SCHOOL OF PHYSICAL AND MATHEMATICAL SCIENCES

DEPARTMENT OF COMPUTER SCIENCE
PHD IN COMPUTER SCIENCE

1) **Background information:**

a. Introduction

Computer Science department is a well-established and vibrant department of the University of Ghana with well qualified staff. The PhD programme in the department offers a unique opportunity for talented candidates to undertake substantial and in depth research in theoretical computer science or applied computing with relevance to national developmental needs. The aim is to train researchers who will have a broad knowledge of the field of computer science as well as being world experts in their particular field of specialization. The PhD programme aims to introduce new lines of thinking in formulating and solving some of the technical challenges that are currently a target of very active research and which are key to our national development and to the advancement of knowledge in general. The research activity of the department focuses on important aspects of computer science and information engineering such as security, wireless sensor networks, photonic device modelling, cognitive radio, image processing, computer science in education, quality of services, applied computing and optimization. The first year of the programme is designed to ensure that candidates have the necessary breadth of knowledge of the core areas of computer science, as well as the research skills to effectively engage with their research, they will be required to undertake coursework in specified areas including the following: Theoretical Foundations of Computer Science, Computer Architecture, Wireless Systems and Networks, Artificial Intelligence as well as Communication Networks

b. Rationale

Computer science is at the heart of all modern economies and all indications are that it will continue to play a decisive role in future economies. It has become pervasive and ubiquitous affecting people's lives in many unimaginable ways a decade or two ago. All major global economies are now becoming knowledge based economies. Such economies of the future will be computing intensive. The workforce must therefore be prepared with the technological skills to be effective players. Additionally, as the University of Ghana repositions itself as a research based university, the role of computer science in contributing to the research efforts of all the other disciplines in solving some of the pertinent developmental challenges the country faces cannot be over looked.

The need to therefore train independent researchers able to formulate substantial research problems and attempt their solutions is acute. Such training requires a scientific approach at a level higher than is provided for at

the Masters level. Therefore, we are proposing to run PhD in Computer Science degree programme.

c. Philosophy

This programme is primarily informed by the theoretical understanding and knowledge generation in computer science. It aims to make independent researchers out of candidates, enabling them to take on leadership roles in academia and industry. Thus, students successfully completing this programme will be well-prepared to set their own research direction, teach at institutions of higher learning and act as mentors for students, and also work at the very frontier of computer science research.

d. Programme Objectives

In view of this rationale, the objectives of the programme are:

- to equip students with scientific knowledge and analytical thinking in Computer Science
- to produce computer science academics that are able to support the Computer Science and Information and Communication Technology education in the country.
- to produce computer science professionals that are able to:
    i. to engage in systematic thinking about the relationship between Computer Science and social systems, and
    ii. to suggest innovative solutions.
- to produce computer science academics and professionals required at various levels of the social, economic and industrial development of Ghana and elsewhere.
- to prepare students for advanced independent research and dissemination of knowledge at the international level.

The philosophy and objectives of the programme fit into the mission and plans of University of Ghana to be among the first class universities in the world, producing graduates in a variety of scientific disciplines for the development of Ghana and Africa. It is clear from all national and international debates on human skills availability that the country continues to experience a shortage of properly trained Computer Science personnel.

2) **Students' admission, progression and graduation:**

a) Entry Requirements

Applicants for the PhD in Computer Science are expected to have met the following prerequisites:

- The minimum requirement for admission shall be the possession of a relevant Masters Degree or a first class or strong upper second-class grade.

- Candidates must be successful at an interview to be scheduled by the department.
- Candidates may also be required to sit an entry examination organised by the department
- Candidates must demonstrate that they have a solid background to conduct independent academic research in computer science.
- Candidates not meeting the minimum requirements may be considered and recommended to take prescribed courses, mini-project or coursework.

In all cases a departmental interview will be conducted to assess suitability of applicants.

A complete application pack must include:

i. A completed University of Ghana postgraduate application form;

ii. Official transcripts of the applicant's previous academic record at the university level;

iii. A full curriculum vitae

iv. A postgraduate research proposal;

v. Three letters of recommendation commenting on the applicant's ability to do the programme

b) Progression and Graduation of Students

i. Duration

The maximum period for completing the programme as stated in the postgraduate handbook will be adhere to. Deferment periods are included. As long as deferment is on medical grounds and is certified by a medical practitioner the duration clause would not be applicable.

ii. Work Load

The typical workload for students in the first year of the programme is between 12 and fifteen 15 credit hours per week. A minimum of 24 and a maximum of 30 credit hours of coursework must be done and passed to make a student eligible for graduating into the second year of the MPhil/PhD programme.

iii. Progression

Time required to complete the PhD programme shall be 4 years for full time students and 6 years for part time students.

iv. Doctoral Qualifying Examination

Candidates who complete the Level 700 course work successfully and progress into the PhD programme shall be required to take and pass a comprehensive examination (a doctoral qualifying exam) to progress to the internship/research years. This examination shall be organised within six

weeks of the first Semester of PhD Year 2 and shall include item (i) below and any one of items (ii)-(iv):

i. A series of written exams based on the general area of study, plus an oral exam by a panel of examiners.

ii. Submission of publishable papers (minimum of 1), based on research done during the Year 1/first semester of Year 2) for assessment.

iii. A presentation of a research proposal in the general area of study, but not on thesis research area; i.e. this should be different from the thesis research proposal.

iv. Submission of in-depth review of literature on a thematic area to be assessed.

Based on the candidate's performance in the Comprehensive Examination, the candidate shall be confirmed as a PhD student.

Coursework

Coursework	18-24 credits
Seminar	12 credits
Thesis	45 credits
Total	75-81 credits

Year Two of PhD: Experiential Learning

All students enrolled on a PhD programme within the department shall in the second year undertake industrially or commercially relevant activities that will enrich their learning experience. The department shall focus attention on a number of activities to include but not limited to the following:

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;

iv. Development of thesis 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. Participation in doctoral academy modules;

ix. Visit partner universities/laboratories to participate in selected programmes/ research;

Graduation Requirements

To be considered for the award of the prescribed degree, a candidate will be expected to carry out an original piece of research and successfully

pass a minimum of 75 credits, made up of coursework (core and elective), Seminars as well as submit a thesis for viva examination

c) Assessment Areas

Students will be assessed in the following areas:

- Knowledge: ability to recall computer science theory, concepts and their applications
- Research Techniques and skills: ability to identify computer science research challenges and opportunities, and design innovative solutions to address them.
- Comprehension: ability to analyse organisational IT problems, to review relevant literature pertaining to them, and to write sound proposals on innovative solutions that can address them.
- Oral presentation and persuasion: ability to convince an audience of the soundness and acceptability of an innovative solution in computer science its sub-domains.

d) Grading System

The postgraduate grading system of the University of Ghana will be used to grade students in this programme. Refer to section 13 for some details of University of Ghana grading system.

3) **Employment:**

The graduates of this programme will be able enter the job market as academics or industry practitioners. They are trained to work as theorists, researchers, or inventors. Their jobs are distinguished by the higher level of theoretical expertise and innovation they apply to complex problems and the creation or application of new technology.

The courses of this programme are advanced areas of computer science which will catalyse the production of expedient computer science manpower needs in Ghana and elsewhere. The contents and structure of the course are such that they will prepare students to take up computer science research and development roles, Information and Communication Technology (ICT) management roles in any organisation, or start their own Technology businesses.

Graduates will be able to initiate ICT adoption projects in organisations. Their in-depth ICT knowledge and skills will enable them to propose innovative software, hardware and network solutions in all human activities. However, they will be aware that solutions to organisational problems are not always purely technological. Many user and organizational issues can be resolved through measures other than purely technological ones.

4) **Consultations:**

The programme has been designed in consultation with the board of faculty of the Faculty of Science, the Association of Computing Machinery (ACM) 2013 publication on Computer Science Curriculum Design Guidelines and industry partners including IBM Ghana, Microsoft Ghana and Airtel Ghana.

5) **Components of the programme:**

This is a 4 year programme consisting of 1 year course work, 1 year experiential learning and two years original research work and Thesis write-up. It is structured according to the following components:

Programme Structure

Year 1 Semester 1

Core

Course Code	Course Title	Credits
FASC 701	Science and Society(Faculty Wide)	3
FASC 700	Special Topics in Science	3

Electives *select minimum 3 credits*

Course Code	Course Title	Credits
CSCD 703	Grand Research Challenges in Computer Science	3
CSCD 707	Emerging Database Models	3
CSCD 709	Research in Bioinformatics and Computational Biology	3
CSCD 711	Ubiquitous Computing	3

Year 1 Semester 2

Core

Course Code	Course Title	Credits
CSCD 708	New Developments in Cyber Security and Networks	3
FASC 702	Advanced Quantitative Research Methods	3

Electives *Select minimum 3 credits*

Course Code	Course Title	Credits
CSCD 704	New Developments in Computer Architecture	3
CSCD 706	Next Generation Wireless Systems and Networks	3
CSCD 716	New Directions in Artificial Intelligence	
CSCD 712	Research Issues in Social Networks	3
CSCD 714	Advances in High Performance Computing	3
FASC 710	Teaching Science at the Tertiary Level	3

Year 2, Semester 1

Core

Course Code	Course Title	Credits
CSCD 710	Seminar I (Research Proposal)	3

Year 2, Semester 2
Core

Course Code	Course Title	Credits
CSCD 720	Seminar II (Experiential research learning)	3

Year 3, Semester 1

Course Code	Course Title	Credits
CSCD 730	Seminar III (Research progress)	3

Year 4, Semester 2

Course Code	Course Title	Credits
CSCD 740	Seminar IV (Research Results)	3
CSCD 700	PhD Thesis	45

6) Course Description

FASC 700: Special Topics in Science
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 complement 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
This course will enable students gain insights on 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 partnerships, networks and appropriate methods of communicating science depending on the 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 make, lay audience and to the media.

FASC 702: Advanced Quantitative Research Methods
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
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.

CSCD 700 Thesis
The candidate, working closely under the supervision of their advisor shall present a thesis for assessment. The candidate's thesis will be the final report on the work done over the period of research investigation. It shall outline the problem, the motivation for the work, previous work done, methodology and present the findings of the current research and any implications for future directions. The candidate must demonstrate in this thesis their fundamental contribution to the area of study.

CSCD 702 Advanced Data Structures and Algorithms
This course will help students to understand some of the highly efficient algorithms and data structures which are fundamental to solving a range of computational problems across a variety of specialist areas. They will be able to understand techniques such as amortised complexity analysis, primality testing, Max flow in networks, discrete Fourier transform and number theoretic algorithms. Asymptotic analysis of upper and average complexity bounds, big O, little o, omega, and theta notation, standard complexity classes, empirical measurements of performance, time and space tradeoffs in algorithms, backtracking, heuristics, pattern matching and string/text algorithms, numerical approximation algorithms

CSCD 703 Grand Research Challenges in Computer Science
This course introduces students to the unsolved and challenging research questions in the field of computer science. Topics will include exploiting division by zero, Synthetic sensory-motor systems for new ecological niches, A community project to create a shared open information security knowledge base, Privacy restrictions in social semantic web research, Hatching a phoenix: reclaiming success from software failure, Innovation everywhere: computing for 9 billion people, Software engineering challenge: achieving zero carbon buildings, Understanding the text Quran, Delivering the healthcare we deserve Modelling

personalised value based healthcare, Towards elastic sensor networks, Supporting independent living for older people, Assisted living - home care technologies Allowing blind people to see and deaf people to hear, Digital signatures: 'What are you' versus 'Who you are', Socially embodied technology, Grass roots distributed healthcare, The AI4FM approach for proof automation within formal methods

CSCD 704 New Developments in Computer Architecture
Fundamentally, computer architecture determines to a very great extent the performance capability of any computer based system. This course would look at how the architecture of the computer has evolved and factors which have influenced their design. The course will consider those mechanisms which are key to implementing an idealised computer from a programmer's point of view. A broad range of architectural designs will be considered and an appreciation of the compromises that were made and the impact they have on program development. Other topics will include: digital logic and data representation, interfacing and I/O Strategies, memory architecture, functional organization, multiprocessing, performance enhancements, distributed architectures, directions in computing.

CSCD 705 Artificial Intelligence
In this course students will be encouraged to focus on some of the fundamental techniques for solving AI problems. Areas to be explored include vision, robotics, probabilistic reasoning, computational logic, machine learning, multi-agent systems, and natural language processing. Some other key issues that students will be encouraged to explore are Turing Test and the feasibility that such a test can be passed in the near or distant future, informed search, greedy search, heuristic function, Constraint satisfaction problems and others.

CSCD 706 Next Generation Wireless Systems and Networks
Wireless devices now permeate every aspect of modern day life and recent advancements in radio technology provide greater flexibility and enhanced capabilities in executing wireless services. The aim of this course is to survey the research landscape in wireless communications. The course will review propagation phenomena, handover in heterogeneous networks, Vanets, modulation techniques, bit error rate, DPSK, DS-CDMA, diversity, fading, multiple access schemes, cognitive radio and coding techniques.

CSCD 707 Emerging Database Models
This course will focus on technologies as well as the principles that lie at the heart of new and emerging database systems and technologies. The aim of this course unit is to survey the research landscape of advanced DBMS systems with a view to understanding how DBMS research is responding to challenges arising from new software architectures, new kinds of data resource and new computational fabrics. Topics include: Architecture, Components: The Classical Case and Variations; The Relational Case: Data Models, Databases, Languages; Query Processing, Equivalence-Based Rewriting; Algorithms, Evaluation Strategies, Cost-Based Optimization; Parallel DBMSs; Distributed DBMSs and Dataspaces; Massively-Parallel/Massively-Distributed Data Processing; NoSQL and Cloud Database;

Stream Data Management; Sensor Network Data Management

CSCD 708 Computer and Network Security
Security is at the heart of modern communication systems, in particular networked systems including wireless systems. This course covers some of the fundamental principles of underpinning the design and operation of secure computer systems such as cryptography, operating systems security, symmetric and asymmetric block ciphers, keyed hashes, digital signatures, and simple key exchange protocols network security, and language-based security.

CSCD 709 Research in Bioinformatics and Computational Biology
Bioinformatics has transformed biology from a purely experimental activity deeply rooted in laboratory work to a science of computation and information technology. Whilst there is no sharp boundary between bioinformatics and computational biology, bioinformatics is focused more on applications, managing and maintaining databases and computational biology on the analysis and interpretation of data, models, algorithms and statistical methods. This course aims to present core topics of these fields with an emphasis on modelling and computation. Some of the issues students will be encourage to explore are: Fundamental Data Structures in Biology: Sequences, Genes, Networks and RNA secondary structure; Stochastic Models of Sequence and Genome Evolution.

CSCD 711 Ubiquitous Computing

Students will explore the emerging field of ubiquitous computing, in which computation spreads away from the desktop to become embedded into the world around us, including into artefacts, furniture, buildings and ultimately into our own bodies. Topics will include the distinctive design challenges in this field including designing for public settings, adapting to context and coping with uncertainty in positioning and wireless communications.

CSCD 712 Research Issues in Social Networks
This course takes a look at some of the important social effects of technological developments such as computers and how modern society also shapes developments in computing. Statistical properties of networked systems will be considered, relationships between social entities, group structures, similarities to biological networks, the concept of centrality in social networks. The aim is to introduce the student to the large body of literature on the course and provide a critical perspective of of the different research directions in social networks.

CSCD 714 Advances in High Performance Computing
High Performance Computing (HPC) is a key technology for modern researchers enabling scientific advances through simulation where experiments are either technically impossible or financially not feasible to conduct and theory is not applicable. However, the high degree of computational power available from today's supercomputers comes at a

cost. This course aims to give an overview of the current state of the art and future techniques to optimize the computational cost in HPC systems. Topics to be covered will include: HPC Architectures, Parallel Numerical Algorithms
Message-Passing Programming, Parallel Programming Languages, Data Analytics with High Performance Computing, Performance Programming

CSCD 716 New Directions in Artificial Intelligence
In this course students will be encouraged to focus on some of the fundamental techniques for solving AI problems. Areas to be explored include vision, robotics, probabilistic reasoning, computational logic, machine learning, multi-agent systems, and natural language processing. Some other key issues that students will be encouraged to explore are Turing Test and the feasibility that such a test can be passed in the near or distant future, informed search, greedy search, heuristic function, Constraint satisfaction problems and others.

CSCD 708 New Developments in Cyber Security and Networks
This course aims to provide our students with an opportunity to appreciate the real-world challenges which arise from security needs in existing and emerging contexts and to equip them with both the expertise and adaptability to address those needs. Students will posses the skills and knowledge to become as agile in their thinking as the attackers are – and as resourceful in defence as their counterparts are in attack. Four thematic areas will be covered cyber-physical security, real-time security, Assurance and 'Big Data' security. Other topics will include Network Infrastructure, Mapping and Scanning, Packet Analysis, Firewalls deployment and management, Intrusion Detection tools and analysis, Vulnerability Analysis, Scanning and Management, Penetration testing, Incident Planning, Handling and Response, Malware Analysis and Tools, Cryptographic Concepts & Physical Security, Footprinting Tools and Techniques, Network Scanning, Computer Systems Attacks, Wireless vulnerabilities, Web and Database Attacks, Sniffers, Session Hijacking and Denial of Service Attacks and Defensive Technologies

CSCD710 Seminar I
This course will focus on developing the original synopsis or other agreed topic into a full PhD proposal. The ultimate aim of this seminar is to enable students to obtain feedback from the supervisory team on what directions to take to successfully complete a quality dissertation. The full proposal should (1) define a problem of interest to the student, (2) summarize past work, (3) outline work on an approach to solving the problem and (4) present initial results obtained. Ideally the subject matter of this proposal should be publishable in conference proceedings ranked at C or above in the ERA list.

CSCD 720 Seminar II (Experiential research learning)
This seminar will provide candidates with the opportunity to demonstrate knowledge they have gained through experience. Opportunities will be provided, as far is possible, to enable candidates gained industrially or commercially relevant

experience and to demonstrate that through their work. The department shall focus attention on a number of activities to include but not limited to the following:

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;
iv. Development of thesis 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. Participation in doctoral academy modules;
ix. Visit partner universities/laboratories to participate in selected programmes/ research;

The current projects in the department which candidates can work on include the following:

Ghana Highway Authority Access Control System on Motorways

The department is working on a project for the GHA on the Design, Development & Implementation of an e-Tolling System for use on highways the GHA manages. Our goal is to deliver comprehensive and reliable e-Toll management software, to print RFID cards for use at tolling points, to manage the application process and the resulting database. Such a system will minimize human involvement and help stop the current revenue leakages the authority is experiencing. This will be achieved by implementing a web-based application using latest Java technologies thereby providing a stable, scalable and robust infrastructure that will ensure speed of information access and security. This will be a major undertaking, with a long lifetime which will offer of PhD candidates a unique opportunity to work on a real world project. The proposed system will consist of a number of modules and components which will encompass the entire gamut of CS principles. The core components will include the following:

- manage the application process for e-cards
- allow users to be able to apply online for e-cards
- enable administrative approval to be given to applications
- be able to print E-cards with the required security features
- store and retrieve relevant information with ease
- feature full report generating capabilities
- have an extensive real-time observance of client and staff data movement
- enable GHA to have full control of the entire working system

Our students will have the unique opportunity of working on anyone one these units, developing and refining them to make the system robust. It can also offer them the opportunity to test new ideas. The total cost for developing such a system will be the equivalent of *One hundred and seventy thousand, two hundred and fifty seven Ghana Cedis and fifty Ghana pesewas* (**GHc170,257.50)**

Low Cost Local Community Wireless Communication System

The paradox of frequency scarcity and frequency underutilization is well known. The current model by which frequencies are allocated and managed has been identified as the main cause of frequency white spectra holes. Additionally the transition from analogue to digital television has resulted in more white holes being created. There is an ongoing global effort to release this spectrum under innovative licensing regimes with an objective to encourage state-of-the-art wireless solutions at low cost to end users. This is particularly important at a time of growing world demand for wireless services especially in developing countries. The work being undertaken in the department consists of a study of current management structures and regulations. It will be required that an initial spectrum map of the Accra/Tema metropolitan area be established through spectrum surveying and developing an experimental test bed for cognitive radio research. This test bed will be used to demonstrate cellular network on University of Ghana Campus and can serve as the basis of a future on campus free wireless communication system. The importance of this project to emergency services in disaster scenarios cannot be over stated. Security services will also gain enormously from the implementation of this project. They will now be able to develop their own communications platform based on the results of this project implementation. This project as in the previous one will provide students with opportunities for postgraduate research, to develop indigenous solutions to white space spectrum utilization and access and contribute to a practical real life work.
Whilst the department is yet to secure funding for this project, it is still ongoing and will encompass many different aspects of computer science where the students can gain practical experience.

Link with Partner Universities

The department currently has good collaborative relations with City University and University of Nottingham, all in the UK. Given availability of funding and the signing of the required MOUs, we envisage that some of our students can spend the experiential year working in the laboratories of the partner institutions. The range of projects available at this institutions are varied and will be defined for each student.

CSCD 730 Seminar III

This seminar, in the third year of the investigation, provides an opportunity for the supervisors to check that work is progressing satisfactorily and that candidate is on course for a successful completion. Candidates will be required to report on the progress of their work. For this an internal examiner shall be appointed. Candidates must see this as preparation for the real viva in the final year. The assessment result for this course shall be classified as either satisfactory or unsatisfactory. In each case student shall be provided guidance on what to do next.

CSCD 740 Seminar IV

This is the final part of the work, a public presentation of the major findings of the research. The presentation will be subject to scrutiny by an external examiner, an internal examiner, the supervisory team and the general public. The aim is to ensure that the work is of an acceptably high standard deserving of an award of the degree of doctor of philosophy.

7) **Assessment of students' performance and achievements:**
The postgraduate grading system of the University of Ghana will be used to grade students in this programme. Below is a brief description of the assessment system.

Areas of Assessment
Students will be assessed in the following areas:

- Knowledge: ability to recall computer science theory, concepts and their applications
- Research Techniques and skills: ability to identify computer science research challenges and opportunities, and design innovative solutions to address them.
- Comprehension: ability to analyse research problems, to review relevant literature pertaining to them, and to write sound proposals on innovative solutions that can address them.
- Oral presentation and persuasion: ability to convince an audience of the soundness and acceptability of an innovative solution in computer science its sub-domains.

Objectives of Assessment
Any form of assessment such as, a test, quiz or seminar for a course is expected to be both formative and summative:

Formative: The objective is to monitor the candidate's progress and improve his/her performance, and to serve as feedback for both learner and instructor, in case adjustments of learning and teaching have to be made;

Summative: the objective is to give the learner the opportunity to demonstrate understanding, and the teacher the opportunity to assess teaching and learning effectiveness.

Forms of Assessment
For the majority of courses, evaluation of students' performance is by classroom participation, seminars and end-of-semester examination.

For the end-of-semester assessment, apart from the usual written examination, other forms may be more suitable, such as a seminar or a project within the course. Performance in the course work will be marked over a hundred.

Grading Item	**Weight**
Final Examination	60 – 70%
Continuous Assessment	30 – 40%

The Grading System is shown below:

Grade	**% Mark**	**Grade Point**
A	80-100	4.00
B+	75-79	3.50
B	70-74	3.00
C+	65-69	2.50

C	60-64	2.00
D+	55-59	1.50
D	50-54	1.00
*E	45-49	0.5
F	0-44	0

Other Grading System

Grade	**Interpretation**	**Grade Point**
X	Fail	0
Z	Disqualification	0
I	Incomplete	0
Y	Continuing	0
AUDI	Audit	0

- **Grade Point (GP)**
  For each (letter) Grade there is a corresponding Grade Point as indicated above. The Grade Point earned by a candidate for each course completed is computed as the product of the number of credits (credit units) for the course and the Grade Point equivalent of the (letter) grade obtained in the course.

- **Grade Point Average (GPA)**

  The Grade Point Average is obtained by dividing the sum of the Grade Points obtained by the total number of credits (credit units) of courses completed. A participant does not earn credits for an F grade.

- **Cumulative Grade Point Average (CGPA)**

  A student's cumulative grade point average is calculated by dividing the total number of Grade Point obtained, up to any specified time, by the total number of credits for all courses for which the participant has completed up to that time.

- **Final Grade Point Average (FGPA)**

  The FGPA is the CGPA for all courses for which the candidate has registered up to the end of the academic programme.

- **Certification**
  Students would be awarded a Certificate of **Doctor of Philosophy in Computer Science** upon the successful completion of the postgraduate (PhD) requirement for Faculty of Science of University of Ghana.

DEPARTMENT OF EARTH SCIENCE
PHD IN EARTH SCIENCE

1. INTRODUCTION
The Doctor of Philosophy degree in Earth Science requires original research in a specific area of Earth Science, demonstration of broad knowledge in the following fields: Geology, Applied Geology, Applied Geophysics and Applied Geochemistry.

The successful candidate must demonstrate a breadth of understanding in Earth Science, 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 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. This work should be of such scope and quality that least one journal article can be derived from it.

Upon successful completion of the programme students will be awarded PhD in Earth Science with any one of the following options, depending on thesis area: Geology, Applied Geology, Applied Geophysics and Applied Geochemistry

2. ADMISSION REQUIREMENTS
Admission to PhD programme in the Earth Science shall be a good Master's degree (i.e., MPhil or MSc) in the relevant field. However, candidates with a good first degree may also apply. Such first degree holders shall take Level 600 courses in the first year. On completion of the Level 600 courses, they will be assessed, and may progress into PhD depending on performance.

3. DURATION OF PROGRAMME
The duration for the completion of PhD degree shall normally be four years for full-time master degree entrants and six years for part-time master degree entrants.

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/Dissertation	45 Credits
Total	**75-81 Credits**

5. STRUCTURE OF PROGRAMME

Code	Title	Credits
Year 1		
Semester 1		
Core		
FASC 701	Science and Society	3
Select one course related to your area of specialization		
EASC 701	Recent Advances in Geology	3
EASC 703	Recent Advances in Geochemistry	3
EASC 705	Recent Advances in Geophysics	3
EASC 707	Recent Advances in Applied Geology	3
Electives (select 3 – 6 credits)		
FASC 700	Special Topics in Science	3
MASC 709	Advances in Marine Geoscience	3
Depending on background in Earth Science, students may be required to take up to three credit courses from Level 600.		
Semester 2		
Core		
FASC 702	Advanced Quantitative Research Methods	3
EASC 702	Analytical Methods and Data Analysis in the Earth Sciences	3
EASC 704	Independent Study in Earth Science	3
Electives (select up to 3 credits)		
FASC 710	Teaching of Science in a Tertiary Institution	3
MASC 702	Current Trends in Remote Sensing and GIS Applications	3
Depending on background in Earth Science, students may be required to take up to three credit courses from Level 600.		
Year 2		
EASC 710	Seminar I	3
EASC 720	Seminar II	3
Year 3		
EASC 730	Seminar III	3
Year 4		
EASC 740	Seminar IV	3
EASC 700	Thesis/Dissertation	45

6. COURSE DESCRIPTIONS

FASC 700: Special Topics in Science

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 complement 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
This course will enable students gain insights on 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 partnerships, networks and appropriate methods of communicating science depending on the 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 make, lay audience and to the media.

FASC 702: Advanced Quantitative Research Methods
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 720: Teaching Science at the Tertiary Level
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.

EASC 701: Recent Advances in Geology
This course seeks to provide in-depth reviews in recent advances in basic geology. Areas to be covered include petrology, mineralogy, structural geology; sedimentology; paleontology; petroleum geology, economic geology, and regional geology. The course will be delivered in seminar format. Experts from industry and academia may be invited as guest speakers.

EASC 702: Analytical Methods and Data Analysis in the Earth Sciences
The objective of this course is to provide training in the laboratory analysis of samples and evaluation of the data. Topics to be covered include: instrumental analytical techniques (including appropriate sample preparation), data processing, and data evaluation. On completion of the course the students will develop skills in laboratory work and use a wide range of analytical methods in the laboratory. The students will also be able to demonstrate in-depth knowledge of the different analytical techniques used. In addition, they will be able to critically assess the data and the validity of different methods of analysis for different purposes. As far as possible, training will be in the form of a project work around a suite of data collected at the start of the course.

EASC 703: Recent Advances in Geochemistry
This course seeks to provide in-depth reviews in recent advances in pure and applied geochemistry. Areas to be covered include distribution and migration of elements in igneous, sedimentary, and metamorphic rocks; isotope geochemistry; petroleum geochemistry; hydrochemistry, cosmochemistry, soild-earth geochemistry, and exploration geochemistry. The course will be delivered in seminar format. Experts from industry and academia may be invited as guest speakers.

EASC 704: Independent Study in Earth Science
The objective of this course is to equip students with the skills of field data collection, analysis and interpretation. Students collect, analyze and interpret specific field data pertaining to their area of specialization. The findings of the study is presented in a report, in a format similar to that of an article submitted for publication in a peer-reviewed earth science journal, and also presented orally. It is expected that on completion of the course the students would have developed practical skills in field work.

EASC 705: Recent Advances in Geophysics
This course seeks to provide in-depth reviews in recent advances in pure and applied geophysics. Areas to be covered include petroleum geophysics, exploration geophysics, borehole geophysics, seismology and solid earth geophysics. The course will be delivered in seminar format. Experts from industry and academia may be invited as guest speakers.

EASC 707: Recent Advances in Applied Geology
This course seeks to provide in-depth reviews in recent advances in applied geology. Areas to be covered include environmental geology, engineering geology, geomathematics, hydrogeology and hydrology. The course will be delivered in seminar format. Experts from industry and academia may be invited as guest speakers.

EASC 710: Seminar 1
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 advanced topics of current interest in their area of interest and attend departmental seminars.

EASC 720: Seminar II

Candidates will be attached to relevant faculty research or a research laboratory to gain experience in data gathering, analysis and interpretation in their areas of research during the first semester of the second year on the program. 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.

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

EASC 740: Seminar IV
Candidates will do oral presentation of research findings. In addition, candidates will attend departmental seminars, and attend and participate in internal and external conferences and workshops.

7. INTENSHIP/EXPERIENTIAL LEARNING PROGRAMME

All PhD candidates shall be required to spend the first Semester of the PhD Year 2 in an internship/experiential learning programme. The candidate will be attached to any one of the following:

i. Industry to acquire industrial experience,
ii. Ongoing projects in the Department,
iii. A Professor to work on specific projects,
iv. A scientific laboratory to acquire specific techniques and expertise,
v. A partner universities/laboratories to participate in selected programmes/research.

In addition to the general activities listed above, students will be engaged in on-going funded research projects in the department. This includes the following:

A: Geology, Geochemistry and Isotopic Studies of the Paleoproterozoic Rocks of Ghana

Funding Agency: Ministry of Lands and Natural Resources
Investigators: Prof. Daniel Asiedu (PI), Prof. Prosper M. Nude, Dr. Patrick Sakyi, Prof. David Atta-Peters, Dr. Jacob Kutu, Prof. Samuel Dampare

Project Summary
The project seeks to adopt a multidisciplinary approach to study the Paleoproterozoic rocks of Ghana. The research integrates field mapping (structural geology), geographic information system (GIS), mineralogy, petrology, geochemistry, geochronology and radiogenic isotopes to aid in understanding the geodynamic evolution of the Paleoproterozoic terrains of Ghana. This work is expected to generate new and comprehensive geochemical and isotopic data for the metavolcanic and metasedimentary rocks and the associated rocks in the greenstone belts and basins of Ghana. These data will provide useful information on the petrogenesis of the rocks and

thus help constrain the mantle source for the rocks in the study areas. The structural, mineralogical, petrological and chemical data of the rocks will be used to infer the geotectonic environment in which they were formed. Students on the project will be expected be actively involved in the field collection of data, laboratory analysis of collected field data, and interpretation of results.

B: White Volta Basin Hydrogeological Research Project

Funding Agency: DANIDA
Investigators: Prof. Mark Sandow Yidana (PI), Dr Larry Pax Chegbeleh and Dr Mrs Yvonne S. Loh

Project Summary
The White Volta Basin Project in the Department of Earth Science is a five year research project which started in January 2015 and funded by the Danish International Development Agency (DANIDA). It is executed in collaboration with the University of Copenhagen, Aarhus University, and the Geological Survey of Denmark and Greenland, GEUS, in Denmark, the Water Research Institute of CSIR, Hydronomics Limited, and the Center for Savannah Ecosystem Research in Ghana. The ultimate goal of this research is to facilitate the development and effective management of groundwater on a large scale for climate resilient irrigation and sustainable livelihood projects in the White Volta Basin. The specific objectives include the (a) development of a robust 3D Geological Model of the terrain using a suite of airborne and ground based geophysical datasets and borehole logs, (b) development of a transient 3D Hydrogeological model and (c) piloting groundwater based irrigation schemes in the basin. There are opportunities in the program for PhD students to spend time in laboratories of the GEUS, University of Copenhagen, and Aarhus University as well as the Ghana Geological Survey for practical experience as part of their experiential learning.

C: Sedimentology of the Voltaian Basin and Capacity Building in Petroleum Geology

Funding Agency: Ghana National Petroleum Corporation
Investigators: Prof. Daniel Asiedu (PI), Prof. David Atta-Peters, Dr. Chris Anani

Project Summary
This is a five-year Project that seeks to build Petroleum Geoscience (PG) research and education capacity at University of Ghana (UG) that will support the optimal exploration and development of Ghana's hydrocarbon resources. The project is being carried out in collaboration with researchers from the University of Aberdeen. The main objective of this project is to build academic infrastructure and expertise in petroleum geoscience in Ghana. To achieve this aim the Project will carry out a sedimentological research on the Voltaian Basin, Ghana's largest sedimentary basin, and training of student to PhD level. The research will cover the following areas of the Voltaian Supergroup:

- Stratigraphy
- Provenance studies on the siliciclastic sedimentary rocks
- Organic diagenetic studies on petroleum source rocks

- Depositional environments using sediment cores and wireline logs
- Sandstone diagenesis and reservoir quality
- Basin tectonics

The PhD students admitted into the project will actively participate in the fieldwork, analyses and the interpretation of data collected from the field.

8. SUMMARY OF ACTIVITIES

Year 1, Semester 1

Course work (9-12 credits). Participate in departmental seminars. Actively think of thesis/dissertation area. Keep abreast of recent scientific literature in field of study. Assignment of Supervisory Committee.

Year 1, Semester 2

Course work (9-12 credits). Participate in departmental seminars. Prepare for comprehensive examination. Select thesis/dissertation area. Keep abreast with scientific literature in thesis/dissertation area.

Year 2, Semester 1

Participate in departmental seminars. Take Comprehensive examination (both oral and written). Actively work on research proposal. Undertake Intenship/Experiential Learning.

Year 2, Semester 2

Present research proposal orally. Participate in departmental seminars. Start dissertation research.

Year 3, Semesters 1 & 2

Continue dissertation research. Oral presentation of research progress. Participate in departmental seminars. Attend and participate in internal and external conferences and workshops. Think actively of developing manuscripts from dissertation.

Year 4, Semesters 1 & 2

Continue with dissertation research. Participate in departmental seminars. Submit at least one manuscript for publication. Complete and defend dissertation. Submit final version of dissertation to Office of the School of Graduate Studies.

DEPARTMENT OF PHYSICS

PHD IN PHYSICS

INTRODUCTION

The PhD programme offered by the Department of Physics aims to give students in-depth training in theoretical and experimental physics. Research opportunities exist in Condensed Matter Physics, Theoretical Physics, Energy Systems, Environmental Physics, and Atomic, Molecular and Optical Physics.

ADMISSION REQUIREMENTS

Admission to the physics PhD programme requires a relevant master's degree.

DURATION OF PROGAMME

The duration of the programme is normally four years for full-time students and six years for part-time students.

REQUIREMENTS FOR GRADUATION

Coursework: 18 to 24 credits
Seminars: 12 credits
Thesis: 45 credits
Total: 75 – 81 credits

STRUCTURE OF PROGRAMME

Year 1

Semester 1: Core Courses

Course code	Course Title	Credits
FASC 701	Science and Society	3
PHYS 711	Advanced Quantum Mechanics	3

Semester 1: Electives (Students are required to select a minimum of 3 credits)

Course code	Course Title	Credits
PHYS 713	Atomic Physics	3
PHYS 715	Optical Waves in Crystals	3
PHYS 717	Semiconductor Physics	3
PHYS 719	Advanced Topics in Condensed Matter Physics	3
PHYS 721	Statistical Optics	3
PHYS 723	Nonlinear Optics	3
PHYS 725	Plasma Physics	3
PHYS 729	Special Topics in Atmospheric Physics	3
PHYS 731	Quantum Field Theory	3
PHYS 733	Topology and Differential Geometry in Physics	3
PHYS 735	Astrophysics	3
PHYS 737	Gravitation	3
PHYS 740*	Advanced Problems in Physics	3
PHYS 750*	Topics in Contemporary Physics	3

Semester 2: Core Courses

Course code	Course Title	Credits
PHYS 712	Advanced Experimental Physics	3
PHYS 714	Advanced Electrodynamics	3

Semester 2: Electives (Students are required to select a minimum of 3 credits)

Code	Title	Credits
PHYS 716	Nuclear Physics	3
PHYS 718	Many-body Physics	3
PHYS 722	Quantum Optics	3
PHYS 724	Nonlinear Fibre Optics	3
PHYS 726	Laser Physics	3
PHYS 728	Special Topics in Energy Systems	3
PHYS 732	Special Topics in Meteorology	3
PHYS 734	Group Theory	3
PHYS 736	Statistical Field Theory	3
PHYS 738	Astrophysical Processes	3
PHYS 742	Cosmology	3
PHYS 740*	Advanced Problems in Physics	3
PHYS 750*	Topics in Contemporary Physics	3

*This course can be taken for credit only once.

Year 2

Core

Course code	Course Title	Credits
PHYS 710	Seminar I	3
PHYS 720	Seminar II	3
PHYS 700	Thesis	-

Note: Students must pass a comprehensive examination to progress to Year 3 of the programme.

Year 3

Core

Course code	Course Title	Credits
PHYS 730	Seminar III	3
PHYS 700	Thesis	-

Year 4

Core

Course code	Course Title	Credits
PHYS 760	Seminar IV	3
PHYS 700	Thesis	45

DESCRIPTION OF COURSES

PHYS 711: Advanced Quantum Mechanics
This course examines the quantum theory of radiation, the Dirac theory of spin-½ particles, and quantum electrodynamics and treats second quantization of several fields, including the electromagnetic field. Topics include the Dirac equation, canonical quantization, interacting field theories, Feynman diagrams, applications to atomic transitions, quantum electrodynamics and introduction to radiative corrections.

PHYS 712: Advanced Experimental Physics
Research programs in the Department are described by faculty members and advanced graduate students. The experimental basis of physics is illustrated through accounts of great experiments of importance to contemporary research. This serves as an introduction to an experimental sequence in which participants solve experiment design, data acquisition and data analysis problems using modern equipment and software.

PHYS 713: Atomic Physics
The atomic physics course examines the physical foundations of modern experiments in atomic, molecular and optical physics. Topics include the theory of atomic structure, emission and absorption of radiation, fine and hyperfine structure, angular momentum coupling schemes, molecular structure and intermolecular forces, atomic and molecular collisions and modern applications.

PHYS 714: Advanced Electrodynamics
The advanced electrodynamics course examines the behaviour of relativistic charged particles in electromagnetic fields and the emission and scattering of electromagnetic radiation. Topics include waveguides and resonant cavities, special theory of relativity, simple radiating systems and antennae, multipole fields, dynamics of relativistic particles and electromagnetic fields, radiation by accelerated charges, and scattering of electromagnetic waves.

PHYS 715: Optical Waves in Crystals
This course aims at a description of the propagation of optical waves in solids and examines the linear and nonlinear electromagnetic wave phenomena that occur in solids. Topics include electromagnetic wave propagation in anisotropic and periodic media, Gaussian beam optics and the ABCD law, electro-optic effects and devices, acousto-optic effects and devices, and introduction to nonlinear optics.

PHYS 716: Nuclear Physics
This course provides a clear, concise, and up-to-date overview of the atomic nucleus and the theories that seek to explain it. Topics include two- and three-nucleon problems, basic nuclear properties, collective and single-particle motion, giant resonances, mean field models, the interacting boson model, nuclei far from stability, nuclear astrophysics, big-bang and stellar nucleosynthesis, electron scattering—nucleon momentum distributions, scaling, polarization observables, parity-violating electron scattering, neutrino physics, current results in relativistic heavy ion physics and hadronic physics, frontiers and future facilities.

PHYS 717: Semiconductor Physics
This course covers the key principles and applications of semiconductor physics and their relevance to current developments in physics. Topics include characterization of semiconductors, electronic structure of ideal crystals, electronic structure of semiconductor crystals with perturbations, electron system in thermodynamic equilibrium, non-equilibrium processes in semiconductors, semiconductor junctions in thermodynamic equilibrium, semiconductor junctions under non-equilibrium conditions.

PHYS 718: Many-body Physics
This course covers the concepts and physical pictures behind various phenomena that appear in interacting many-body systems. Topics include second quantization, "free" systems—the building block of the quasiparticle concept, phonons and photons, Fermi and Bose fluids, spin systems (x-y) model, interactions, Green functions and Feynman diagrams, finite temperature Green functions, application of finite temperature Feynman diagrams to the electron-phonon problem and to transport theory, functional integral approach, broken symmetry and superconductivity; local moments and heavy electron physics.

PHYS 719: Advanced Topics in Condensed Matter Physics
This course gives basic concepts and theory of the traditional condensed matter theory and the modern condensed matter theory. Topics include the nature of condensed matter, order and disorder crystals, scattering and correlations, surfaces and crystal growth, classical and quantum waves, the non-interacting electron model, dynamics of non-interacting electrons, dielectric and optical properties, electron interactions, superfluidity and superconductivity.

PHYS 721: Statistical Optics
The aim of this course is to cover the statistical nature of optical fields via concepts such as spatial and temporal coherence. Topics include coherence properties of optical waves, first-order properties of light and higher-order coherence effects, partial coherence, imaging through randomly inhomogeneous media; photoelectric detection of light.

PHYS 722: Quantum Optics
This course provides a broad overview of the quantum mechanical nature of light and its interaction with matter. Topics include quantum theory of radiation, mechanical effects of light, squeezed states of light, interaction between atoms and quantized fields, system-reservoir interactions, resonance fluorescence, and cavity quantum electrodynamics.

PHYS 723: Nonlinear Optics
This course gives students a working knowledge of the fundamental concepts and modern applications of nonlinear optics. Topics include nonlinear optical susceptibility, Kramers-Kronig relations, nonlinear optical interactions, quantum theory of nonlinear optical susceptibility, intensity-dependent refractive index, light scattering, electro-optic and photorefractive effects, multiphoton processes.

PHYS 724: Nonlinear Fibre Optics
The aim of this course is to cover the basic up-to-date overview of the nonlinear phenomena occurring inside optical fibers. Topics include fibre characteristics and nonlinearities, propagation of optical pulses in optical fibres, dispersion in optical fibres,

self-phase modulation and cross-phase modulation in optical fibres, optical solitons, Raman scattering and parametric processes.

PHYS 725: Plasma Physics
This course serves as an introduction to plasma phenomena and discusses the main elements of their application in current energy research. Topics include plasma phenomena and plasma characterization, Coulomb collisions, relaxation times, transport processes, two-fluid hydrodynamic and MHD descriptions, plasma confinement by magnetic fields, simple equilibrium and stability analysis, wave propagation in a magnetic field, RF plasma heating, kinetic theory, the Vlasov, Boltzmann and Fokker-Planck equations, relationship between fluid and kinetic descriptions, electron and ion acoustic plasma waves, and Landau damping.

PHYS 726: Laser Physics
This course is concerned with the physics of the laser, particularly the generation, propagation, and applications of laser beams. Topics include optical beams and resonators: Gaussian beams, ABCD matrices, beam perturbation and diffraction, resonators and resonator stability; laser dynamics: rate equations, threshold conditions, laser spiking and mode-locking, injection locking, hole burning, saturation spectroscopy; Laser spectroscopy: dressed states, double resonance techniques, multi-photon processes.

PHYS 728: Special Topics in Energy Systems
The aim of this course is to introduce the student to elements of current energy research. It discusses the theoretical underpinnings of several energy systems. Topics include characteristics of solid, liquid and gaseous fuels; combustion reaction kinetics; combustion technology; flames; heat generation systems: gas-fired furnaces, premixed-charged engines, oil-fired furnaces, gas-turbines, fixed-bed combustors, pulverised fuel combustors, fluidised bed combustors; heat exchangers; thermodynamics and energy efficiency analysis; power cycles; conventional and clean coal technologies; biomass energy; solar thermal power; wind power; geothermal power; nuclear power; environmental impact; carbon capture and sequestration.

PHYS 729: Special Topics in Atmospheric Physics
This course provides a review of atmospheric physics and its application to climatology. Topics include fundamentals of atmospheric science, atmospheric physics, radiative transfer processes in the atmosphere, radiative transfer processes in the ocean, modelling of climatic change; physical climatology.

PHYS 731: Quantum Field Theory
This Course provides a theoretical framework for constructing quantum mechanical models of systems classically represented by an infinite number of degrees of freedom, that is, fields and (in a condensed matter context) many-body systems. Topics include functional integral quantization of field theories, quantization of gauge theories, renormalization, spontaneous symmetry breaking and the Higgs mechanism.

PHYS 732: Special Topics in Meteorology
Physical: Global climate system, radar meteorology, radiative transfer, cloud physics, satellite remote sensing of planetary atmosphere, physics of the air-sea boundary Layer; Dynamical: Introduction to fluid dynamics, dynamic climatology, large-scale atmospheric

circulations, dynamical weather prediction, modelling the climate system, advanced topics in dynamical meteorology, advanced topics in geophysical applications;
Synoptic: Tropical meteorology, dynamical weather prediction, statistical weather prediction, advanced topics in synoptic meteorology;
Other Topics: Applied time series analysis.

PHYS 733: Topology and Differential Geometry in Physics
This course introduces the ideas and techniques of differential geometry and topology at a level suitable for postgraduate students and researchers in theoretical and mathematical physics. Topics to be discussed include the following: Topology; Differentiable manifolds; Vector fields; Lie groups; Fibre bundles and connections.

PHYS 734: Group Theory
The goal of this course is to answer several questions pertaining to the state of a physical system solely on the basis of symmetry considerations. Topics to be discussed include the following: Groups and their representations; Group isomorphism theorems; Group automorphism: cyclic groups, elementary abelian groups, Group actions on sets; Discrete and continuous groups; SU(n) groups; Lie algebras; Lie groups; Applications to atomic, solid state, nuclear, and high energy physics.

PHYS 735: Astrophysics
This course principally examines the physics of stars and galaxies. Topics include the Sun and stellar radiation, stellar spectra and classification; stellar structure and evolution, thermonuclear processes, interstellar material, the formation of stars and planets; binary systems, exo-planets; galaxies and active galactic nuclei; single-dish and interferometric radio techniques. The role of radio astronomy is highlighted throughout the course.

PHYS 736: Statistical Field Theory
This course uses tools such as perturbation theory, exact solutions and renormalization groups to demonstrate the emergence of scale invariance and universality, and the non-equilibrium dynamics of interfaces and directed paths in random media.
Topics to be discussed include phase transitions, lattice models, Landau-Ginsburg theory, mean field theory, universality, scaling, renormalization group and critical exponents.

PHYS 737: Gravitation
This course examines the modern theory of gravitation and its application in cosmology. Topics include Newtonian cosmology, principles of general relativity, differential geometry, energy and momentum of flat spacetime, curvature of spacetime near rotating and non-rotating centres of attraction, black holes, galactic dynamics, modified Newtonian dynamics, dark matter, and experimental tests.

PHYS 738: Astrophysical Processes
This course takes a global view of the various processes in the universe that give rise to observable radiation or particles: Compton scattering, bremsstrahlung, synchrotron radiation, Cherenkov radiation, cosmic rays, cosmic plasmas, magnetospheres, solar flares, accretion disks, X-ray sources, primordial nucleosynthesis, cosmic microwave background, dark matter, neutrinos, gravitational waves.

PHYS 740: Advanced Problems in Physics
The advanced problems in physics course is a problem-solving course that applies

principles of physics as in classical mechanics, quantum mechanics, electrodynamics, statistical mechanics to a variety of problems including problems in atomic physics, molecular physics, optical and laser physics, solid-state physics, nuclear physics.

PHYS 742: Cosmology
This course applies the theoretical principles of cosmology to specific structures in the universe. Topics include: cosmological principle, relativistic cosmology, types of universe, the beginning and evolution of the universe, competing models of the universe, inflationary models, cosmic background radiation, nucleosynthesis, baryosynthesis, large scale structures, and experimental and observational evidence.

PHYS 750: Topics in Contemporary Physics
The Topics in Contemporary Physics course deals with selected topics from current trends in physics and physics related fields, including medical physics, biophysics, condensed matter, atomic, molecular and optical physics, energy systems, physics of the environment, science of sustainability, mathematical physics, and complex systems. This course can be taken for credit only once.

PHYS 710: Seminar I
The seminar series aim at exposing students to contemporary research in physics while giving them an avenue to present their research. Seminars are given by faculty and invited experts at which contemporary research in physics are discussed. In this course, students give at least one seminar each semester and present their thesis research proposal.

PHYS 720: Seminar II
The seminar series aim at exposing students to contemporary research in physics while giving them an avenue to present their research. Seminars are given by faculty and invited experts at which contemporary research in physics are discussed. In this course, students give at least one seminar each semester and present a report on their year-long experiential learning activities.

PHYS 730: Seminar III
The seminar series aim at exposing students to contemporary research in physics while giving them an avenue to present their research. Seminars are given by faculty and invited experts at which contemporary research in physics are discussed. In this course, students give at least one seminar each semester and present progress reports on their research.

PHYS 760: Seminar IV
The seminar series aim at exposing students to contemporary research in physics while giving them an avenue to present their research. Seminars are given by faculty and invited experts at which contemporary research in physics are discussed. In this course, students give at least one seminar each semester and present their research results.

PHYS 700: Thesis

Details of Experiential Learning

The second year activities aim at guiding students to acquire specific laboratory, analytical, theoretical and computational expertise of relevance to contemporary research in physics. Students will participate in on-going research programmes in the Department. Projects include the following.

A: Imaging through scattering media (PI: Amos Kuditcher)

This is an ongoing project in the Department that is developing techniques for extending imaging depth in scattering media while maintaining high transverse resolution. The ultimate goal of the project is to achieve high resolution imaging of biological structures. The project uses interferometric and ultrafast techniques for acquiring data. Students attached to this project will learn optical alignment techniques as well as data acquisition with point and array detectors. They will perform analysis image data collected using interferometers. This project is also pursuing applications of short-wave infrared and terahertz radiation to imaging. Students will participate in setting up the imaging system.

B: Fabrication and characterization of nano-particles

This is an on-going multi-faceted project, involving several senior members of the Department, which is aimed at developing functional materials for applications in photovoltaics, optoelectronics, and sensing. This project has fabricated several nano-particle and thin film compound semiconductor materials, including zinc oxide, copper oxide, cuprous sulphide, and iron disulphide. Students attached to this project will learn the techniques that have been developed in the project for nano-particle and thin film fabrication, including chemical bath, physical vapour, and chemical vapour deposition. They will also learn to use x-ray diffraction techniques (small and wide angle diffraction), electron microscopy, and optical and infrared spectroscopy to acquire data on existing samples as well as new samples generated by the project. They will use the data to determine physical properties such as band gap of the materials.

C: Electronic structure calculations of materials (PI: George Nkrumah-Buandoh)

This is an ongoing project that applies theoretical and computational methods for predicting properties of materials. The project uses state-of-the art codes such as Quantum Espresso to generate electronic structure data which are then analysed to determine electronic, optical, and mechanical properties of materials. Students attached to this project will be involved in hands-on computational training in density functional theory, pseudopotentials, plane waves and iterative diagonalization methods. They will use Quantum Espresso to generate electronic structure data, particularly for the materials that are of interest to the experimental research activities in the Department, such as zinc oxide and copper oxide. They will use the data to determine band gap and absorption spectra of such materials and compare their results to experimental results that have been obtained in the Department.

D: Anaerobic digester (PI: Michael Addae-Kagyah)

This is an on-going project to develop biogas digesters. The project is currently in the design phase. By the time students join the project, design would have been completed. Therefore, students will participate in construction and characterization of the anaerobic biogas digesters. They will learn about active feedback-control systems and construct prototype control systems. They will also participate in gas production measurements. They will use data from the measurements to optimize the designs.

Collaboration

The Department maintains working relationships with local and international institutions which involve various activities, including faculty and student visits and access to laboratory and computational facilities. The following institutions are included.

1. Abdus Salam International Centre of Theoretical Physics, Trieste
2. University of the Witwatersrand, Johannesburg
3. University of Leeds, UK
4. University of South Wales, UK
5. University of Leicester, UK
6. Institute of Physics, UK
7. Ghana Space Science and Technology Institute, GAEC, Kwabenya
8. Ghana Atomic Energy Commission, Kwabenya
9. National Nuclear Research Institute, Kwabenya
10. Radiation Protection Institute, Kwabenya
11. Ghana Standards Authority, Accra
12. Ghana Meteorological Agency, Accra
13. Utah State University, USA
14. The NIMROD Team, USA
15. Institute of Industrial Research, Accra
16. Energy Commission, Accra

DEPARTMENT OF STATISTICS

PHD IN STATISTICS

1 Introduction

The new structure of the four-year PhD programme in STATISTICS involves course work in Year 1, a practical attachment/internship in Year 2 with comprehensive PhD qualifying examinations, and thesis research completed by the end of Year 4.

The program of study leading to the degree of Doctor of Philosophy in Statistics seeks to strike a balance between theoretical and applied Statistics. The Ph.D. program will prepare students for university teaching and/or research careers, and also for industrial and governmental positions involving research in new methods of statistical application. The program will provide the students a broader exposure to the state of application of Statistics in various fields, and strengthen their ability to do cutting edge research in a number of disciplines including Statistics and Probability, Mathematical Statistics, Biomedical field, Engineering field, Social Science, Management Science, Demography, etc.

1.1 Objectives

The main objective of the Ph.D. program is to provide a high caliber manpower which will lead eventually to the correction of deficiencies in the state of application of Statistics in various sectors of our economy and those of other countries. Thus, the program seeks to provide highly qualified manpower for the following institutions in Ghana and other countries in the sub-region.

- Statistics departments of universities and polytechnics
- Research units of state and private institutions
- Research units of global institutions
- Etc.

2 ADMISSION REQUIREMENTS

Admission to PhD will be limited to candidates whose academic records show a potential for successful completion of a doctoral degree programme.

Two main categories of students will be expected to enroll for PhD programmes at UG:

(i) Candidates applying with first degree; and,

(ii) Candidates applying with Masters degree.

The admission requirements and progression in the PhD programme for the two categories of applicants are outlined below:

2.1. Candidates applying with a first degree

i. Candidates with a good first degree may apply into an MPhil or a PhD programme.

ii. The PhD applicants will be given conditional admission letters by the School of Graduate Studies.

iii. They shall take prescribed courses (Level 600 courses) in the first year.

iv. On completion of the Level 600 courses, candidates will be assessed, and may progress into PhD depending on performance;

v. Candidates who are not able to progress into PhD will undertake their MPhil thesis research and on successful completion, will be awarded an MPhil degree.

vi. Candidates who progress into PhD will be given conditional admission into the PhD programme. They shall take Level 700 courses and continue to fulfill the requirements as outlined in Section 2.2.

vii. Candidates who are unable to meet the criteria for the M.Phil degree may be offered the option to undertake an MSc. dissertation. They will be awarded M.Sc. degree upon successful completion.

2.2. Candidates applying with a Master's degree (e.g. MA/MSc/MPh/MBA/MPhil)

i. Students with a Masters' degree may apply into a PhD programme.

ii. Such students will be given conditional admission letters by the School of Graduate Studies.

iii. They shall take prescribed courses (Level 700 courses) in Year 1 as well as "make-up courses", as necessary, in Years 1 & 2.

iv. Candidates will be assessed on successful completion of the prescribed courses, and may progress to the PhD depending on performance.

v. Candidates who qualify to progress to PhD will be admitted to the PhD programme.

vi. Candidates who are unable to meet the criteria may be offered the option to do an MPhil, in which case, they shall proceed to do an MPhil thesis research.

3. PROCEDURE FOR ADMITTING APPLICANTS INTO THE PHD PROGRAMME

The procedures outlined below shall be followed in admitting students into the PhD programme:

3.1 Entry point (screening at Academic Unit level)

All students applying to do PhD shall go through the following exercises.

i. Take an entrance examination, comprising a written examination and an oral presentation on a topical issue in Statistics and;

ii. Attend an interview to be organised at the Departmental level by the Departmental Graduate Committee.

3.2. Transition from Level 600/700 to PhD

Students progressing from the course work year into the research years will have to take and pass both written and oral examinations in the courses taken.

3.3 Doctoral Qualifying Examination

Candidates who complete the Level 700 course work successfully and progress into the PhD programme shall be required to take and pass a comprehensive examination (a doctoral qualifying exam) to progress to the internship/research years. The purpose of the comprehensive examination is to determine the candidate's capacity to do a PhD in the area selected as well as to test capability in critical thinking. The comprehensive examination should be such that candidates will demonstrate the set of skills required to complete a PhD programme (e.g., ability to do independent work, in-depth knowledge of selected discipline, ability to analyse and critique published works in candidate's area, etc.). This examination shall be organised within eight weeks of the First Semester of PhD Year 2 and shall include item (i) below and any one of items (ii)-(iv):

i. A series of written exams based on the general area of study, plus an oral exam by a panel of examiners.

ii. Submission of publishable papers (minimum of 1), based on research done during the Year 1/first semester of Year 2) for assessment.

iii. A presentation of a research proposal in the general area of study, but not on thesis research area; i.e. this should be different from the thesis research proposal.

iv. Submission of in-depth review of literature on a thematic area to be assessed.

Based on the candidate's performance in the Comprehensive Examination, the candidate shall be confirmed as a PhD student.

4. CRITERIA FOR ADMITTING PHD STUDENTS

In addition to existing requirements detailed in the UG Graduate Handbook (Vol.1), candidates selected into a PhD programme must:

i. Present a good research idea either developed by student or in consultation with a potential supervisor (to be developed into a proposal by the end of the first semester in Year 2). The research idea must fit into the research interest/research themes of the targeted department and there must be an expert in the area within the department, cognate department or external partner university to supervise the thesis research;

ii. Demonstrate ability to carry out research (publications would be an advantage e.g., publications from a Masters' thesis);

iii. Demonstrate capability to pay his/her fees and cover research costs.

5. DURATION OF PROGRAMME

This programme normally takes ***four*** years to complete and the mode of delivery is full-time and ***six*** years to complete on part-time basis.

6. GRADUATION REQUIREMENTS

The candidate to be awarded PhD degree in Statistics must satisfy the following graduation requirements:

Coursework	18-24 Credits
Seminars (4)	12 Credits

Thesis 45 Credits

Total 75-81 Credits

7. PROGRAMME STRUCTURE

YEAR 1, FIRST SEMESTER

Course Code	Course Title	Credits
	CORE COURSES	
FASC 701	Science and Society	3
STAT 701	Advances in Probability, Measure and Stochastic Processes	3
	ELECTIVE COURSES	
Electives (Minimum of 3 Credit and a maximum of 6 Credits)		
FASC 700	Special Topics in Science	3
STAT 703	Advanced Survey Methods and Design	3
STAT 705	Demographic Models	3
STAT 707	Applied Econometrics for Statisticians	3

Minimum Credits for Semester 1 9
Maximum Credits for Semester 1 12

YEAR 1, SECOND SEMESTER

Course Code	Course Title	Credits
	CORE COURSES	
STAT 706	Bayesian Methods and Computation	3
	ELECTIVE COURSES	
Electives (Minimum of 6 Credit and a maximum of 9 Credits)		
FASC 710	Teaching Science at the Tertiary Level	3
STAT 708	Advanced Topics in Mathematical Statistics	3
STAT 712	Linear Statistical Models	3
STAT 714	Forecasting and Time Series Analysis	3
STAT 718	Re-sampling Methods	3

Minimum Credits for Semester 2 9
Maximum Credits for Semester 2 12

YEAR 2, 3 and 4

Course Code	Course Title	Credits
	CORE COURSES	
STAT 710	Seminar I	3
STAT 720	Seminar II	3
STAT 730	Seminar III	3
STAT 730	Seminar IV	3
STAT 700	Thesis	45

8. YEAR II EXPERIENTIAL LEARNING/INTERNSHIP PROGRAMME

All PhD students shall be required to spend six months (half) of the PhD Year 2 in an internship/experiential learning programme. The Department's ongoing projects in which doctoral students will have their experience include the following:

The Department has a **Statistical Consulting Practicum** (SCP), a consulting unit which will provide a year-long experiential learning opportunity to students in Statistical Consulting. The Practicum will offer opportunity for small teams of PhD students to work on "real life" quantitative consulting projects. These projects are drawn from both business and academic sources. The emphasis is on providing relevant and comprehensible solutions to client problems. In-session brainstorming, client presentations, and written reports that will give students the opportunity to test for the existence of an intersection between their quantitative and communication skills. Also students could partake in local/international seminars where papers are presented.

The purpose of the SCP is to assist researchers and postgraduate students with advice on statistical aspects of their research. Necessary assistance is given with the calculation and interpretation of results. The service is also available to researchers and institutions outside the University. The consultation includes the following:

- Advice during planning phases of research projects, Experimental design, Sample size calculation,
- Assistance and planning of data capturing, Statistical analysis of data,
- Assistance with interpretation of statistical results, commenting on results sections of papers/theses.

We strive to keep up to date with the latest statistical techniques/software. Students at the Department participate in these consultations, developing statistical programs to solve the presented cases and writing reports.

Ghana Insurance Industry Database (GIID) Development Project (PI: Dr. Isaac Baidoo)

This is an on-going development projection in partnership with the Ghana Insurers Association to develop a common data platform for the insurance industry, while providing data to support the actuarial activities of member companies, academics, and other interested parties. Students who participate in this project will initially work on the user interface for data acquisition and work on compiling a set of templates for basic actuarial calculations as well as coming up with new statistical methodologies and models to handle such large data sets.

Prevalence of Albinism in Sub-Saharan Africa Research
[PI: Dr. Patricia Lund (Coventry, UK), Prof. Mark Roberts (Surrey, UK), F. O. Mettle, E. N. N. Nortey & K. Doku-Amponsah]

This project was started by Patricia Lund in the mid 1990's in Zimbabwe. The project is currently in Ghana starting in two administrative districts, namely the Assin North District and the Mfantseman Municipal District. The project which started with an initial aim of providing empirical evidence on the prevalence of albinism in Sub-Saharan Africa is now focused in addition on the following:

- Statistics and Stochastic Models of the Genetic Condition Albinism
- The effect of genetic drift on the incidence of albinism in different populations
- Genetic drift in migrating populations

Doctoral students would support fieldwork and the data processing as well as develop stochastic models which can end up in academic papers that can be published in international journals.

Statistical Models for Longitudinal, Repeated Measures and Clustered Data (PI: Dr. Iddi)

Clustered, longitudinal and multilevel data are often encountered in medical, pharmaceutical, public health, social science (economics, finance and quantitative psychology) etc. research. These kinds of data exhibit certain characteristics which conventional linear models that assume independence may be inadequate to help draw valid inferences. Typically, data may be correlated, overdispersed, have excess zeros etc. and therefore require careful modeling. The generalized linear mixed model widely used for correlated non-Gaussian data has been shown to underperform when overdispersion and excess zeros are present. An extension of such a model has been proposed by Molenberghs *et. al.* (2010). The so-called combined model flexibly handles overdispersion and correlation. In recent years, this model has formed the basis for further extensions, some of which the PI has been involved in over the past few years. A student who will spends the experiential learning period under the PI, stands to acquire enormous amount of knowledge, experience and skills to begin a rigorous research in developing useful statistical models. This will adequately prepare the student to come up with a suitable PhD proposal which will lead to excellent dissertation and publications in international journals.

State Space and Graphical models for estimating networks dynamics (PI: Dr. Anani Lotsi)

Biological networks have arisen as an attractive paradigm of genomic science ever since the introduction of large scale genomic technologies, which carried the promise of elucidating the relationship in functional genomics. However the sheer dimensionality of all possible networks combined with the noisy nature of the observations and the complex structure of genomic regulations and signaling have meant that simply reading off a network from the data turned out somewhat optimistic. Instead, only statistical models of sufficient biological relevance are capable of discovering direct and indirect interactions between genes, proteins, and metabolites. In 1991, Albert-Laszolo Barabasi introduced the concept of scale free networks and proposed the Barabassi-Albert model to explain networks from the World Wide Web to genomics. Despite superficial fit to some data, it has become clear that genomic systems are more complex. The last decade has seen an extension of these models. Integrating these models in mainstream statistics is an exciting challenge from a theoretical, computational and applied perspective.

The aim of this PhD. Project is to infer biological networks using genomics data. The students will be required to devise methods for inferring networks from high-throughput data sources with potentially hidden states. The candidates will come up with a mathematical model, able to capture the stochastic nature of the biological process as well as their dynamic behavior. Part of the project will consist of implementing the methods in an R software library.

The Department of Statistics already has a number of links of collaboration with Bank of Ghana and also with University of Stellenbosch *in training PhD students in various aspects of Statistics. Some of the areas in which these collaborations will offer our doctoral students experience include the following:*

Loss of degrees-of-freedom in quadratic goodness-of-fit tests. [PI: T de Wet (University of Stellenbosch, South Africa)]

In many goodness-of-fit statistics one has a number of unknown parameters which have to be estimated from the data in order to apply the procedure. Quadratic-type goodness-of-fit statistics have asymptotic distributions equivalent to that of a weighted sum of independent chi-square random variables, each with one degree-of-freedom. For some of these quadratic statistics, estimation of the unknown parameters can lead to a loss of terms in the sum of chi-squares. This has become known in the literature as the property of "losing degrees-of-freedom". Under this project, this property was investigated for Wasserstein type distance measures and conditions found where the property holds. In particular it was shown how it holds for location and scale families separately. Further work is in progress to consider related statistics for which the property holds jointly for location-scale families. A student who will spends the experiential learning period under the PI, will acquire knowledge and experience in this area of study that will adequately prepare him/her to come up with a good thesis proposal which may lead to an excellent work and publications in international journals.

SAS Institute Enterprise miner: A Statistical Perspective [PI: W. J. Conradie (University of Stellenbosch, South Africa) and C. J. B. Muller (University of Stellenbosch, South Africa)]

Enterprise Miner is one of the, if not the, most powerful data mining software packages currently available on the market. It uses a large number of sophisticated statistical techniques. In this project the statistical techniques used in Enterprise Miner are studied and evaluated. The research is structured around the SEMMA methodology of SAS. SEMMA is the acronym for **S***ample*, **E***xplore*, **M***odify*, **M***odel* and **A***sses*. A data mining analysis is performed in Enterprise Miner by building an algorithm with various nodes inside a graphical interface. A student who spends the experiential learning period under the PIs, will acquire enormous skills in management of large datasets and practical experience in sophisticated statistical techniques to solve real life problems.

Saddlepoint approximation and areas of application [PI: T de Wet (Stellenbosch University, South Africa) and P. J. U. van Deventer (Stellenbosch University, South Africa)]

Suppose we are interested in the density of some statistic, based on identical independent observations with an underlying density. Unless the sample statistic and/or the underlying density have special forms, one cannot usually compute analytically the distribution of the statistic and one has to rely on an asymptotic distribution. The latter however, often does not provide a good approximation unless the sample size is (very) large. Moreover, such approximations tend to be inaccurate in the tails of the distribution, where one often wants to use them. Saddlepoint approximation together with the Edgeworth expansion often lead to a very accurate approximation to a required distribution, even for very small sample sizes. Furthermore saddlepoint approximations do not show the polynomial-like waves exhibited for instance by Edgeworth expansions per sé. The success of this approach has led to the study of more general areas of application, inter alia regressions quantiles.

Financial applications of LULU smoothing procedures [PI: W. J. Conradie (Stellenbosch University, South Africa), T. de Wet (Stellenbosch University, South Africa) and C. H. Rohwer(Stellenbosch University, South Africa)]

A new class of data smoothing procedures has been developed by CH Rohwer over the last 15 years. They are called LULU smoothers, are based on combinations of the minimum and maximum operators (and thus nonlinear) and have very attractive mathematical properties, especially compared to other nonlinear smoothers. LULU smoothers have already been applied successfully to many problems in, for example, the earth sciences. However, to date they have not yet been applied to financial data. In this project we consider such applications. In particular, application to data series consisting of returns and volatility are being investigated. These types of data are extremely important in many financial applications and the role of outliers in such data need to be properly understood and their influence on predictions must be properly controlled. The behaviour of LULU in such cases is being investigated as well as the comparison of LULU with other smoothing procedures.

Currently, the Department of Statistics, University of Ghana, is in collaboration with Stellenbosch University, South Africa on the following:

a. Established exchange agreement which permits students to spend up to one academic year at the Stellenbosch University to undertake statistics courses or research projects not offered at UG.

b. Partnership with the Center of Statistical Consultation unit (University of Stellenbosch) for students to take part in statistical consulting and other programmes offered at the center.

c. Split-site Supervision agreement which allows students to be supervised by a team of supervisors from both UG and Stellenbosch University.

d. Visits by academic staff members of both departments.

Within six weeks to the end of Year 2, the student shall produce a report and give a seminar on what he/she 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.

9. 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 complement 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 gain insights on 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 partnerships, networks and appropriate methods of communicating science depending on the 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 makers, lay audience and to the media.

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.

STAT 701: Advances in Probability, Measure Theory and Stochastic Processes,
This course provides grounding in stochastic processes, probability and measure theory suitable for statistical work. Topics include: Principles of modeling and classification of stochastic processes, Martingales, Markov Chains, Markov processes, Poisson Processes, Brownian motion, stochastic differential equations and diffusion processes, Gauss-Wiener processes. Simulation methods and applications for stochastic processes. Probability spaces, theory of measure and integration, random variables, and limit theorems. Distribution functions, densities, and characteristic functions; convergence of random variables and of their distributions; uniform convergence. Weak laws of large numbers, variants of the central limit theorem, rates of convergence of limit theorems, local limit theorems, stable laws.

STAT 703: Advanced Survey Methods and Design
This course will cover the design and analysis of sample surveys. Topics include methods and design of field surveys in education, the social sciences, criminal justice research, and other areas. It treats methods of eliciting information through household, mail and telephone surveys, methods of assuring privacy, enhancing cooperation rates and related matters. In-depth methods of statistical sampling and sample design are covered. Much of the course is based on contemporary surveys sponsored by the Ghana Statistical Service and other Government agencies. Simple random sampling, stratified sampling, cluster sampling, graphics, regression analysis using complex surveys and methods for handling non-response bias will be discussed.

STAT 704: Scientific Writing and Research in Statistics
Students will be exposed to writing and or reporting scientifically, researches conducted in Statistics. Topics include, conducting research in Statistics, ethics in research, reviewing related literature, writing a proposal for grants etc., Budgeting and time lines construction for a research study, scientific report writing, power point presentation, dissemination of research results etc.

STAT 705: Demographic Models
This course discusses demographic concepts and measures, collection and evaluation of demographic data, analysis of demographic data and the dynamics of population change. Specific topics include: Population structure and population change. The components of population change. Vital events. Rates of incidence and rates of change. Crude and specific rates. Life expectancy. Fertility measures based on Vital Statistics : Computation, uses and limitations of birth rates. Measures based on Censuses and Surveys : Child-woman ratio, number of children ever born. Completed family size. Their justification as measures of Fertility. Parity progression ratios. Reproduction concepts and measures. Mortality Measure based on vital statistics.

STAT 706: Bayesian Methods and Computations
This course provides an in-depth discussion to sophisticated tools for probability modeling and data analysis from the Bayesian perspective. Some topics include: Hierarchical model building techniques, optimization algorithms and Monte Carlo simulation techniques. These techniques allow one to account for risk in quantitative analysis and decision making. The techniques are used by professionals in such widely disparate fields as finance, project management, energy, manufacturing engineering, research and development, insurance, oil and gas transportation and the environment.

STAT 707: Applied Econometrics for Statisticians
This is a graduate course in applied econometrics. The goal is to prepare students for empirical research by studying econometric methodology and its theoretical foundations. Topics include multiple linear regression, the bootstrap, quantile regression, instrumental variables, maximum likelihood and probit regression. Ordinary least squares estimation, the bootstrap and jackknife, instrumental variables, solving systems of equations, M-estimation, maximum likelihood, the generalized method of moments, discrete response models, and time series analysis.

STAT 708: Advanced Topics in Mathematical Statistics
Students will delve into advanced topics in mathematical statistics. Topics include; Modern trends in Decision theory and statistical optimality criteria, sufficiency, mini-max criteria, invariance, estimation and hypothesis testing theory: likelihood ratio test, Neyman-Person Test, large sample theory and information theory would be discussed.

STAT 712: Linear Statistical Models
Students will explore concepts in linear statistical models. Topics include: Theory of the Gaussian Linear Model, with applications to illustrate and complement the theory. Distribution theory of standard tests and estimates in multiple regression and ANOVA models. Model selection and its consequences. Random effects, Bayes, empirical Bayes and mini-max estimation for such models. Generalized (Log-linear) models for specific non-Gaussian settings.

STAT 714: Forecasting and Time Series Analysis
Students are given a grounding of time series models. Topics include: Fourier analysis of data, traditional Time Series models: EWMA, EWR, ARMA. Time series Stationarity, Autocorrelation, ARIMA models, identification, estimation, diagnostic checking and linear prediction. Non-stationarity and differencing. Properties of autoregressive moving average models and estimation of their parameters, spectral analysis, forecasting. Dynamic linear models (DLMs). Bayesian learning, forecasting, and smoothing. Mathematical structure of

DLMs and related models. Intervention. Discussion of applications to problems in economics, engineering, physical science, and life science.

STAT 718 Re-sampling Methods

The course aims at exploring concepts of resampling methods and related computer intensive methods that will enable students to correctly use re-sampling techniques or methods with confidence levels to solve statistical problems in practice. Traditional procedures of statistical inference in many cases are true only asymptotically or under strict assumptions for small samples. For many problems it is impossible to find solutions analytically. Re-sampling techniques are computer intensive methods using repeated re-sampling from the original sample in order to obtain solutions for inferential statistical problems. The theoretical overview of the permutation Methods, Bootstrapping and the Monte Carlo methods are explored in this course.

STAT 700: Thesis

A statistics project is undertaken in either an applied area or theoretical development of statistical methods, after presenting a proposal as specified in STAT 710. The final write-up of the project should be submitted by the end of the fourth academic year of study.

STAT 710: Seminar I

This is the first of four seminars organized in the department. Each student in the Department or Programme is expected to attend all seminars scheduled. Each student is expected to make his/her own presentation on a project proposal. Topics must relate to statistical issues such as insurance, medicine, mortality and mobility, health outcomes, economics, policy, pension, social phenomena, mathematical finance, statistics, and other related fields with particular reference to the advancement of the statistic profession.

STAT 720: Seminar II

This is the second in the sequel of seminar presentations. Each student in the Department or Programme is expected to attend all seminars scheduled. Each student is expected to make his/her own presentation on the experiential research learning progress made on his/her research.

STAT 730: Seminar III

This is the third in the sequel of seminar presentations. Each student in the Department or Programme is expected to attend all seminars scheduled. Each student is expected to make his/her own presentation on the progress made on his/her research.

STAT 740: Seminar IV

This is the fourth and final in the sequel of seminar presentations. Each student in the Department or Programme is expected to attend all seminars scheduled. Each student is expected to make his/her own presentation to discuss the findings of his/her research.