) in any of the following fields: Physics, Mathematics, Computer Science or Chemical/Nuclear/Mechanical/Electrical/Electronics/Materials/Civil Engineering.

ii. A candidate who does not satisfy the requirement in an appropriate field of study as above but is otherwise adjudged suitable by virtue of appropriate experience will be considered.

YEAR 1.

OPTION 1: REACTOR PHYSICS

CORE COURSES

NENG 601: Basic Reactor Physics 3
NENG 603: Types of Reactors 2
NENG 605: Nuclear Heat Transfer & Fluid Flow 3
NENG 607: Health Physics & Radiation Protection 3
NENG 609: Radiation Detection 2
NENG 611: Computational Methods in Engineering 2
NENG 620: Seminar 1 3

INTER-SEMESTER PRACTICALS ON RADIATION AND HEALTH PHYSICS MEASUREMENTS.

NENG 624: Experiments on radiation measurement:
  i. Gamma-Ray spectroscopy using NaI(Tl).
  ii. Study of hydrogenous materials for neutron shielding.

NENG 626: Experiments on Activation Analysis:
  i. Measurement of average neutron flux using HPGe detector.
  ii. Determination of manganese in steel using NAA

PRESCRIBED ELECTIVES

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<td>NENG 602:</td>
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<td>NENG 604:</td>
<td>Reactor Dynamics</td>
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<td>NENG 608:</td>
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### YEAR 2

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**OPTION 2: REACTOR ENGINEERING**

### CORE COURSES

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<td>NENG 607:</td>
<td>Health Physics &amp; Radiation Protection</td>
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<td>NENG 611:</td>
<td>Computational Methods in Engineering</td>
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<td>NENG 619:</td>
<td>Seminar 1</td>
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**INTER-SEMESTER PRACTICALS ON REACTOR EXPERIMENTS AND COMPUTER EXERCISES**

- NENG 618: Reactor experiments.
  - i. Control Rod Calibration
  - ii. Measurement of neutron temperatures in the inner and outer irradiation sites

- NENG 622: Computer exercises on computer exercises
  - i. Computer exercises for calculation of reactor parameters
  - ii. Computer simulation of reactivity transients

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<td>Radiation Shielding</td>
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<td>Reactor Materials and Radiation Damage</td>
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<td>NENG 616:</td>
<td>Analysis of Cycles of Nuclear Power Plants</td>
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Total Credits in year 1: 34
Total Credits in year 2: 33

Students are expected to choose one of the two options. (Reactor Physics or Reactor Engineering). In the second year of the options, students are expected to undertake research projects and prepare dissertations in any of the following fields:

1. Neutron and Reactor Physics
2. Nuclear Fuel Management
3. Control and Instrumentation
4. Core Thermal-hydraulics
5. Radiation Shielding
6. Two-phase Flows and Head Transfer
7. Reactor Materials and radiation damage

COURSE DESCRIPTIONS

NENG 601: BASIC REACTOR PHYSICS (3 Credits)
Atomic Structure and Decay of Radiation Nuclei: Neutron Interactions; Steady State Reactor Core; Transient Reactor Behaviour and Control

NENG 603: TYPES OF REACTORS (2 Credits)
Classification and Use of Reactors: Research Reactors: i.e. MNSR, SLOWPOKE, TRIGA; Nuclear Power Plants (Fission Reactors); Pressurize Water Reactor (PWR); Boiling Water Reactor (PWR); Gas-Cooled Reactors (AGR); Sodium-Cooled Fast Breeder Reactor

NENG 605: NUCLEAR HEAT TRANSFER AND FLUID FLOW (3 Credits)
Fuel-Rod Design: Forced-Convention Heat Transfer; Boiling Heat Transfer; Fluid Flow; Core Thermohydraulic Design

NENG 607: HEALTH PHYSICS AND RADIATION PROTECTION (3 Credits)
Units and Measurements. Exposure and Biological Damage. External and Internal Effects and Treatment. Exposure Protection Guides; Shielding.

NENG 609: RADIATION DETECTION (2 Credits)
Light and Heavy Charged Particles: Gamma, X-Rays and Neutrons; Dosimeter; Ionization Type Detector; Ion Chambers; Proportional, Geiger-Muller Counters; Neutron Detectors and Fission Chambers; Fact Neutron and Solid-State Detectors; Thermoluminescent Dosimetry.
NENG 611: COMPUTATIONAL METHODS IN ENGINEERING  (2 Credits)
Fundamental of Numerical Analysis; Computer Solutions of 1-D Eigen value Problems; Interactive Computational Methods for Solving PDEs; Finite Element Methods; Monte Carlo Methods

NENG 602: REACTOR STATICS  (3 Credits)
Introduction to Reactor Statics; Neutron Cross-section; Reactor Rates; Differentiation Cross-section; Transport Equation; Integral Forms of the Transport Equation; Eigen values and Criticality; Multigroup Nuclear Data Libraries; Treatment of Energy, Angle and Space; Integral Transport Theory; Collision Probabilities; PL Approximation and Diffusion Theory; Discrete SN Method; Multigroup Iteration Methods; Group Constants in the Resonance Region; Critically Spectrum; Burnup; Nodal Equations for 3D Calculation.

NENG 604: REACTOR DYNAMICS  (3 Credits)
Basic Equations; Time-Dependent Transport and Diffusion Equations; Multigroup Time-Dependent Diffusion Equations; Classification of Reactor Transients; Transients and Accident Classification; Prompt Neutron Lifetime and Generation Time; Effective Delayed Neutron Fraction; Solutions of Neutron Kinetic Equations; Analytical Methods; Numerical Methods; Linear Reactor Process Dynamics with Feedback; Neutronics Transfer Function; Void Effects; Reactor Thermal Transients; Reactor Plant Dynamics; Reactor Control Elements; Reactor Stability; Stability Evaluation; Reactor Transfer Equation; Stability Criteria; Fluctuations and Rector Noise; Probability Equations; Feynman-alpha Technique; Rossi-alpha Technique; Experimental Applications

NENG 606: NUCLEONICS  (3 Credits)
Power Supplies: High voltage-supplies, Switch mode power supplier; Analog Circuits; Digital Circuits, Scalars; Rate meters, Multi-Channel Analyzers, PC-based MCA; Interfacing nuclear experiments to PC Radiation Dectects; Ionization chamber; GM counters; Scintillation Counters

NENG 608: FUEL MANAGEMENT  (3 Credits)
Review of Reactor Parameters: Nuclear Power Plant Systems and Components; Nuclear Fuel Cycle; Fuel Loading Requirements; Reactivity Control Management; Fuel Depletion Analysis; In-Core Fuel Management; Fuel Loading Variables and Constraints; Selection of Fuel Reload Fraction; Fuel and Control Arrangement Strategies; Reactor Cycle Stretchout

NENG 610: TWO-PHASE FLOWS AND HEAT TRANSFER IN NUCLEAR REACTOR  (3 Credits)
Basic Equations Two-Phase Flow and Heat Transfer: Nucleate Boiling Heat Transfer; Bubble and Slug Flows; Annular Two-Phase Flow; Heat Transfer in High Quality Two-Phase Flows; Burnout and Critical Two-Phase Flows; Oscillatory Two-Phase Flows; Steady-State Sub-channel Analysis; Measuring Techniques in Two-Phase Flows; Emergency Core Cooling: Blowdown; Refilling

NENG 612: RADIATION SHIELDING  (3 Credits)
Radiation Shielding Principles; Radiation Attenuation Calculations; Point-Kernel Techniques; Experimental Point Kernel; Buildup Factors; Radiation Atternuation from a Line Source; Radiation Atternuation from a Plane Source; Volume-Distributed Source with Self Absorption; Reactor Shield Calculation using computer codes; Transport Equation and its Solution Method: Discrete or SN Method; Input Data Description or 1-D Transport Code; Description of the code structure; Reactor Shield Analysis.
NENG 614: REACTOR MATERIALS AND RADIATION DAMAGE (3 Credits)
Amorphous Materials: Temperature and Mobility Effects; Increase in Transition Temperature for BCC Metals; Stainless Steel in Fast Reactors; Comparison Between Thermal and Fast Neutron Damage; Nuclear Fuels and Fuel Densification; Dispersion-Type Alloys; Calculation of Atom Displacements in Materials.

NENG 616: ANALYSIS OF CYCLES OF NUCLEAR POWER PLANTS (3 Credits)
Power Plant Performance Parameters: Steam Plant; Closed-Circuit Gas-Turbine Plant; Internal-Combination Power Plant; Gas-Turbine Plant; Steam-Turbine Plant; Nuclear Power Plant Analysis: Simple Dual-Pressure Cycle: Calculation of HP and LP steam flows and cycle efficiency; Efficiency of the corresponding ideal dual-pressure cycle; Effects of circular power on the plant efficiency; Pressured Water Reactors; Boiling Water Reactors; Dual-Cycle BWR; Advanced Gas-cooled reactor (AGR) plant; High-temperature Gas-cooled Reactor (HTGR) plant

RECOMMENDED TEXTBOOKS
5. Elements of Nuclear Power, Longman Group Ltd. D.J. Bennet
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Name of Lecturer</th>
<th>Highest qualification, Institution &amp; Year</th>
<th>Status</th>
<th>Status of Appointment</th>
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<tr>
<td>NENG 601</td>
<td>Basic Reactor Physics</td>
<td>Prof. E.H.K. Akaho</td>
<td>Ph.D., Univ. Lond, 1982</td>
<td>Professor</td>
<td>Full-Time</td>
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<tr>
<td>NENG 603</td>
<td>Types of Reactors</td>
<td>Mr. Anim- Sampong</td>
<td>M.Phil., UG.,</td>
<td>Srn. Lecturer</td>
<td>Full-Time</td>
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<tr>
<td>NENG 605</td>
<td>Nuclear Heat Transfer Fluid Flow</td>
<td>Prof. E.H.K. Akaho</td>
<td>Ph.D., Univ. Lond, 1982</td>
<td>Professor</td>
<td>Full-Time</td>
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<tr>
<td>NENG 607</td>
<td>Health Physics &amp; Radiation Protection</td>
<td>Prof. J.J. Fletcher</td>
<td>Ph.D.,</td>
<td>Assoc. Prof.</td>
<td>Part-Time</td>
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<tr>
<td>NENG 609</td>
<td>Radiation Detection</td>
<td>Mr. B.J.B. Nyarko</td>
<td>M.Phil., UG.,</td>
<td>Srn. Lecturer</td>
<td>Full-Time</td>
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<tr>
<td>NENG 611</td>
<td>Computational Methods in Engineering</td>
<td>Prof. A. Ayensu</td>
<td>Ph.D.,</td>
<td>Assoc. Prof.</td>
<td>Part-Time</td>
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<tr>
<td>NENG 602</td>
<td>Reactor Statics</td>
<td>Prof. E.H.K. Akaho</td>
<td>Ph.D., Univ. Lond, 1982</td>
<td>Professor</td>
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<tr>
<td>NENG 604</td>
<td>Reactor Dynamics</td>
<td>Prof. A.K. Addae</td>
<td>Ph.D., MIT</td>
<td>Professor</td>
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<tr>
<td>NENG 606</td>
<td>Nucleonics</td>
<td>Mr. P.K. Obeng</td>
<td>M.Sc.</td>
<td>Srn. Lecturer</td>
<td>Full-Time</td>
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<td>NENG 608</td>
<td>Fuel Management</td>
<td>Mr. B.J.B. Nyarko</td>
<td>M.Phil., UG.,</td>
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<tr>
<td>NENG 612</td>
<td>Radiation Shielding</td>
<td>Mr. Anim- Sampong</td>
<td>M.Phil., UG.,</td>
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<tr>
<td>NENG 614</td>
<td>Reactor Mat. &amp; Radiation Damage</td>
<td>Dr. K.A. Danso</td>
<td>Ph.D., Surrey, UK</td>
<td>Srn. Lecturer</td>
<td>Full-Time</td>
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