SCHOOL OF NUCLEAR AND ALLIED SCIENCES

DEPARTMENT OF NUCLEAR SCIENCES AND APPLICATIONS

PHD APPLIED NUCLEAR PHYSICS

1. INTRODUCTION

The Doctor of Philosophy degree in Applied Nuclear Physics requires a one year course work and original research in a specific area of applied Nuclear Physics, demonstration of broad knowledge in the following field: Applied Nuclear Physics, Physics, Electronics and Engineering Science or related discipline from a recognized University. The successful candidate must demonstrate a good understanding of Nuclear Physics. The PhD candidate will be expected to do a more in-depth creative research in order to make an original and significant contribution to the body of knowledge in the selected research area. This research should be carried out during a significant period of time (i.e. during at least one year or three semesters in residence). Thus, each successful PhD candidate will produce a significant piece of original research, presented in a written dissertation and defended in an oral examination. The candidate will also be expected to have submitted at least one (1) full paper originating from the research to a conference or publication in a reputable peer-review journal.

2. ADMISSION REQUIREMENTS

Admission to PhD programme in Applied Nuclear Physics will be limited to applicants who have a relevant Master's Degree from a recognized University.

3. DURATION OF PROGRAMME

The duration for the completion of PhD degree shall normally be four years for full-time students and six years for part-time students.

4. REQUIREMENTS FOR GRADUATION

The following are the credits that a registered student is required to earn in order to graduate:

Coursework	18 – 24 Credits
Seminars	12 Credits
Thesis	45 Credits
Total	**75 – 81 Credits**

5. STRUCTURE OF PROGRAMME

First Year: First Semester

CORE

Course Code	Course Title	Credits
FASC 701	Science and society	3

Elective

FASC 700	Special Topics in Science	3
NSAP 703	Aerosol Physics - Measurements, Techniques And Characterisation	3

Total **9 – 12 Credits**

First Year: Second Semester

Core

FASC 702	Advanced Quantitative Research Methods	3
NSAP 704	Statistical Mechanics	3

Elective (Select between 3 and 6 Credits)

FASC 705	Teaching of Science at the Tertiary level	3
SNAS 702	Project Design, Formulation and Management	3
NSAP 706	Dispersion Of Air Pollution And Receptor Modeling	3
NSAP 728	Nuclear Activation Analysis and Allied Analytical Techniques	3
NSAP 738	Quality Management in Testing Laboratories	3

Total **9 – 12 Credits**

Year 2, 3 and 4

Course Code	Course Title	Credits
NSAP 710 NSAP 720	Seminar I (Year 2, 1st Semester) Seminar II (Year 2, 2nd Semester)	3 3
NSAP 730	Seminar III (Year 3, 1st & 2nd Semester)	3
NSAP 740 NSAP 700	Seminar IV (Year 4) PhD Thesis (Year 4)	3 45
	Total	**57**

Students are free to audit Level 600 courses at SNAS

6. YEAR 2 ACTIVITIES

YEAR 2 OF THE NEW PhD STRUCTURE

All PhD students shall be required to spend the whole or part of the PhD Year 2 in an internship/experiential learning programme. The opportunities and types of projects /activities available will vary from one Academic Unit to the other. Each Academic Unit recommending admission of a candidate into a PhD programme shall be require to define in detail what the student will do within the internship Year to be submitted to the School of Graduate Studies as part of the documentation submitted for consideration.

Within six weeks to the end of Year 2, the student shall produce a report and give a seminar on what she/he has done during the year. The report and seminar shall be graded by the Departmental Graduate Committee and the grade shall be submitted to the SGS together with the recommendation for confirmation, or otherwise, of the PhD admission.

The list below gives examples of the activities that students may undertake in the internship year:

I. Attachment to industry or professional placement for a period; e.g.
II. SGMC Ltd, Nuclear Medicine and Radiotherapy Centers, Institutes and Laboratories of GAEC, Hospitals, Mining Companies, etc using nuclear gadgets etc.
III. Internal arrangements to attach PhD students to ongoing projects;
IV. Participation in colloquia, conferences, seminars to present papers;
V. Development of research proposals;
VI. Working with Professors on specific projects;
VII. Acquiring specific techniques and expertise
VIII. Development of methodologies to be used in the PhD research;

IX. Development of experimental protocols;
X. Participation in special courses in transferrable skills;
XI. Participation in doctoral academy modules;
XII. Visit partner universities/laboratories to participate in selected programmes/research;
XIII. Participate in laboratories rotations where replicable;
XIV. Action research (e.g. community projects) in the humanities.

The SGS shall provide guidance on the activities that shall count towards the Year 2 internship/experiential learning and assessment, and support to academic units in the elaboration of such activities

7. COURSE DESCRIPTION

FASC 700: Special Topics in Science (3 credits)
The course examines historical and contemporary issues in science, relating to the student's area of specialization and relevance. Such topics are expected to challenge the students into exploring current and relevant research trends/discoveries in scientific approaches. The course will enable students explore scientific knowledge in modern science, and add on to their depth of information in their chosen areas of specialty. It is expected that, the course will compliment other courses on the PhD flagship of the various departments in the Sciences and elsewhere. Additionally, it will expose students to current trends of presentations, and foster stronger confidence-building attitude that will enable enhanced international academic competitive spirit.

FASC 701: Science and Society (3 credits)
This course will enable students to gain insights in the practice of science as a discipline including major scientific concepts like inductivism are examined as well as the history of science and science itself, an overview of current approaches to research and an understanding of research partnership, networks and appropriate methods of communicating science depending on audience. The aim of the course is to help students to fit their research to relevant trends and directions for national development. Course content will cover topics such as the basis for the scientific method; conceptual frameworks; the philosophy of science; ethics in research; pure versus applied science debates; approaches to research; science for development and the merit of broader impact criteria; north south/south south collaboration and partnerships; research networks; communicating science to the policy maker, lay audience and to the media.

Readings List
Creswell, J. W. (2009) *Research Design: Qualitative, Quantities, and Mixed Methods Approaches (3rd Edition)* Sage publication London 296pp
Curd, M and Cover J. A. (1998) *Philosophy of Science: The Central Issues*. New York: Norton
Hirsch H. G. et al., (2008) Handbook of Transdisciplinary Research Springer 448 p
Kendler, H. H. (2003) should scientists remain objective? *Science* 301: 310-311.
Kuhn, T. S. (2012) *The structure of scientific revolutions*. Chicago, III. University of

Chicago Press
NCTE (2004) First National Forum on Research, Science and Technology, Accra, Ghana (ed. Prof. K. Kyekye)

FASC 702: Advanced Quantitative Research Methods (3 credits)
The course will serve as a step up for students who need to add up to their knowledge in quantitative methods of research techniques and analyses. Topics to be covered include: Sampling distributions and hypothesis testing. Sample size determination. Categorical data and chi-square, Non parametric tests. Principles of Design of Experiments. Analysis of variance and its assumptions. Experiments with single and multiple factors. Orthogonal and multiple Comparisons. Completely Randomized, Randomized Complete Block, repeated measures, cross over and Latin square designs. Nested designs. Fixed, random and mixed effects models. Factorial designs. Confounding. Fractional factorial designs. Split plot designs. Incomplete block designs. Analysis of covariance. Regression models: basic concepts; Regression Model Diagnostics. Categorical data analysis. Logistic regression, univariate and multivariate. Confounding and collinearity in logistic regression. Model selection in logistic regression.

FASC 710: Teaching Science at the Tertiary Level (3 credits)
It is anticipated that many of the students who go through the PhD programme in the Sciences may nurse special interest in teaching and academia. Focusing on group discussions, this course is expected to equip students with the requisite knowledge in overall management of students at the tertiary level. The course will focus on teaching the methodologies and techniques in handling Science-teaching at the undergraduate level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, examination preparation, teacher/student relationship, tertiary education management, will be discussed through reading, class/group discussions as well as presentations

SNAS 702: Project Design, Formulation and Management (3 Credits)

To improve the students performance in project planning, development and also upgrade their skills regarding techniques for implementing and managing research projects as well as increase their understanding on the relevance of the projects to national development. Specific areas include practical guidance on how research projects and facilities are managed form commencement to the end. It includes national development perspective, project concept, project cycle, project analysis, project appraisal/risk analysis, project scheduling, management of projects, project implementation; research cost estimation techniques, procurement procedures and managing contracts, monitoring and evaluation as well as report writing planning.

NSAP 703: Aerosol Physics - Measurements, Techniques and Characterisation. (3 Credits)

Nuclear Analytical Techniques (NAT) is one of the most successful analytical tools that have been applied to identify and characterise particulate matter in the atmosphere. In order to understand and describe the behaviour of the particles bound in air pollution a substantial amount of knowledge of Physics (Newton. Einstein and Stoke law, etc) is necessary. The course will include: Definitions related to air quality, and concepts of particle size. Siting criteria: macro-

and micro-siting, siting strategies for specific environments, sampling site characteristics. Sampling, sample handling, and choice of collection substrates. Analytical techniques employed in characterisation with emphasis on gravimetric analysis after size fractionation, and NAT. Physical characterisation due to generation, transformation, changing of particle size via coagulation process, specific types of aerosols -bulk motion of aerosols -dust explosion - bioaerosols and their effects, transport and deposition of aerosols, deposition of aerosol in human respiratory system, effect of meteorological conditions on aerosols, effect of aerosols on humans, vegetation, monuments, ecosystems and climate, interaction between particles and electromagnetic radiation.

NSAP 704: Statistical Mechanics (3 Credits)

Elements of statistical mechanics: description of state of microscopic system (equilibrium thermodynamics and statistical methods). Statistical Mechanics of Non-Interacting Particles: equipartition and virial theorems, degenerate gases, canonical and microcanonical ensembles. Landau Field Theory. Classical and Quantal ideal gases: Maxwell-Boltzmann Distribution: the perfect classical gas, the partition function, heat capacity, chemical potential, equipartition theorem and its applications. Fermi-Dirac distribution: the ideal fermion gas, electron distribution in metals, and their applications. Bose-Einstein distribution: the ideal boson gas, black body radiation (photon gas), Planck's radiation law, phonon gas, Bose-Einstein condensation. Applications of statistical mechanics: neutron spectrum, and photon radiation.

NSAP 706: Dispersion of Air Pollution and Receptor Modelling (3 Credits)

The transport and deposition of air particulates is strongly dependent on the size of the particles. When dispersion takes place, there is a strong influence from meteorological factors like temperature, wind, precipitation and other as well as geological situation. The aims of this course are to give a broad view of the factors to consider when dealing with dispersion of air pollutants, source assessment or characterisation and modelling of air pollution. The course include atmosphere and dispersion of air pollution - energy balance and temperature, models for dispersion of pollutants, dispersion in complex wind fields, cleaning processes of the atmosphere, types (Eulerian, Gaussian, etc) and scale (local, regional and global) of dispersion. Statistical (rapid assessment and empirical) models. Mass balance analysis, principle of mass conservation, sources apportionment, source profiles and receptor modelling. Chemical mass balance and multivariate methods in Receptor modelling. Tracer techniques, physical constraints, predicted mass and species. Long distance transport: models for the determination of air mass origins (HYSPLIT).

NSAP 728: Neutron Activation Analysis and Allied Analytical Techniques (3 credits)

The objective of the course is to expose doctoral students to recent advances in the use of Neutron Activation Analysis (NAA) and allied analytical techniques for trace elemental analysis/characterization in the fields of environment, health and nutrition, industrial processes, forensic, and archaeological investigations, and cosmochemistry. Quality assurance/quality

control in NAA, Ionization methods in AA; PIXE, X-ray fluorescence spectrometry, Alpha spectrometry, Liquid Scintillation Counter (LSC), Mossbauer spectrometry, Rutherford backscattering spectrometry; Modern trends in trace element speciation analysis using High performance liquid chromatography (HPLC) hyphenated with other analytical techniques like NAA (HPLC-NAA), Hydride generation atomic absorption spectrometry (HPLC-HG-AAS), inductively coupled plasma-mass spectrometry (HPLC-ICP-MS); Current trends in trace element determination (total) using various atomic absorption spectrometric (AAS) techniques [Hydride generation-AAS, Cold Vapour-AAS, Flame AAS].

NSAP 738: Quality Management in Testing Laboratories (3 credits)
The course is intended to give students in-depth knowledge on the requirements, implementation, and sustainability of quality management systems. The course will review international standards of the International Standards Organization's (ISO), quality management systems guidelines for nuclear analytical laboratories of the International Atomic Energy Agency (IAEA). Quality system implementation for nuclear analytical techniques: quality control and validation, instrument and laboratory management, documentation, document control, trackability, procurement, management of internal improvement, customers, reporting, human resource management; Clean laboratories and clean rooms for analysis of radionuclides and trace elements; Quality management systems; ISO 9001, ISO 17025, ISO 19011 and ISO 14001.

NSAP 710: Seminar I
This course is a research proposal seminar to be presented by the candidate. The seminar is to be accompanied by a detailed written research proposal. Candidates will also present seminars on current advanced topics of interest in the study area and attend departmental seminars.

NSAP 720: Seminar II
Candidates will be attached to relevant faculty research to gain experience in data collection and interpretation in their areas of research during the second semester of the second year on the programme. At the end of the second semester, each candidate is expected to submit a comprehensive report on the experience and present it orally to faculty and students at the end of the semester.

NSAP 730: Seminar III
Candidates will do oral presentation of research progress. In addition, candidates will present seminars on current advanced topics of interest in the study area, attend departmental seminars, attend and participate in both local and external conferences and workshops.

NSAP 740: Seminar III
Candidates will do oral presentation of research findings. Also, candidates will attend departmental seminars, attend and participate in both local and external conferences and workshops.

Linkages with other Departments/Organizations/Institutions

Department/Institution/Organization	Nature of support to programme
Geological Survey Department of Ghana	Provision of energy dispersive X-ray fluorescence (EDXRF) spectrometric analysis for practical work.
Ghana Atomic Energy Commission	Provision of most analytical instruments for practical work (AAS, NAA, GC-ECD, FP, IC, FTIR, LWSIA, GM counter, LSC, Alpha spectrometer)

PHD NUCLEAR AND ENVIRONMENTAL PROTECTION

1. INTRODUCTION

The Doctor of Philosophy degree in Nuclear and Environmental Protection requires a one year course work and original research in a specific area of Environmental Science, demonstration of broad knowledge in the following field: Nuclear Sciences, Physics, Chemistry, Geology, Biology, and Engineering Sciences or other related discipline from
a recognized university. The successful candidate must demonstrate a good understanding of Nuclear and Environmental Protection. The PhD candidate will be expected to do a more in-depth creative research in order to make an original and significant contribution to the body of knowledge in the selected research area. This research should be carried out during a significant period of time (i.e. during at least one year or three semesters in residence). Thus, each successful PhD candidate will produce a significant piece of original research, presented in a written dissertation and defended in an oral examination. The candidate will also be expected to have submitted at least one (1) full paper originating from the research to a conference or publication in a reputable peer-review journal.

2. ADMISSION REQUIREMENTS

Admission to PhD programme in Nuclear and Environmental Protection will be limited to applicants who have a relevant Master's Degree from a recognized University.

3. DURATION OF PROGRAMME

The duration for the completion of PhD degree shall normally be four years for full-time students and six years for part-time students.

4. REQUIREMENTS FOR GRADUATION

The following are the credits that a registered student is required to earn in order to graduate:

Coursework	18 – 24 Credits
Seminars (4)	12 Credits
Thesis	45 Credits
Total	**75 – 81 Credits**

5. STRUCTURE OF PROGRAMME

First Year: First Semester

Core

Course Code	Course Title	Credits
FASC 701	Science and society	3
NSAP 731	Interaction of Radiation with Matter-Advanced	3
NSAP 751	Contaminated sites investigation and remediation	3

ELECTIVE (select a maximum of 3 credits)

FASC 700	Special Topics in Science	3
NSAP 755	Advance Human Toxicology and Hazardous chemicals	3
NSAP 775	Stable Isotope Geochemistry	3
Total		**9 – 12 credits**

First Year: Second Semester

CORE

FASC 702	Advanced Quantitative Research Methods	3
NSAP 728	Nuclear Activation Analysis and Allied Analytical Techniques	3
NSAP 756	Environmental Chemistry	

Elective (Select between 3 and 6 credits)

FASC 710	Teaching of Science at the Tertiary level	3
SNAS 702	Project Design, Formulation and Management	3

NSAP 738	Quality Management in Testing Laboratories	3
NSAP 758	Advance Occupational Health And Safety	3
Total		**9 – 12 credits**

Year 2, 3, and 4

Course Code	**Course Title**	**Credits**
NSAP 710 NSAP 720	Seminar I (Year 2, 1st Semester) Seminar II (Year 2, 2nd Semester)	3 3
NSAP 730	Seminar III (Year 3, 1st & 2nd Semesters)	3
NSAP 740 NSAP 700	Seminar IV (Year 4) PhD Thesis (Year 4)	3 45
	Total	**57**

Students are free to audit Level 600 courses at SNAS

6. YEAR 2 ACTIVITIES

YEAR 2 OF THE NEW PhD STRUCTURE

All PhD students shall be required to spend the whole or part of the PhD Year 2 in an internship/experiential learning programme. The opportunities and types of projects /activities available will vary from one Academic Unit to the other. Each Academic Unit recommending admission of a candidate into a PhD programme shall be require to define in detail what the student will do within the internship Year to be submitted to the School of Graduate Studies as part of the documentation submitted for consideration.

Within six weeks to the end of Year 2, the student shall produce a report and give a seminar on what she/he has done during the year. The report and seminar shall be graded by the Departmental Graduate Committee and the grade shall be submitted to the SGS together with the recommendation for confirmation, or otherwise, of the PhD admission.

The list below gives examples of the activities that students may undertake in the internship year:

XV. Attachment to industry or professional placement for a period; e.g.
XVI. SGMC Ltd, Nuclear Medicine and Radiotherapy Centers, Institutes and Laboratories of GAEC, Hospitals, Mining Companies, etc using nuclear gadgets etc.
XVII. Internal arrangements to attach PhD students to ongoing projects;
XVIII. Participation in colloquia, conferences, seminars to present papers;
XIX. Development of research proposals;
XX. Working with Professors on specific projects;
XXI. Acquiring specific techniques and expertise
XXII. Development of methodologies to be used in the PhD research;
XXIII. Development of experimental protocols;
XXIV. Participation in special courses in transferrable skills;
XXV. Participation in doctoral academy modules;
XXVI. Visit partner universities/laboratories to participate in selected programmes/research;
XXVII. Participate in laboratories rotations where replicable;
XXVIII. Action research (e.g. community projects) in the humanities.

The SGS shall provide guidance on the activities that shall count towards the Year 2 internship/experiential learning and assessment, and support to academic units in the elaboration of such activities

7. COURSE DESCRIPTION

FASC 700: Special Topics in Science (3 credits)
The course examines historical and contemporary issues in science, relating to the student's area of specialization and relevance. Such topics are expected to challenge the students into exploring current and relevant research trends/discoveries in scientific approaches. The course will enable students explore scientific knowledge in modern science, and add on to their depth of information in their chosen areas of specialty. It is expected that, the course will compliment other courses on the PhD flagship of the various departments in the Sciences and elsewhere. Additionally, it will expose students to current trends of presentations, and foster stronger confidence-building attitude that will enable enhanced international academic competitive spirit.

FASC 701: Science and Society (3 credits)
This course will enable students to gain insights in the practice of science as a discipline including major scientific concepts like inductivism are examined as well as the history of science and science itself, an overview of current approaches to research and an understanding of research partnership, networks and appropriate methods of communicating science depending on audience. The aim of the course is to help students to fit their research to relevant trends and directions for national development. Course content will cover topics such as the basis for the scientific method; conceptual frameworks; the philosophy of science; ethics in research; pure versus applied science debates; approaches to research; science for development and the merit of broader impact criteria; north south/south south collaboration and partnerships; research networks; communicating science to the policy maker, lay audience and to the media.

FASC 702: Advanced Quantitative Research Methods (3 credits)
The course will serve as a step up for students who need to add up to their knowledge in quantitative methods of research techniques and analyses. Topics to be covered include: Sampling distributions and hypothesis testing. Sample size determination. Categorical data and chi-square, Non parametric tests. Principles of Design of Experiments. Analysis of variance and its assumptions. Experiments with single and multiple factors. Orthogonal and multiple Comparisons. Completely Randomized, Randomized Complete Block, repeated measures, cross over and Latin square designs. Nested designs. Fixed, random and mixed effects models. Factorial designs. Confounding. Fractional factorial designs. Split plot designs. Incomplete block designs. Analysis of covariance. Regression models: basic concepts; Regression Model Diagnostics. Categorical data analysis. Logistic regression, univariate and multivariate. Confounding and collinearity in logistic regression. Model selection in logistic regression.

FASC 710: Teaching Science at the Tertiary Level (3 credits)
It is anticipated that many of the students who go through the PhD programme in the Sciences may nurse special interest in teaching and academia. Focusing on group discussions, this course is expected to equip students with the requisite knowledge in overall management of students at the tertiary level. The course will focus on teaching the methodologies and techniques in handling Science-teaching at the undergraduate level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, examination preparation, teacher/student relationship, tertiary education management, will be discussed through reading, class/group discussions as well as presentations

SNAS 702: Project Design, Formulation and Management (3 Credits)

To improve the students performance in project planning, development and also upgrade their skills regarding techniques for implementing and managing research projects as well as increase their understanding on the relevance of the projects to national development. Specific areas include practical guidance on how research projects and facilities are managed form commencement to the end. It includes national development perspective, project concept, project cycle, project analysis, project appraisal/risk analysis, project scheduling, management of projects, project implementation; research cost estimation techniques, procurement procedures and managing contracts, monitoring and evaluation as well as report writing planning.

NSAP 728: Neutron Activation Analysis and Allied Analytical Techniques (3 credits)
The objective of the course is to expose doctoral students to recent advances in the use of Neutron Activation Analysis (NAA) and allied analytical techniques for trace elemental analysis/characterization in the fields of environment, health and nutrition, industrial processes, forensic, and archaeological investigations, and cosmochemistry. Quality assurance/quality control in NAA, Ionization methods in AA; PIXE, X-ray fluorescence spectrometry, Alpha spectrometry, Liquid Scintillation Counter (LSC), Mossbauer spectrometry, Rutherford backscattering spectrometry; Modern trends in trace element speciation analysis using High performance liquid chromatography (HPLC) hyphenated with other analytical techniques like NAA (HPLC-NAA), Hydride generation atomic absorption spectrometry (HPLC-HG-AAS), inductively coupled plasma-mass spectrometry (HPLC-ICP-MS); Current trends in trace element determination (total) using various atomic absorption spectrometric (AAS) techniques [Hydride generation-AAS, Cold Vapour-AAS, Flame AAS].

NSAP 731: Interaction of Radiation with Matter-Advanced (3 credits)
The course will review how photons and charged particles from radiation are absorbed and emitted, the effect of those processes and how they factor into quantum radiation theory. Students will also learn practical applications for these interactions and how to use them in academic and professional research. Interaction of electromagnetic radiation with matter, gamma-ray interaction; Photoelectric effect, Compton effect, Pair production, Mathematics of gamma-ray interactions, Absorption, Elastic and inelastic scattering; Heavy charged-particle interaction, range, stopping power, relative stopping power, ionization and energy loss during scattering of charged particles; Beta-particle interaction, range relationships for beta particles, the feather method, Bremsstrahlung radiation, Cerenkov radiation, beta backscatter, Positron interactions, Neutron interaction; General physical effects of radiation on matter, Energy transfer and radiation dose; Linear energy transfer; Effects of radiation on matter, Radiation induced synthesis; Classical electrodynamics, quantum theory of radiation, time-dependent perturbation theory, transition probabilities and cross sections describing interaction of various radiations with atomic systems.

NSAP 738: Quality Management in Testing Laboratories (3 credits)
The course is intended to give students in-depth knowledge on the requirements, implementation, and sustainability of quality management systems. The course will review international standards of the International Standards Organization's (ISO), quality management systems guidelines for nuclear analytical laboratories of the International Atomic Energy Agency (IAEA). Quality system implementation for nuclear analytical techniques: quality control and validation, instrument and laboratory management, documentation, document control, trackability, procurement, management of internal improvement, customers, reporting, human resource management; Clean laboratories and clean rooms for analysis of radionuclides and trace elements; Quality management systems; ISO 9001, ISO 17025, ISO 19011 and ISO 14001.

NSAP 751: Contaminated Sites Investigation And Remediation (3 Credits)

With increasing industrialisation in developing countries, environmental scientists are confronted with dealing with the effects of the contamination of a variety of media including soil, water, and air. Shrinking urban spaces and changing technologies imposes a critical need for remediation of polluted media and its adaptive re-use. The course addresses the mechanisms of contamination, pathway for distribution and prepares students to develop innovative practises in remedying such polluted media. Students will be able to understand the sources of these contaminants and the pathology of its impact on human and other living organisms. It provide students with an in depth knowledge in contaminated site investigation, risk assessment, remediation issues and management.

NSAP 755: Advance Human Toxicology and Hazardous Chemicals (3 Credits)

Naturally Occurring Chemicals in the Environment: Sources of toxicants; Minamata and environmental toxicity of mercury; Symptoms of methyl mercury poisoning; Treatment of Poisoning; Pesticides Classification, formulations and Use, 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)-; 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; Stockholm Convention

NSAP 756: Environmental Chemistry (3 Credits)

To provide students with an understanding of the roles of industries in the health of the environment and research, developments and technologies for minimization of environmental problems, sustainable development, and efficient utilization of resources and energy. Advanced Environmental Chemical Analysis, Industrial Ecology and Green Chemistry, Aquatic chemistry, Atmospheric chemistry, Environmental toxicology, Environmental Fate and transport of contaminants, Fossil Fuel and the environment, Resources and Energy Energy and mass transfer in the atmosphere; Chemical and photochemical reactions in the atmosphere (Photochemical processes, chemical and biochemical processes), Chemical fate and transport in the atmosphere. Particles in the atmosphere: Physical and chemical processes for particle formation; Industrial ecology for waste minimization, utilization and treatment (Recycling, biodegradation, treatment and composting, phytoremediation, Green waste treatment.

NSAP 758: Occupational Health and Safety (3 Credits)

General principles in evaluating the Occupational Environment; Significance of the occupational environment as part of the total ecological system. Physiology of heat stress; Ergonomic aspects of Biomedicines; Principles of controlling the occupational environment; Principles of ventilation; Local exhaust systems. Uses, benefits of radiation sources and ionizing radiation in, 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 environmental laboratory; Principles of nuclear safety as applied to radiation sources and relevant installations. Practical demonstration: measurements of radionuclides in environmental samples.

NSAP 775: Stable Isotope Geochemistry (3 Credits)

Introduction and Physics of the Nucleus, Energy, Entropy, and fundamental Thermodynamic concepts, thermodynamics of multicomponent systems, Application of thermodynamics in the Earth, Reaction kinetics, stable Isotope fractionation, Kinetic and Equilibrium fractionation, Predicting isotope fractionations. Mass dependent and mass independent fractionations, Isotope Geothermonetry, Rayleigh fractionation, Isotope fractionation in biological systems, carbon isotope fractionation, Isotope during photosynthesis. Isotope in hydrothermal activity, metamorphism and ore deposits. Isotope in climate research. Isotope techniques in terrestrial and extraterrestrial evolution. Current topics and Case studies in stable Geochemistry

NSAP 710: Seminar I
This course is a research proposal seminar to be presented by the candidate. The seminar is to be accompanied by a detailed written research proposal. Candidates will also present seminars on current advanced topics of interest in the study area and attend departmental seminars.

NSAP 720: Seminar II
Candidates will be attached to relevant faculty research to gain experience in data collection and interpretation in their areas of research during the second semester of the second year on the programme. At the end of the second semester, each candidate is expected to submit a comprehensive report on the experience and present it orally to faculty and students at the end of the semester.

NSAP 730: Seminar III
Candidates will do oral presentation of research progress. In addition, candidates will present seminars on current advanced topics of interest in the study area, attend departmental seminars, attend and participate in both local and external conferences and workshops.

NSAP 740: Seminar III
Candidates will do oral presentation of research findings. Also, candidates will attend departmental seminars, attend and participate in both local and external conferences and workshops. Complete thesis and submit for external examination. Submit at least one journal article for publication

Linkages with other Departments/Organizations/Institutions

Department/Institution/Organization	Nature of support to programme
Geological Survey Department of Ghana	Provision of energy dispersive X-ray fluorescence (EDXRF) spectrometric analysis for practical work.
Ghana Atomic Energy Commission	Provision of most analytical instruments for practical work (AAS, NAA, GC-ECD, FP, IC, FTIR, LWSIA, GM counter, LSC, Alpha spectrometer)

DOCTOR OF PHILOSOPHY DEGREE IN NUCLEAR EARTH SCIENCE

1. INTRODUCTION

The Doctor of Philosophy degree in Nuclear Earth Science requires a one year course work and original research in a specific area of Earth Science, demonstration of broad knowledge in the following field: Nuclear Earth Science, Applied geophysics, Applied geology, Geology, Applied Geochemistry or other related discipline from a recognized University. The successful candidate must demonstrate a good understanding of Nuclear Earth Science. The PhD candidate will be expected to do a more in-depth research in order to make an original and significant contribution to the body of knowledge in the selected research area. This research should be carried out during a significant period of time (i.e., during at least one year or three semesters in residence). Thus, each successful PhD candidate will produce a significant piece of original research presented in a written dissertation and defended in an oral examination. The candidate will also be required to have submitted at least one (1) full paper originating from the research to a conference or publication in a reputable peer – reviewed journal.

2. ADMISSION REQUIREMENTS

Admission to PhD programme in Nuclear Earth Science will be limited to applicants who have a relevant Master's Degree from a recognized University.

3. DURATION OF PROGRAMME

The duration for the completion of PhD degree shall normally be four years for full-time students and six years for part-time students.

4. REQUIREMENTS FOR GRADUATION

The following are the credits that a registered student is required to earn in order to graduate:

Coursework	18 – 24 Credits
Seminars	12 Credits
Thesis	45 Credits
Total	**75 – 81 Credits**

5. STRUCTURE OF PROGRAMME

First Year: First Semester

CORE

Course Code	Course Title	Credits
FASC 701	Science and society	3
NSAP 775	Advanced Stable Isotope Geochemistry	3

Elective (Select between 3 and 6 credits)

FASC 700	Special Topics in Science	3
NSAP 777	Nuclear Geochemistry	3
NSAP 779	Environmental Hydrogeology	3
Total		**9 – 12 Credits**

First Year: Second Semester

Core

FASC 702	Advanced Quantitative Research Methods	3
NSAP 776	Nuclear techniques in Hydrology and hydrogeology	3

Elective (Select between 3 and 6 Credits)

FASC 705	Teaching of Science in a Tertiary Institution	3
SNAS 702	Project Design, Formulation and Management	3
NSAP 728	Nuclear Activation Analysis and Allied Analytical Techniques	3
NSAP 780	Advanced Aqueous Geochemistry	3
NSAP 738	Quality Management in Testing Laboratories	3
Total		**9 – 12 Credits**

Year 2, 3 and 4

Course Code	Course Title	Credits
NSAP 710 NSAP 720	Seminar I (Year 2, 1st Semester) Seminar II (Year 2, 2nd Semester)	3 3
NSAP 730	Seminar III (Year 3, 1st & 2nd Semester)	3
NSAP 740 NSAP 700	Seminar IV (Year 4) PhD Thesis (Year 4)	3 45
	Total	**57**

Students are free to audit Level 600 courses at SNAS

6. YEAR 2 ACTIVITIES

YEAR 2 OF THE NEW PhD STRUCTURE

All PhD students shall be required to spend the whole or part of the PhD Year 2 in an internship/experiential learning programme. The opportunities and types of projects /activities available will vary from one Academic Unit to the other. Each Academic Unit recommending admission of a candidate into a PhD programme shall be require to define in detail what the student will do within the internship Year to be submitted to the School of Graduate Studies as part of the documentation submitted for consideration.

Within six weeks to the end of Year 2, the student shall produce a report and give a seminar on what she/he has done during the year. The report and seminar shall be graded by the Departmental Graduate Committee and the grade shall be submitted to the SGS together with the recommendation for confirmation, or otherwise, of the PhD admission.

The list below gives examples of the activities that students may undertake in the internship year:

XXIX. Attachment to industry or professional placement for a period; e.g.
XXX. SGMC Ltd, Nuclear Medicine and Radiotherapy Centers, Institutes and Laboratories of GAEC, Hospitals, Mining Companies, etc using nuclear gadgets etc.
XXXI. Internal arrangements to attach PhD students to ongoing projects;
XXXII. Participation in colloquia, conferences, seminars to present papers;
XXXIII. Development of research proposals;
XXXIV. Working with Professors on specific projects;
XXXV. Acquiring specific techniques and expertise
XXXVI. Development of methodologies to be used in the PhD research;
XXXVII. Development of experimental protocols;
XXXVIII. Participation in special courses in transferrable skills;
XXXIX. Participation in doctoral academy modules;

XL. Visit partner universities/laboratories to participate in selected programmes/research;
XLI. Participate in laboratories rotations where replicable;
XLII. Action research (e.g. community projects) in the humanities.

The SGS shall provide guidance on the activities that shall count towards the Year 2 internship/experiential learning and assessment, and support to academic units in the elaboration of such activities

7. COURSE DESCRIPTION

FASC 700: Special Topics in Science (3 credits)
The course examines historical and contemporary issues in science, relating to the student's area of specialization and relevance. Such topics are expected to challenge the students into exploring current and relevant research trends/discoveries in scientific approaches. The course will enable students explore scientific knowledge in modern science, and add on to their depth of information in their chosen areas of specialty. It is expected that, the course will compliment other courses on the PhD flagship of the various departments in the Sciences and elsewhere. Additionally, it will expose students to current trends of presentations, and foster stronger confidence-building attitude that will enable enhanced international academic competitive spirit.

FASC 701: Science and Society (3 credits)
This course will enable students to gain insights in the practice of science as a discipline including major scientific concepts like inductivism are examined as well as the history of science and science itself, an overview of current approaches to research and an understanding of research partnership, networks and appropriate methods of communicating science depending on audience. The aim of the course is to help students to fit their research to relevant trends and directions for national development. Course content will cover topics such as the basis for the scientific method; conceptual frameworks; the philosophy of science; ethics in research; pure versus applied science debates; approaches to research; science for development and the merit of broader impact criteria; north south/south south collaboration and partnerships; research networks; communicating science to the policy maker, lay audience and to the media.

FASC 702: Advanced Quantitative Research Methods (3 credits)
The course will serve as a step up for students who need to add up to their knowledge in quantitative methods of research techniques and analyses. Topics to be covered include: Sampling distributions and hypothesis testing. Sample size determination. Categorical data and chi-square, Non parametric tests. Principles of Design of Experiments. Analysis of variance and its assumptions. Experiments with single and multiple factors. Orthogonal and multiple Comparisons. Completely Randomized, Randomized Complete Block, repeated measures, cross over and Latin square designs. Nested designs. Fixed, random and mixed effects models. Factorial designs. Confounding. Fractional factorial designs. Split plot designs. Incomplete block designs. Analysis of covariance. Regression models: basic concepts; Regression Model

Diagnostics. Categorical data analysis. Logistic regression, univariate and multivariate. Confounding and collinearity in logistic regression. Model selection in logistic regression.

FASC 710: Teaching Science at the Tertiary Level (3 credits)
It is anticipated that many of the students who go through the PhD programme in the Sciences may nurse special interest in teaching and academia. Focusing on group discussions, this course is expected to equip students with the requisite knowledge in overall management of students at the tertiary level. The course will focus on teaching the methodologies and techniques in handling Science-teaching at the undergraduate level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, examination preparation, teacher/student relationship, tertiary education management, will be discussed through reading, class/group discussions as well as presentations.

SNAS 702: Project Design, Formulation and Management (3 Credits)

To improve the students performance in project planning, development and also upgrade their skills regarding techniques for implementing and managing research projects as well as increase their understanding on the relevance of the projects to national development. Specific areas include practical guidance on how research projects and facilities are managed form commencement to the end. It includes national development perspective, project concept, project cycle, project analysis, project appraisal/risk analysis, project scheduling, management of projects, project implementation; research cost estimation techniques, procurement procedures and managing contracts, monitoring and evaluation as well as report writing planning.

NSAP 728: Neutron Activation Analysis and Allied Analytical Techniques (3 credits)
The objective of the course is to expose doctoral students to recent advances in the use of Neutron Activation Analysis (NAA) and allied analytical techniques for trace elemental analysis/characterization in the fields of environment, health and nutrition, industrial processes, forensic, and archaeological investigations, and cosmochemistry. Quality assurance/quality control in NAA, Ionization methods in AA; PIXE, X-ray fluorescence spectrometry, Alpha spectrometry, Liquid Scintillation Counter (LSC), Mossbauer spectrometry, Rutherford backscattering spectrometry; Modern trends in trace element speciation analysis using High performance liquid chromatography (HPLC) hyphenated with other analytical techniques like NAA (HPLC-NAA), Hydride generation atomic absorption spectrometry (HPLC-HG-AAS), inductively coupled plasma-mass spectrometry (HPLC-ICP-MS); Current trends in trace element determination (total) using various atomic absorption spectrometric (AAS) techniques [Hydride generation-AAS, Cold Vapour-AAS, Flame AAS].

NSAP 738: Quality Management in Testing Laboratories (3 credits)
The course is intended to give students in-depth knowledge on the requirements, implementation, and sustainability of quality management systems. The course will review international standards of the International Standards Organization's (ISO), quality management systems guidelines for nuclear analytical laboratories of the International Atomic Energy Agency (IAEA). Quality system implementation for nuclear analytical techniques: quality control and validation, instrument and laboratory management, documentation, document control, trackability,

procurement, management of internal improvement, customers, reporting, human resource management; Clean laboratories and clean rooms for analysis of radionuclides and trace elements; Quality management systems; ISO 9001, ISO 17025, ISO 19011 and ISO 14001.

NSAP 775: Advanced Stable Isotope Geochemistry (3 Credits)

This course is intended to give the students advanced and in-depth knowledge of the latest developments in the field of stable isotope geochemistry. The course will include advance theoretical considerations of isotope fractionation; mass dependent and mass-independent fractionations; Stable isotopes in the mantle, the core, the crust of the Earth and magmatic systems; Stable isotope in ore deposits; Stable isotopes of oxygen, carbon, sulfur, nitrogen and hydrogen applied to problems in paleontology and paleoecology, carbonate diagenesis, petroleum exploration, isotopic paleotemperature, isotopes in environmental and catchment studies; Isotopes in climate research studies; The use of mathematical models to interpret isotope data. The students will be introduced to up-to-date issues which are the subject of recent research and publications.

NSAP 776: Nuclear Techniques in Hydrology and Hydrogeology (3 Credits).

The hydrological cycle, water as a resource, contamination of groundwater as a geotechnical problem and groundwater and geological processes. D'Arcy's law in two and three dimensions. Hubbert's analysis of the fluid potential, Piezometers and tensiometers. Richard's equation. Basic surface water Hydrology. Hydraulic conductivity and permeablility, Saturated and Unsaturated flow. Laplace's equation, Transmissivity and Storativity. Equations of Groundwater flow. Models of groundwater flow Develop unit of mathematical model using Finite Element method. Relationship between surface water and groundwater. River Basin Studies, concept of watershed hydrology/hydrogeology, Stable and Radioactive isotopes applications in Hydrology and hydrogeology. Suspended Sediment transport using gamma ray scattering gauges, Bedload transport using radioisotopes, nuclear borehole logging, lake dynamics and Sedimentation in lakes and reservoirs using environmental isotopes and labeling of lake waters. Radioactive Waste Disposal. Current research topics and case studies. Review of on-going research in the field and discussions on published research works.

NSAP 777: Nuclear Geochemistry (3 Credits)

Nucleosythesis and Cosmochemistry. Radiogenic Isotope Geochemistry, Basics of radiogenic isotope geochemistry. Noble Gases and evolution of the atmosphere. Growth of Radiogenic daughters. Radiogenic Isotope Geochronometers. Origin of Igneous rocks. Short–lived Radionuclide and their application. Radiation damage methods. Extinct radionuclides, Thermonuclear Radionuclides. Physics of the Nucleus and the structure of the nuclei. The decay of excited and unstable nuclei, decay systems and their applications, Advanced methods of geochronology, Radiogenic Isotope geochronometers, The Rb-Sr method, the K-Ar method,

$^{40}Ar/^{39}Ar$ method, The _/Ca method, The Sm-Nd method, The U-Pb, Th-Pb and Pb-Pb methods, La-Ce methods and La-Ba method, Uranium/Thorium Series disequilibria, Helium and Tritium, Radiation-Damage methods, Themonuclear radionuclides, Isochrons, Evolution of Pb isotope ratios, cosmogenic and fossil isotopes, Review and discussions of current and research papers in nuclear geochemistry. Mathematical models applied to nuclear geochemistry. Current research topics and Case Studies in Nuclear Geochemistry.

NSAP 779: Environmental Hydrogeology (3 Credits)

Basic Hydrogeology. Movement of groundwater in the Unsaturated and the Saturated Zone. D'Arcy's law and Richards' equation. Continuity equation and Laplace equation. Ground water flow modeling. Oxidation and Reduction processes, microbal factors, P^E-P^H diagrams, lon exchange and Adsorption, water quality and hydrochemistry, Transport processes, nonreactive constituents in homogeneous media, migration of contaminants in homogeneous media, migration of contaminants in homogeneous media, Transport of Reactive constituents. Hydrochemical behavior of Contaminants, Trace Non-mentals organic substances. Land disposal of solid waste and effect on groundwater. Groundwater in Urban areas. Sewage disposal on land, Agricultural activities, Petroleum leakage and spills, disposal of liquid waste Disposal of radioactive waste. Hazardous waste management. Mathematical modeling of contaminant transport. The Fate of pollutants into Ghana's rivers, groundwqater and the marine environment. This course will include discussions of recent and topical issues on environmental hydrogeology.

The use of tracers and isotopes such as ^{15}N in contaminant studies. Isotopes as pollution tracer. Current research topics and case studies.

NSAP 780: Advanced Aqueous Geochemistry (3 Credits)

Advanced topics in solutions and thermodynamics of multicomponent systems, phase equilibria, equilibrium and disequilibrium indices, congruent and incongruent dissolution, complexation, proton accounting, chemical balance and conservation equations, conservative and non-conservative ions, mineral surfaces and their interactions with solutions, kinetics of water-rock interactions and its applications, soils and stream chemistry, The oceans as a chemical system, biogeochemical cycling, geochemical hydrology/hydrogeology, oxidation and reduction processes, pE-pH diagrams, the role of bacteria, Ion exchange and adsorption. The course will include special topics relevant to scientific projects. The use of geochemical and isotopic methods for oil exploration and reservoir evaluation. Mathematical modeling of geochemical systems. Reading and discussions of current research topics in the field of aqueous geochemistry. To review and critically discuss the most recent scientific research and publications in the field.

NSAP 710: Seminar I
This course is a research proposal seminar to be presented by the candidate. The seminar is to be accompanied by a detailed written research proposal. Candidates will also present seminars on current advanced topics of interest in the study area and attend departmental seminars.

NSAP 720: Seminar II
Candidates will be attached to relevant faculty research to gain experience in data collection and interpretation in their areas of research during the second semester of the second year on the programme. At the end of the second semester, each candidate is expected to submit a comprehensive report on the experience and present it orally to faculty and students at the end of the semester.

NSAP 730: Seminar III
Candidates will do oral presentation of research progress. In addition, candidates will present seminars on current advanced topics of interest in the study area, attend departmental seminars, attend and participate in both local and external conferences and workshops.

NSAP 740: Seminar III
Candidates will do oral presentation of research findings. Also, candidates will attend departmental seminars, attend and participate in both local and external conferences and workshops.

Linkages with other Departments/Organizations/Institutions

Department/Institution/Organization	Nature of support to programme
Geological Survey Department of Ghana	Provision of energy dispersive X-ray fluorescence (EDXRF) spectrometric analysis for practical work.
Ghana Atomic Energy Commission	Provision of most analytical instruments for practical work (AAS, NAA, GC-ECD, FP, IC, FTIR, LWSIA, GM counter, LSC, Alpha spectrometer)

DOCTOR OF PHILOSOPHY IN NUCLEAR AND RADIOCHEMISTRY

1. INTRODUCTION

The Doctor of Philosophy degree in Nuclear and Radiochemistry requires a one year course work and original research in a relevant area of Nuclear and Radiochemistry, demonstration of broad knowledge in the following fields: Nuclear Chemistry, Chemical Engineering or any other related discipline from a recognized university.

The successful candidate must demonstrate a good understanding of Nuclear and Radiochemistry. The PhD candidate will be expected to do a more in-depth creative research in order to make an original and significant contribution to the body of knowledge in the selected research area. This research should be carried out during a significant period of time (i.e. during at least one year or three semesters in residence). Thus, each successful PhD candidate will produce a significant piece of original research, presented in a written dissertation and defended in an oral examination. The candidate will also be required to have submitted at least one (1) full paper originating from the research to a conference or publication in a reputable peer-review journal.

2. ADMISSION REQUIREMENTS

Admission to PhD programme in Nuclear and Radiochemistry will be limited to applicants who have relevant Masters Degree from a recognized university.

3. DURATION OF PROGRAMME

The duration for the completion of the PhD programme shall normally be four years for full-time students and six years for part-time students

4. REQUIREMENT FOR GRADUATION

The following are the credits that a registered student is required to earn in order to graduate:

Coursework:	18-24 Credits
Seminars (4)	12 Credits
Thesis	45 Credits
Total	**75-81 Credits**

5. STRUCTURE OF PROGRAMME

First Year: First Semester

Core

Course Code	Course Title	Credits
FASC 701	Science and Society	3
NSAP 731	Interaction of Radiation with Matter-Advanced	3
NSAP 727	Advanced Nuclear and Radiochemistry	3

Elective (Select a maximum of 3 credits)

FASC 700	Special Topics in Science	3
NSAP 735	Chemistry of Radionuclides	3

Total **9-12**

First Year: Second Semester

Core

Course Code.	Course Title	Credits
FASC 702	Advanced Quantitative Research Methods	3
NSAP 728	Nuclear Activation Analysis and Allied Analytical Techniques	3

Elective (Select between 3 and 6 credits)

FASC 710	Teaching Science at the Tertiary Level	3
NSAP 732	Radiation Chemistry and Dosimetry	3
NSAP 738	Quality Management in Testing Laboratories	3
SNAS 702	Project Design, Formulation and Management	3

Total **9-12**

Year 2, 3 and 4

Course Code	Course Title	Credits
NSAP 710	Seminar I (Year 2, 1st Semester)	3
NSAP 720	Seminar II (Year 2, 2nd Semester)	3
NSAP 730	Seminar III (Year 3, 1st & 2nd Semesters)	3
NSAP 740	Seminar IV (Year 4)	3
NSAP 700	PhD Thesis (Year 4)	45
	Total	**57**

Students are free to audit Level 600 courses at SNAS

6. YEAR 2 ACTIVITIES

YEAR 2 OF THE NEW PHD STRUCTURE

All PhD students shall be required to spend the whole or part of the PhD Year 2 in an internship/experiential learning programme. The opportunities and types of projects /activities available will vary from one Academic Unit to the other. Each Academic Unit recommending admission of a candidate into a PhD programme shall be require to define in detail what the student will do within the internship Year to be submitted to the School of Graduate Studies as part of the documentation submitted for consideration.

Within six weeks to the end of Year 2, the student shall produce a report and give a seminar on what she/he has done during the year. The report and seminar shall be graded by the Departmental Graduate Committee and the grade shall be submitted to the SGS together with the recommendation for confirmation, or otherwise, of the PhD admission.

The list below gives examples of the activities that students may undertake in the internship year:

XLIII. Attachment to industry or professional placement for a period; e.g. SGMC Ltd, Nuclear Medicine and Radiotherapy Centres, Institutes and Laboratories of GAEC, Hospitals, Mining Companies, etc using nuclear gadgets etc.
XLIV. Internal arrangements to attach PhD students to ongoing projects;
XLV. Participation in colloquia, conferences, seminars to present papers;
XLVI. Development of research proposals;
XLVII. Working with Professors on specific projects;
XLVIII. Acquiring specific techniques and expertise
XLIX. Development of methodologies to be used in the PhD research;
L. Development of experimental protocols;
LI. Participation in special courses in transferrable skills;
LII. Participation in doctoral academy modules;
LIII. Visit partner universities/laboratories to participate in selected programmes/research;
LIV. Participate in laboratories rotations where replicable;
LV. Action research (e.g. community projects) in the humanities.

The SGS shall provide guidance on the activities that shall count towards the Year 2 internship/experiential learning and assessment, and support to academic units in the elaboration of such activities

7. COURSE DESCRIPTION

FASC 700: Special Topics in Science (3 credits)
The course examines historical and contemporary issues in science, relating to the student's area of specialization and relevance. Such topics are expected to challenge the students into exploring current and relevant research trends/discoveries in scientific approaches. The course will enable students explore scientific knowledge in modern science, and add on to their depth of

information in their chosen areas of specialty. It is expected that, the course will compliment other courses on the PhD flagship of the various departments in the Sciences and elsewhere. Additionally, it will expose students to current trends of presentations, and foster stronger confidence-building attitude that will enable enhanced international academic competitive spirit.

FASC 701: Science and Society (3 credits)
This course will enable students to gain insights in the practice of science as a discipline including major scientific concepts like inductivism are examined as well as the history of science and science itself, an overview of current approaches to research and an understanding of research partnership, networks and appropriate methods of communicating science depending on audience. The aim of the course is to help students to fit their research to relevant trends and directions for national development. Course content will cover topics such as the basis for the scientific method; conceptual frameworks; the philosophy of science; ethics in research; pure versus applied science debates; approaches to research; science for development and the merit of broader impact criteria; north south/south south collaboration and partnerships; research networks; communicating science to the policy maker, lay audience and to the media.

FASC 702: Advanced Quantitative Research Methods (3 credits)
The course will serve as a step up for students who need to add up to their knowledge in quantitative methods of research techniques and analyses. Topics to be covered include: Sampling distributions and hypothesis testing. Sample size determination. Categorical data and chi-square, Non parametric tests. Principles of Design of Experiments. Analysis of variance and its assumptions. Experiments with single and multiple factors. Orthogonal and multiple Comparisons. Completely Randomized, Randomized Complete Block, repeated measures, cross over and Latin square designs. Nested designs, Fixed, random and mixed effects models. Factorial designs. Confounding. Fractional factorial designs. Split plot designs. Incomplete block designs. Analysis of covariance.Regression models: basic concepts; Regression Model Diagnostics. Categorical data analysis. Logistic regression, univariate and multivariate. Confounding and collinearity in logistic regression. Model selection in logistic regression.

FASC 710: Teaching Science at the Tertiary Level (3 credits)
It is anticipated that many of the students who go through the PhD programme in the Sciences may nurse special interest in teaching and academia. Focusing on group discussions, this course is expected to equip students with the requisite knowledge in overall management of students at the tertiary level. The course will focus on teaching the methodologies and techniques in handling Science-teaching at the undergraduate level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, examination preparation, teacher/student relationship, tertiary education management, will be discussed through reading, class/group discussions as well as presentations.

SNAS 702: Project Design, Formulation and Management (3 credits)
To improve the students performance in project planning, development and also up grade thier skills regarding techniques for implementing and managing research projects, as well as increase thier understanding on the relevance of the projects to national development. Specific areas include practical guidance on how research projects and facilities are managed form commencement to the end. It includes national development persperctive, project concept, project cycle, project analysis, project appraisal/risk analysis, project scheduling, management of projects, project implementation; research cost estimation techniques, procurement procedures and managing contracts, monitoring and evaluation as well as report writing planning.

NSAP 727: Advanced Nuclear and Radiochemistry (3 credits)
To provide the students with in-depth knowledge in radiochemistry, nuclear analytical methods of analysis, radiation chemistry, and nuclear spectrometry. Nuclear stability, binding energy, properties of nucleons; Nuclear models (Shell Model, Liquid drop model), Radioactive decay characteristics, Radioactive decay schemes, decay kinetics, α, β and γ decay, nuclear reactions, types, radiative capture, reaction cross section, nuclide chart, theory of fission; Detection and measurement of activity, GM counters, Gamma-ray spectrometry, Liquid scintillation counting, alpha spectrometry; Application of radioactivity, Szilard Chalmers reaction, Isotope dilution analysis, Reverse isotope dilution analysis, Neutron activation analysis, post-irradiation chemical separations, methods of chemical yield determination in radiochemical analysis, pre-irradiation chemical separations. Diagnostic and therapeutic applications of radionuclides.

NSAP 728: Neutron Activation Analysis and Allied Analytical Techniques (3 credits)
The objective of the course is to expose doctoral students to recent advances in the use of Neutron Activation Analysis (NAA) and allied analytical techniques for trace elemental analysis/characterization in the fields of environment, health and nutrition, industrial processes, forensic, and archaeological investigations, and cosmochemistry. Quality assurance/quality control in NAA, Ionization methods in AA; PIXE, X-ray fluorescence spectrometry, Alpha spectrometry, Liquid Scintillation Counter (LSC), Mossbauer spectrometry, Rutherford backscattering spectrometry; Modern trends in trace element speciation analysis using High performance liquid chromatography (HPLC) hyphenated with other analytical techniques like NAA (HPLC-NAA), Hydride generation atomic absorption spectrometry (HPLC-HG-AAS), inductively coupled plasma-mass spectrometry (HPLC-ICP-MS); Current trends in trace element determination (total) using various atomic absorption spectrometric (AAS) techniques [Hydride generation-AAS, Cold Vapour-AAS, Flame AAS].

NSAP 731: Interaction of Radiation with Matter-Advanced (3 credits)
The course will review how photons and charged particles from radiation are absorbed and emitted, the effect of those processes and how they factor into quantum radiation theory. Students will also learn practical applications for these interactions and how to use them in academic and professional research. Interaction of electromagnetic radiation with matter, gamma-ray interaction; Photoelectric effect, Compton effect, Pair production, Mathematics of gamma-ray interactions, Absorption, Elastic and inelastic scattering; Heavy charged-particle interaction, range, stopping power, relative stopping power, ionization and energy loss during scattering of charged particles; Beta-particle interaction, range relationships for beta particles,

the feather method, Bremsstrahlung radiation, Cerenkov radiation, beta backscatter, Positron interactions, Neutron interaction; General physical effects of radiation on matter, Energy transfer and radiation dose; Linear energy transfer; Effects of radiation on matter, Radiation induced synthesis; Classical electrodynamics, quantum theory of radiation, time-dependent perturbation theory, transition probabilities and cross sections describing interaction of various radiations with atomic systems.

NSAP 732: Radiation Chemistry and Dosimetry (3 credits)

To provide the students with in-dept knowledge in radiation chemistry and dosimetry. 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 methylacrylate (PMMA)]

NSAP 735: Chemistry of Radionuclides (3 credits)

The course is intended to give students advanced theoretical and practical knowledge of the chemistry of radionuclides. Identification and measurement of alpha particles using silicon detectors and Neutron Activation Analysis would also be gained. Statistical Nature of Radioactive decay; Inverse Square Law; Absorption of Gamma Rays; Guide classification of short lived radionuclides, medium lived radionuclides, and long lived radionuclides. Qualitative and Quantitative analyses of short, medium and long-lived radionuclides in soil, food, water, sediment, and gold tailings using the Absolute and Comparator standardization methods of NAA.

NSAP 738: Quality Management in Testing Laboratories (3 credits)

The course is intended to give students in-depth knowledge on the requirements, implementation, and sustainability of quality management systems. The course will review international standards of the International Standards Organization's (ISO), quality management systems guidelines for nuclear analytical laboratories of the International Atomic Energy Agency (IAEA). Quality system implementation for nuclear analytical techniques: quality control and validation, instrument and laboratory management, documentation, document control, trackability, procurement, management of internal improvement, customers, reporting, human resource management; Clean laboratories and clean rooms for analysis of radionuclides and trace elements; Quality management systems; ISO 9001, ISO 17025, ISO 19011 and ISO 14001.

NSAP 710: Seminar I

This course is a research proposal seminar to be presented by the candidate. The seminar is to be accompanied by a detailed written research proposal. Candidates will also present seminars on current advanced topics of interest in the study area and attend departmental seminars.

NSAP 720: Seminar II

Candidates will be attached to relevant faculty research to gain experience in data collection and interpretation in their areas of research during the second semester of the second year on the programme. At the end of the second semester, each candidate is expected to submit a comprehensive report on the experience and present it orally to faculty and students at the end of the semester.

NSAP 730: Seminar III

Candidates will do oral presentation of research progress. In addition, candidates will present seminars on current advanced topics of interest in the study area, attend departmental seminars, attend and participate in both local and external conferences and workshops.

NSAP 740: Seminar IV

Candidates will do oral presentation of research findings. Also, candidates will attend departmental seminars, attend and participate in both local and external conferences and workshops. Complete thesis and submit for external examination. Submit at least one journal article for publication.

Linkages with other Departments/Organizations/Institutions

Department/Institution/Organization	Nature of support to programme
International Atomic Energy Agency	Provision of equipment, PhD sandwich programmes, Fellowships, Books and Publications
Geological Survey Department of Ghana	Provision of energy dispersive X-ray fluorescence (EDXRF) spectrometric analysis for practical work.
Ghana Atomic Energy Commission	Provision of most analytical instruments for practical work (AAS, NAA, GC-ECD, FP, IC, FTIR, LWSIA, GM counter, LSC, Alpha spectrometer)

DEPARTMENT OF NUCLEAR ENGINEERING

PHD NUCLEAR ENGINEERING

1. INTRODUCTION

The Doctor of Philosophy degree in Nuclear Engineering requires original research in a specific area of Nuclear Engineering and demonstration of broad knowledge in the following fields: Reactor Physics, Nuclear Heat Transfer and Fluid Flow, Health Physics and Radiation Protection and Radiation Detection.

The successful candidate must demonstrate a breadth of understanding in Nuclear Engineering, as well as a depth of understanding in his or her chosen area(s) of emphasis. Potential students must show an ability to do creative research. This research should be carried out during a significant period of time (i.e., during at least one year or three semester in residence). Thus, each successful PhD candidate will produce a significant piece of original research, presented in a written dissertation and defended in an oral examination. This work should be of such scope and quality that more than one journal or conference article can be derived from it.

2. ADMISSION REQUIREMENTS

Admission to PhD programmes in the Nuclear Engineering will be limited to candidates with a relevant Master's degree from a recognized university.

3. DURATION OF PRGRAMME

The duration for the completion of PhD degree shall be four years full time students and six years for part-time students.

4. REQUIREMENTS FOR GRADUATION

The following are the credits that a registered student is required to earn in order to graduate:

Coursework	18 – 24 Credits
Seminars (4)	12 Credits
Thesis	45 Credits
Total	**75 – 81 Credits**

5. STRUCTURE OF PROGRAMME

First Year: First Semester

Core

Course Code	Course Title	Credits
FASC 701	Science and Society	3
NENG 709	Computing for Engineers	3

Electives (Select between 3 and 6 credits)

Course Code	Course Title	Credits
FASC 700	Special Topics in Science	3
NENG 703	Mathematics for Engineering Research	3
NENG 705	Experimental Flux Measurements and Special Reactor Physics Calculations	3
NENG 707	Corrosion and Mechanics of Nuclear Materials	3
	Total	**9 - 12**

First Year: Second Semester

Core

Course Code	Course Title	Credits
FASC 702	Advanced Quantitative Research Methods	3
NENG 704	Mathematical Modeling and Simulation of Physical Processes	3

Electives (Select between 3 and 6 credits)

Course Code	Course Title	Credits
FASC 710	Teaching Science at the Tertiary Level	3
NENG 706	Advances in Two Phase Flows in Nuclear Thermal Hydraulics and Reactor Safety Research	3
NENG 708	Radiation Materials Science	3
	Total	**9 - 12**

Year 2, 3 and 4

Course Code	Course Title	Credits
NENG 710	Seminar I (Year 2, 1st Semester)	3
NENG 720	Seminar II (Year 2, 2nd Semester)	3
NENG 730	Seminar III (Year 3, 1st & 2nd Semester)	3
NENG 740	Seminar IV (Year 4)	3
NENG 700	PhD Thesis (Year 4)	45
Total		**57**

6. YEAR 2 ACTIVITIES

YEAR 2 OF THE PHD STRUCTURE

All PhD students shall be required to spend the whole or part of the PhD Year 2 in an internship/experiential learning programme. The opportunities and types of projects /activities available will vary from one Academic Unit to the other. Each Academic Unit recommending admission of a candidate into a PhD programme shall be required to define in detail what the student will do within the internship Year to be submitted to the School of Graduate Studies as part of the documentation submitted for consideration.

Within six weeks to the end of Year 2, the student shall produce a report and give a seminar on what she/he has done during the year. The report and seminar shall be graded by the Departmental Graduate Committee and the grade shall be submitted to the SGS together with the recommendation for confirmation, or otherwise, of the PhD admission.

The list below gives examples of the activities that students may undertake in the internship year:

I. Attachment to industry or professional placement for a period;
II. Internal arrangements to attach PhD students to ongoing projects;
III. Participation in colloquia, conferences, seminars to present papers;
IV. Development of research proposals;
V. Working with Professors on specific projects;
VI. Acquiring specific techniques and expertise
VII. Development of methodologies to be used in the PhD research;
VIII. Development of experimental protocols;
IX. Participation in special courses in transferrable skills;
X. Participation in doctoral academy modules;
XI. Visit partner universities/laboratories to participate in selected programmes/research;
XII. Participate in laboratories rotations where replicable;
XIII. Action research (e.g. community projects) in the humanities.

The SGS shall provide guidance on the activities that shall count towards the Year 2 internship/experiential learning and assessment, and support to academic units in the elaboration of such activities

7. COURSE DESCRIPTION

FASC 700: Special Topics in Science (3 credits)

The course examines historical and contemporary issues in science, relating to the student's area of specialization and relevance. Such topics are expected to challenge the students into exploring current and relevant research trends/discoveries in scientific approaches. The course will enable students explore scientific knowledge in modern science, and add on to their depth of information in their chosen areas of specialty. It is expected that, the course will compliment other courses on the PhD flagship of the various departments in the Sciences and elsewhere. Additionally, it will expose Students to current trends of presentations, and foster stronger confidence-building attitude that will enable enhanced international academic competitive spirit

FASC 701: Science and Society (3 credits)

The course will enable students gain insights in the practice of science as a discipline including major scientific concepts like intuitivism are examined as well as the history of science and science itself, an overview of current approaches to research and an understanding of research partnerships, networks and appropriate methods of communicating science depending on audience. The aim of the course is to help students to fit their research to relevant trends and directions for national development. Course content will cover topics such as the basis for the scientific method; conceptual frameworks; the philosophy of science; ethics in research; pure

versus applied science debates; approaches to research; science for development and the merit of broader impact criteria; north south/south collaboration and partnerships; research networks; communicating science to the policy maker, lay audience and to media.

FASC 702: Advanced Quantitative Research Methods (3 credits)

The course will serve as a step up for students who need to add up to their knowledge in quantitative methods of research techniques and analyses. Topics to be covered include: Sampling distributions and hypothesis testing. Sample size determination. Categorical data and chi-square, Non parametric tests. Principles of Design of Experiments. Analysis of variance and its assumptions. Experiments with single and multiple factors. Orthogonal and multiple comparisons. Completely randomized, Randomized Complete Block. Repeated measures, cross over and Latin square designs. Nested designs. Fixed, random and mixed effects models. Factorial designs. Confounding. Fractional factorial designs. Split plot designs. Incomplete block designs. Analysis of covariance.

Regression models: basic concepts; Regression Model Diagnostics. Categorical data analysis. Logistic regression, univariate and multivariate. Confounding and collinearity in logistic regression. Model selection in logistic regression.

FASC 710: Teaching Science at the Tertiary Level (3 credits)

It is anticipated that many of the students who go through the PhD programme in the sciences may nurse special interest in teaching and academia. Focusing on group discussions, this course is expected to equip students with the requisite knowledge in overall management of students at the tertiary level. The course will focus on teaching the methodologies and techniques in handling Science-teaching at the undergraduate level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, examination preparation, teacher/student relationship. Tertiary education management will be discussed through reading, class/group discussions as well as presentations.

NENG 703: Mathematics for Engineering Research (3 credits)

This course will provide an in-depth knowledge of the main mathematical topics required for students planning a career in engineering or sciences. The core areas of this course are devoted to linear algebra, calculus, ordinary differential equations, and approximation methods. Topics covered will include: Eigenvalues, System of nonlinear equations: Newton (and related) methods, limiters, Dynamical System: Analytical and numerical solutions, Stability of numerical methods, Dynamical system stability. Laplace, Fourier transforms, FFT, Z-transforms, Power series solution of ODEs (eg. Leibritz theorem, Frobenius method, Bessel equations, Legendres equations.

NENG 704: Mathematical Modeling and Simulation of Physical Processes (3 credits)

The objective of this course is to provide the students with the requisite knowledge of the mathematics and procedures required for the development of scientific modeling of physical processes and the implementation of the model by simulation. Contents of the course will include:

Finite Difference methods, Analysis of numerical schemes: consistency, stability, convergence.

Finite Volume and Finite Element methods; stiffness method, principle of potential energy, functional, strain-displacement relationships, constitutive models, boundary conditions, matrix assembly and properties, element properties, convergence requirements, types of finite elements and their formulations: beam, bar, plane, solid, isoparametric elements, consistent loads, Gauss quadrature, coordinate transformation.

NENG 705: Experimental Flux Measurement and Special Reactor Physics Calculations

Characterization of neutron flux spectra in sites of reactor using the Westcott-formalism, principles of kϕ methods for 1/υ and non -1/υ nuclides, expressions for $g(T_n)$ in terms of Cadmium ratio, $R_{cd,\ x,}$ Evaluation of effective cross-section factor, P_x (F_i, T_n), Experimental techniques.

In-Core Fuel Management: Fuel loading variables, Selection of the Fuel Reload Fraction, Inter-cycle coupling effects, Fuel and Control Arrangements Strategies, Reactor Cycle Stretch out. Methods of Computer Codes for Reactor Physics in Nuclear Design: Calculational Flow Chart, Integral Transport Theory, Multi-group Iteration Methods, Two group Nodal Technique, Coarse Mesh Computation. Application of Computer Codes, WIMS, CITATION etc.

NENG 706: Advances in Two Phase Flows in Nuclear Thermal Hydraulics and Reactor

Regime Transition in Boiling Heat Transfer. Two-phase flow instabilities and Propagation Phenomenon, Types of instabilities, Instabilities resulting from the pressure drop, Flow rate characteristics of the system, Ledinegg instability, Flow distribution instabilities, Pressure Drop oscillations, Density wave oscillations, heat transfer and two-phase flow regime instabilities, current instability concerns in nuclear systems.

Codes and Two-Phase Flow heat transfer calculations, Physical modeling of the thermo hydraulic process, Approximations and uncertainties of codes, Code requirements for equation selection, Examples of codes for thermal-hydraulic calculations: Transient reactor analysis code (TRAC) ELP for reactor safety thermal-hydraulic analysis or similar codes.

NENG 707: Corrosion and Mechanics of Nuclear Materials (3 credits)

The course will address specific concerns related to corrosion and the effects of various environments on the mechanical behavior of materials used in nuclear energy systems Contents

of the course will include: Intensive study of corrosion and the mechanical properties and the effects of processing on the structure and behavior of nuclear engineering materials; kinetics of corrosion reactions, kinetics of oxidation, Griffith-Orowan theory of predicting brittle fracture, Fracture mechanics: the stress intensity parameter, relationship between fracture toughness and tensile properties, application of fracture mechanics to various classes of materials, Fatigue fracture: correlations between fatigue strength and other mechanical properties, a fracture mechanics approach to fatigue.

NENG 708: Radiation Materials Science (3 credits)

The purpose of this course is to provide students with in depth knowledge for understanding the theory and mechanisms of irradiation on engineering materials. The course will cover topics including: Irradiation hardening and deformation, elastic and plastic deformation, deformation in irradiated metals, Simulation of neutron irradiation effects with ions; Motivation for using ion irradiations as a surrogate for neutron irradiation, Review of aspects of radiation damage relevant to ion irradiation, Particle type dependence of RIS, advantages and disadvantages of the various particle types, irradiation parameters for particle irradiations, emulation of neutron irradiation damage with proton irradiation.

NENG 709: Computing for Engineers (3 credits)

The aim of the course is to provide a solid practical and theoretical computing to enable the students carry out research in the fields of modeling, simulation and experimentation. Contents of the course will include: Learning of Graphical packages (OriginPro, Gnuplot); Fortran programming using Fortran 90; running Mathematica and Matlab and other programming software; advanced mathematics including numerical operation on data and functions, and Monte Carlo methods

NENG 710: Seminar I

This course is a research proposal seminar to be presented by the candidate. The seminar is to be accompanied by a detailed written research proposal. Candidates will also present seminars on current advanced topics of interest in the study area and attend departmental seminars.

NENG 720: Seminar II

Candidates will be attached to relevant faculty research to gain experience in modeling, simulation, data collection and interpretation in their areas of research during the second semester of the second year on the programme. At the end of the second semester, each

candidate is expected to submit a comprehensive report on the experience and present it orally to faculty and students at the end of the semester.

NENG 730: Seminar III

Candidates will do oral presentation of research progress. In addition, candidates will present seminars on current advanced topics of interest in the study area, attend departmental seminars, attend and participate in both local and external conferences and workshops.

NENG 740: Seminar IV

Candidates will do oral presentation of research findings. Also, candidates will attend departmental seminars, attend and participate in both local and external conferences and workshops.

Linkages with other Departments/Organizations/Institutions

Department/Institution/Organization	Nature of support to programme
Ghana Standards Authority (GSA)	Mechanical and Civil Testing Machines Moulding Equipment