MAKERERE UNIVERSITY

College of Computing and Information Sciences

School of Computing and Informatics Technology

Department of Computer Science

https://cs.mak.ac.ug

Revised Curriculum for the Doctor of Philosophy in Computer Science Programme (PCSC)

Revised: February 2025

Contents

1 Introduction

1.1 Title of the Programme

The title of the programme is Doctor of Philosophy in Computer Science (PCSC).

1.2 Justification for the Programme

Computer science is driving digital transformation in the modern era. Advanced training in Computer Science has potential to propel Uganda and the African continent to harness the full potential of the digital economy. Data and digital innovations are considered the "new oil". They are at the forefront of scientific discovery and the heart of the modern economic growth. Utilizing society's wealth of data requires people who can blend computational research, technology and ingenuity.

The PhD in Computer Science programme is designed to combine Computer Science theory and practice. It provides training in advanced computer science fields and research approaches including artificial intelligence, digital security, programming, research and scholarly practices. The program has a rich and diverse theories that underpin computational science at the advanced level.

Computer science directly contributes to the ICT priority area of the government of Uganda as stipulated in the National Development Plan III and strategies such as the Fourth Industrial revolution strategy. These strategies have emphasized the lack of human capital in the computer science fields.

The programme is also aligned with the United Nations Sustainable Development Goals and Uganda's Vision 2040. One of the core fundamental opportunities of the Uganda's 2040 vision is ICT and business. Therefore it is important to train graduates especially at the advanced level that can be able to support the country and the region in harnessing the potential of ICTs and emerging technologies and their role in strengthening the fundamentals of the Uganda economy. In so doing, the programme is also aligned with the United Nation's Sustainable Development Goals (SDGs).

At the PhD level, the Department of Computer Science aims position itself as a leader in **Digital Security and Artificial Intelligence and Data Science**. In addition, the department wishes to strengthen the foundational and theoretical aspects in Computer Science as a crosscutting knowledge area. These priority areas are aligned with the national and global development plans and thus expected to impact on the industry, in the short, medium and long term. The Department's teaching and research at Masters and Doctoral are aligned to these areas so as to increase the capacity with in the department as well as the impact in industry and academia. A student pursuing an PhD in Computer Science will be required to specialize in one of these tracks. The

choice of the areas of specialization was dictated by the current trends and needs in the Computing field in the region and internationally.

1.2.1 Digital Security

Uganda and the rest of the African continent have witnessed a tremendous increase in the adoption and use of automated computing systems. The region has also seen increase in the usage of the Internet and online IT systems. Computerization increases precision, speed, reliability, availability and reduces cost. Computerization has been applied in sensitive/critical areas like finance (e.g., mobile money and online banking), records keeping, monitoring and tracking. Designing and implementing secure computer systems is an ever increasing challenge worldwide. Unfortunately, most organizations put emphasis on the functionality of the computerized systems but pay less attention on the susceptibility of the systems to malicious attack by intruders. Without proper implementation of security, organizations could suffer from high security risks including financial losses. According to The Center for Strategic and International Studies (CSIS), globally cybercrime leads to $ 1 trillion economic loss per year[1]. In some cases, businesses can be thrown several years back and rendered non-competitive. There is shortage of computer security professionals in Uganda and internationally. The Software and Systems Security track therefore aims at producing computer security experts who will be able to design, develop, implement and manage secure computing systems and networks. The graduates will also be able to critically evaluate threats and vulnerabilities and integrate appropriate security strategies in computing systems and networks.

1.2.2 Artificial Intelligence and Data Science

The proliferation of Artificial Intelligence (AI) and Data Science in the recent years has demonstrated the impact of Computer Science in every sector including health, agriculture, automotive, legal, education, among others. Uganda and other African countries need to actively be involved in the design and development of cutting edge AI-driven solutions and research. The focus of this programme on Artificial Intelligence and Data Science option aims at producing graduates equipped with skills to undertake advanced research in AI, machine learning and data science. There is need for expertise to process, analyse and extract insight from huge amounts of data. The proposed programme draw upon our world-leading expertise in the areas of machine learning, computer vision and image processing, visual analytics, high-performance computing, data mining and information retrieval. Through this programme the Department of Computer Science will continue to demonstrate leadership in training, research and innovations in responsible artificial intelligence research and innovations.

[1] https://www.csis.org/analysis/hidden-costs-cybercrime

1.3 Justification for Review

The PhD Computer Science has been revised so as to:

i focus the research to areas of strategic importance to regional and international trends and needs.

ii expand the depth and breadth in the areas of cyber security, artificial intelligence and data science, and theoretical aspects of computer science. This is an improvement of the previous curriculum that had a focus on computer vision and image processing.

iii include the emerging computer science topics in the area of cyber security and artificial intelligence.

iv be responsive to the University and the National Council for Higher Education (NCHE) requirements for regularly revising curricula.

1.4 Programme Objectives

The PhD in computer Science programme builds upon the Department's Master's Programme in Computer Science to advance the training and production of world class researchers and innovators in the areas of Digital Security, Artificial Intelligence and Data Science.

The objectives of the PhD (Computer Science) are to:

i Build human resource capacity in the area of Computer Science in both the public and private sectors as well as in universities.

ii Develop research capacity in the areas of Computer Science so as to improve research and innovations output in the country and region

iii Address the increasing demand for PhD holders in the areas of computer science

iv Provide masters holders with potential for PhD with opportunities to develop skills in formulating, conducting and presenting their own scholarly research through the production of research-based dissertations and publications.

v Increase the Computer Science knowledge base through scientific publications, innovations and research translation.

1.5 Programme Outcomes

The programme is expected to lead to the following outcomes:

i Enhanced human resource capacity in the area of Computer Science and able to meet capacity needs in Universities, public and private sectors.

ii Improved research and innovations output in the country and region.

iii PhD graduates who have improved capacity in conducting Computer Science research including but not limited to formulating, conducting and presenting their own scholarly research through the production of research-based dissertations and publications.

iv Ugandans and Africans have an increased home-generated Computer Science knowledge base and demonstrating leadership in advanced Computer Science areas of digital security and Artificial Intelligence.

1.6 Employment/Career Prospects

The graduates from the PhD in Computer Science programme are well positioned for high-level roles across different sectors including academia, research, industry, and government. The list below provides some of the possible career opportunities for a graduate of the PhD in Computer Science programme. The list is indicative and not meant to be exhaustive.

i Pioneers and leaders of Computer Science-driven innovation startups

ii CEOs and heads of units of/in technology companies

iii Senior software and machine learning engineers, advisors, and experts

iv Computer Science researchers, lecturers and professors

v Senior research scientists

vi Cyber/Digital security experts and advisors

vii Senior data scientists

viii Senior software engineers

ix Senior ICT project consultants

1.7 The Review Process

The curriculum review process included consultation with various stakeholders at all levels, including students, staff, professionals, field experts, and academic leaders. The curriculum review was spearheaded by the staff of the Department of Computer Science where the programme is hosted. The curriculum review process was as follows:

1.7.1 SWOT analysis of the Old Programme

The Department subjected the old PhD in Computer Science programme to a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis so as to formulate a strategic focus for the PhD training. The SWOT analysis provided an understanding of the existing strengths of the programme and the department and informed the review aimed at harnessing the emerging and current opportunities, improving on the weaknesses in the current programme design and delivery and mitigate any potential threats to the successful PhD in Computer Science training at Makerere University. The old curriculum had four specialization areas including Computer Security, Computer Vision and Image Processing, Study and Optimization of Operating Systems, and Theoretical Foundations of Computing, which was considered a weakness of lack of focus and alignment with the trends. There is an opportunity of the growing global uptake and investment in AI, data science, and cybersecurity solutions. Given the staffing levels of the Department there was a strategic decision to focus the programme on two high priority areas, that is digital security and Artificial Intelligence.

1.7.2 Benchmarking

Through ongoing and previous collaborations with universities around the globe, the Department of Computer Science continuously benchmarks best practices in graduate research, training and administration. During the curriculum review process, staff shared experiences of Doctoral training experienced through collaborations with other institutions. Furthermore, the Department considered the best practices and guidelines of the focus of Computer Science from the international bodies such as the Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE).

1.7.3 Stakeholder Workshop

We conducted a stakeholder validation workshop on July 11, 2023 via Zoom. The stakeholders included representatives of government entities, industry, field experts, graduates of the programme, current students of the programme, and academia. During the workshop, feedback was received on various aspects of the programme including: (i) alignment of the courses to the trends e.g., the growing threat of cybersecurity and large language models, (ii) providing a research direction and focus for the students (iii) review of the admission requirement to focus on Computer science graduates (iv) strengthening the core foundational courses such as algorithm theory and design. The feedback from the stakeholders was incorporated.

1.7.4 Consideration at Various Academic Boards

The reviewed programme was presented and considered at the various University Academic Boards including the Department, School, College, Research and Graduate Training, and University Senate. At each of the boards feedback was received and incorporated.

1.8 Key Changes and Justification

Key changes in the revised curriculum are provided in the Table 1.

S/N	Key change	Justification
1	Revision of the focus areas to Computer Science Theory, Digital Security, and Artificial Intelligence and Data Science	Digital security and AI are priority areas in the industry and research. The areas align with the Department's strength and research.
2	Reviewed content to incorporate new advances in digital security, machine learning and theoretical computer science	To prepare the student to undertake research in the two area while also providing grounding in the foundational computational theory.
3	Introduced new courses units on machine learning theory and methods, natural language processing including large language models, responsible software systems, systems security and privacy, analysis and design of algorithms	To provide skilling and research training in new and emerging areas, for example, large language models that are a foundation for generative AI. Emphasize responsive AI and systems research
4	The number of electives to select from has been consolidated and aligned with related programmes in the School of Computing and IT	Electives have been consolidated to align with the focus areas and the Department's capacity.
5	The model of delivery has been expanded to include use of blending learning approaches combining physical and online lectures	Inline with the University policy on blended learning and research

Table 1: Key changes in the revised PhD Computer Science curriculum and the justification for the changes.

1.9 Comparison of the Old and Revised Curricula

Old curriculum			**Revised curriculum**				
Code	**Name**	**CU**	**Code**	**Name**	**CU**	**Status**	**Remark**
Year I Semester I: Core courses							
PSE 9101	Science of Computer Programming	3	PSE 9101	Science of Computer Programming	4	Modified	Content enriched
PCS 9101	Philosophy of Computing	3	PCS 9101	Philosophy of Computing	4	Modified	Content refined
PIT 9102	Advanced Research Methods	3	PIT 9102	Advanced Research Methods	4	Modified	Content updated
Year I Semester I: Elective courses							
			PCS 9102	Advances in Digital Security	4	Modified	Modified and moved to Year 1
			PCS 9104	Machine Learning Theory and Algorithms	4	New	New course to provide grounding in ML research
Year I Semester II: Core Courses							
PIS 9203	Presentations, Scientific Writing and Research Ethics	3	PIS 9203	Presentations, Scientific Writing and Research Ethics	4	Modified	Content improved
			PCS 9202	Analysis and Design of Algorithms	4	New	New course
Year I Semester II: Elective courses							
PCS 9201	Advances in Digital Security	3					Course moved to Year 1
PCS 9202	Advances in Computer Vision & Image Processing	3	PCS 9202	Advances in Computer Vision & Image Processing	4	Modified	Content improved
PCS 9203	Advanced Applied Queuing Systems	3					Course dropped
PSE 9201	Models of Software Systems	3	PSE 9201	Models of Software Systems	4	Modified	Content improved
			PCS 9207	Natural Language Processing	4	New	New course to cater for emerging areas
			PCS 9208	Systems Security and Privacy	4	New	New content for grounding in security research
			PCS 9206	Responsible software systems	4	New	New course to cater for emerging area
	TOTAL	**18**			**32**		

Table 2: Side-by-side comparison of the old and new curricula.

1.10 Key Knowledge Areas

The revised PhD in Computer Science programme covers the following key knowledge areas:

KA1: Theoretical Foundations of Computing: Computer Science Theory, Programming languages.

KA2: AI, Machine learning and data Science

KA3: Digital and software systems security

KA4: Research methods and scholarly knowledge

The table 3 shows the course distribution by the key knowledge areas.

Knowledge area (KA)							
KA1		**KA2**		**KA3**		**KA4**	
Code	**CU**	**Code**	**CU**	**Code**	**CU**	**Code**	**CU**
Year I Semester I							
PCS 9101	4	PCS 9104	4	PCS 9102	4	PIT 9102	4
PSE 9101	4						
Year I Semester II							
PCS 9202	4			PCS 9208	4	PIS 9203	4
PCS 9201	4	PCS 9209	4				
		PCS 9207	4	PCS 9206	4		
		PCS 9206	4				
Year II Semester I							
						PCS 9301	5
Year II Semester II							
						PCS 9401	3
Year III Semester I							
						PCS 9501	2
Year III Semester II							
						PCS 9601	3
Year IV Semester I							
						PCS 9701	3
Year IV Semester II							
		PCS 9801	12	PCS 9801	12		
TOTAL	**16**		**28**		**24**		**24**

Table 3: Course distribution by the key knowledge areas.

2 Conduct of the Programme

2.1 Nature of Programme

The PhD in Computer Science programme is a full-time day programme.

2.2 Target Group

The program targets holders of a Masters in Computer Science and related fields interested in pursuing advanced graduate study in Computer Science. The PhD in Computer Science programme targets those with interest in industry, research and academia career prospects at senior levels.

2.3 Programme Duration

The program duration is four academic years including eight semesters.

2.4 Designation of the Award

Upon Successful completion of the programme, a candidate will be awarded the Degree of Philosophy in Computer Science of Makerere University.

2.5 Tuition Fees

Tuition fees for privately sponsored students shall be **UGX 7,000,000** (Seven million Uganda Shillings) per academic year for East African students and **UGX 10,000,000** (Ten million Uganda Shillings) per academic year for international students. In addition, students shall pay functional fees as determined by the University Council from time-to-time.

3 Programme Regulations

3.1 Admission Requirements

To qualify for admission on the program, the candidate must fulfill the general Makerere University entry requirements for admission to a PhD Degree, and in addition, the candidate should have:

i Master's degree in Computer Science or a closely related field, with a CGPA of at least 3.0 or equivalent from a recognised chartered university. **Candidates from a closely related field should have completed courses, a research thesis and acquired advanced knowledge at master's level in computer programming, machine learning, cryptology, security, and mathematics.**

3.2 Course Categorization

Inline with the University regulations, courses under this programme are categorised as Core, Elective, or Audited.

3.2.1 Core Course

This is a course which is essential to and mandatory the PhD in Computer Science programme. A core course is compulsory for all students who have registered for the programme and must be passed.

3.2.2 Elective Course

This is a course offered in order to broaden a student's knowledge or to allow for specialization. It is chosen from a given group of courses. The minimum number of elective courses must be passed. However, another elective course may be substituted for a failed elective course and must be passed.

3.2.3 Audited

This is a course taken by a student for which a credit/credit unit is not awarded. This course enables the student to follow or understand another subject/course. Audited courses may be recommended by supervisors and the department for students with prerequisite knowledge gaps in certain areas. Such courses may be selected from existing programmes at Master's or PhD level.

3.2.4 Pre-requisite

Core courses and electives of the programme require previous knowledge, skills. Therefore, depending on the background, a student may be required to take remedial courses, which shall be specified by the Department and supervisor.

3.3 Progression

Progression shall be regarded as normal, probationary or discontinuation as per the standard Makerere University Senate guidelines:

3.3.1 Normal Progress

This occurs when a student passes each course unit taken with a minimum Grade Point (GP) of 3.0.

3.3.2 Probationary

This is a warning stage and occurs if either the Cumulative Grade Point Average (CGPA) is less than 3.0 and/or the student has failed a core course unit. Probation is waved when these conditions cease to hold.

3.3.3 Discontinuation

A student shall be discontinued from the programme if

i He/she fails to get a grade point of at least 3.0 from any course unit for three consecutive sittings.

ii Overstays on the programme beyond the maximum programme duration stipulated by the University policies.

3.3.4 Retaking a Course Unit

A student will retake all courses where he/she has a grade point less than 3.0.

i A student shall retake a course unit when next offered in order to obtain at least the pass mark (60%) if s/he had failed the course unit during the first attempt. A student may take a substitute elective course unit where s/he does not wish to retake a failed elective course unit.

ii A student who has failed to obtain at least the pass mark of 60% after the second attempt of the same course unit s/he has retaken shall receive a warning.

iii Where students miss to sit examinations for justified reasons; they should not be recorded as those who retake when they sit the examinations when next offered.

iv A student shall not be allowed to accumulate more than five (5) retake course units at a time. Students are required to register for retake course units first before registering for course units the will be attempting for the first time in that semester and the retake course units should fit into the approved normal load so as to avoid timetable clashes.

v Students who have a course unit or course units to retake and where the total credit load for this course unit or course units is more than the set normal semester load for their programme will be required to pay additional tuition for the retake course unit(s). Such students will also be required to pay the re-examination fees per retake course unit and the registration fees for that semester.

3.4 Certificate of Due Performance

i A student who fails to submit their assignment on the given deadline without justifiable causes(s) shall receive a score of zero.

ii A student who does not have coursework marks shall be denied Certificate of Due Performance and will not be allowed to sit the University Examinations.

iii Other Makerere University Graduate guidelines concerning certificate of due performance shall apply.

3.5 Approval of Examination Results

Approval of all examination results should be done during the School's Higher Degrees and Research committee meeting, then forwarded to College Academic Board, and then to Senate. Submission of results to the Senate should be accompanied with Appropriate Pass Lists and College Board Minutes. Students shall be provided with examination results using the approved testimonial format.

3.6 Appeals

Any student or candidate aggrieved by a decision of the Board of the College/ School may appeal to the Senate Examinations for reversal or moderation of the decision of the Board.

3.7 Course Assessment

The General Regulations and Statutes of Makerere University shall govern examinations for the programme. Assessment will be in form of writing technical reports, reviewing literature, critiquing papers or any other approach a student can use to demonstrate in-depth understanding and synthesis of academic matter. The approach used will depend on the course unit being studied. Specific course assessment are defined per course in this programme.

3.8 Grading of Courses

Each course unit shall be graded out of 100% and assigned appropriate letter grade and grade points (GP) as shown in Table 4. The pass mark in each course is 60%. The marks obtained out of 100 are assigned an appropriate letter grade and grade point average. The Cumulative Grade Point Average (CGPA) and Grading of the award will be as follows: Grade points will be allocated to the final mark got in every course unit according to the table below:

Marks	**Letter Grade**	**Grade Point (GP)**	**Interpretation**
90 - 100	A+	5	Exceptional
80 - 89	A	5	Excellent
75 - 79	B+	4.5	Very good
70 - 74	B	4	Good
65 - 69	C+	3.5	Fairly good
60 - 64	C	3	Pass
55 - 59	D+	2.5	Marginal fail
50 - 54	D	2	Clear fail
45 - 49	E	1.5	Bad fail
40 - 45	E-	1	Qualified fail
Below 45	F	0	Qualified fail

Table 4: Marks and Grade points

The following additional letters will be used, where appropriate:
W - Withdraw from Course;
I - Incomplete;
AU - Audited course only;
P - Pass;
F - Failure.

3.9 Calculation of Cumulative Grade Point Average (CGPA)

The CGPA shall be calculated as follows:

$$CGPA = \frac{\sum_{i=1}^{n} GP_i \times CU_i}{\sum_{i=1}^{n} CU_i}$$

Where GP_i is the Grade Point score of a particular course unit i; CU_i is the number of Credit Units of course unit i; and n is the number of course units done so far.

3.10 Classification of the Award

In accordance with the standing guidelines and regulations of the Makerere University on Higher Degrees, the PhD degree in Computer Science is not classified.

3.11 Semester Load

The normal load for Year one (i.e., the course work year) is 16 credit units per semester. The maximum semester load shall be 28 Credit Units to cater for students who have courses to retake.

3.12 Academic Programme Load

Duration		**No. of core courses**	**No. of electives**	**Remark**	**Total CUs**
Year I	Semester I	3	1	3 core 1 elective	16
	Semester II	2	2	2 core 2 elective	16
Year II	Semester I	1	0	1 core	5
	Semester II	1	0	1 core	3
Year III	Semester I	1	0	1 core	2
	Semester II	1	0	1 core	3
Year IV	Semester I	1	0	1 core	3
	Semester II	1	0	1 core	12
TOTAL		**11**	**3**		**60**

Table 5: Academic programme load

3.13 Minimum Graduation Load

To qualify for the award of the degree of Doctor of Philosophy in Computer Science, a candidate is required to obtain a minimum of 60 credit units.

3.14 Course Weighting System

The weighting unit is the Credit Unit (CU). The Credit Unit is a series of 15 contact hours (CH) in a semester. A contact hour is equal to (i) one lecture hour (LH), (ii) two practical hours (PH) or (iii) two tutorial hours (TH).

4 Programme Structure

The details of the course structure are shown below: where LH, TH, PH, CH and CU stand for Lecture Hours, Tutorial Hours, Practical Hours, Contact Hours and Credit Units respectively.

Year I, Semester I

Code	**Course Name**	**LH**	**PH**	**CH**	**CU**	Remark
PCS 9101	Philosophy of Computing	30	60	60	4	Modified
PSE 9101	Science of Programming	30	60	60	4	Modified
PIT 9102	Advanced Research Methods	30	60	60	4	Old
Electives (Select 1)						
PCS 9102	Advances in Digital Security	30	60	60	4	Modified
PCS 9104	Machine Learning Theory and Algorithms	30	60	60	4	New
TOTAL					16	

Year I, Semester II

Code	**Course Name**	**LH**	**PH**	**CH**	**CU**	Remark
PIS 9203	Presentations, Scientific Writing and Research Ethics	30	60	60	4	Modified
PCS 9202	Analysis and Design of Algorithms	30	60	60	4	New
Electives (Select 2)						
PCS 9209	Advances in Computer Vision and Image Processing	30	60	60	4	Modified
PCS 9207	Natural Language Processing	45	30	60	4	New
PSE 9201	Models of Software Systems	30	60	60	4	Modified
PCS 9208	Systems Security and Privacy	30	60	60	4	New
PCS 9206	Responsible software systems	30	60	60	4	New
TOTAL					16	

Year II Semester I

Code	Course Name	LH	PH	CH	CU	Remark
PCS 9301	Thesis Proposal	-	150	75	5	New
TOTAL					**5**	

Years II Semester II

Code	Course Name	LH	PH	CH	CU	Remark
PCS 9401	Research Seminar I	-	90	45	3	New
TOTAL					**3**	

Years III Semester I

Code	Course Name	LH	PH	CH	CU	Remark
PCS 9501	Scientific Presentation at a Conference	-	60	30	2	New
TOTAL					**2**	

Years III Semester II

Code	Course Name	LH	PH	CH	CU	Remark
PCS 9601	Scientific Paper Manuscript	-	90	45	3	New
TOTAL					**3**	

Years IV Semester I

Code	Course Name	LH	PH	CH	CU	Remark
PCS 9701	Research Seminar II	-	90	45	3	New
TOTAL					**3**	

Years IV Semester II

Code	Course Name	LH	PH	CH	CU	Remark
PCS 9801	PhD Thesis	-	360	180	12	New
TOTAL					**12**	

Key:

1. Modified: This remark means that the course unit has been revised by content.
2. New: Means the course unit has been freshly introduced in the department
3. Old: Means no change on the course unit's name, code and content.

5 Detailed Content Per Course Unit

5.1 Year I Semester I

5.1.1 PCS 9101: Philosophy of Computing

Course Code:	PCS 9101
Course Name:	Philosophy of Computing
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
This course explores the philosophical foundations of the computing field. It explores the computational understanding of the major parameters that make up and support the computing field. It explores their foundations and philosophical underpinnings. The course covers philosophy of machine intelligence and mind, models for real and virtual worlds, representation of language and knowledge, philosophy of computer languages, and logic and probability theories. The course will focus on supporting students to develop analytical, critical and logical rigour required for structured scientific inquiry in advanced Computing research areas.

(b) Course Objectives
The aims of the course are:

1 To give students an avenue of exploring the philosophical foundations of computing as an academic field

2 To give students the historical foundation of computational thinking and interpretation

3 To expose students to the philosophical thinkings of the different areas of computing

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Explain the philosophical foundations of computing

2 describe and demonstrate understanding of the foundations of theoretical thinking and interpretations

3 Apply and the demonstrate the understanding of the philosophical thinkings of the different fields of computing

(e) Detailed Course Content

1 Mind and Artificial Intelligence (AI) **(15 Hours)**: The philosophy of artificial intelligence and its critique, computationalism, connectionism and the philosophy of mind.

2 Real and virtual worlds **(15 Hours)**: Ontology, virtual reality, the physics of information, physics as a traditional model of the ideal science of the philosophy of science, cybernetics and artificial life.

3 Language and knowledge **(15 Hours)**: Information and content, knowledge, the philosophy of computer languages, hypertext.

4 Logic and probability **(15 Hours)**: probability in artificial intelligence, game theory – Nash equilibrium.

(f) Study Materials
The materials shall include textbooks, journal/conference papers, cloud platforms, and several digital resources.

(d) Mode of Study
Teaching will be by lectures, group work, group discussions and presentations in blended mode.

(g) Mode of Assessment
Assessment will be by take-home assignments and presentations (40%). Students will be given tasks to read and write about then present in class. The lecturer will award marks for the final scientific review paper (60%).

(h) Reading List

[1] Angius, Nicola, Giuseppe Primiero, and Raymond Turner The philosophy of computer science Metaphysics Research Lab, Stanford University, 2021

[2] William J. Rapaport Philosophy of computer science University at Buffalo, 2020.

[3] Floridi, Luciano. Philosophy and Computing: An Introduction. Routledge: London / New York, 1999

[4] Bynum, Terrel Ward; Moor, James H.. The Digital Phoenix: How Computers are Changing Philosophy Blackwell Publishers: Oxford, UK, 2000.

[5] Colburn, Timothy R.. Philosophy and Computer Science M.E. Sharpe: Armonk, NY, USA, 2000.

5.0.1 PSE 9101: Science of Programming

Course Code:	PSE 9101
Course Name:	Science of Programming
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
This course introduces foundational concepts and techniques of programming languages. We use typed $\lambda-$calculi and operational semantics as models of programming language concepts. These models are applicable to the design, analysis, and implementation of programming languages. The course demonstrates the utility of a mathematical approach to programming languages in answering questions about program correctness, the pro's and con's of various languages, compiler correctness, and other practical issues. The focus is on two of the most successful styles of semantic description: denotational and operational. The course deals with small "core" languages, each chosen to illustrate a specific paradigm. The course demonstrates the use semantics to prove properties of a language, to analyze programs, to design correct programs, to prove correctness of compiler optimizations, and to prove general laws of program equivalence.

(b) Course Objectives
The aims of the course are:

1 To study formal techniques for describing computation and compilation.

2 Provide a more general understanding of programming languages, specification, logic, mathematics, and proof theory.

3 Apply formal reasoning to nondeterministic programs and to concurrent programs, and provide an introduction to reasoning about distributed systems (temporal logic).

(c) Learning Outcomes
At the end of the course students will be able to:

1 describe and relate different programming paradigms and the mathematical models on which they build;

2 demonstrate understanding of techniques for describing computation and compilation processes

3 select appropriate methodology to use in the final research work and dissertation.

4 apply formal reasoning to nondeterministic programs

(e) Detailed Course Content

1 Inductive definitions, types and abstractions **(20 Hours)**. Inductive sets of data, data abstraction, expressions, state, continuation passing interpreters, types, modules, objects, classes and sub-typing.

2 Type inference and unification denotational and operational, referential transparency, criteria for choosing models **(8 Hours)**.

3 Sequential imperative programs **(8 Hours)**: state transformations, partial and total correctness, traces and runtime.

4 Machine language **(8 Hours)**: jumps and continuations, tail forms, compiling sequential programs, correctness of compiler optimizations.

5 Parallel programming **(8 Hours)**: data ow networks, shared-memory parallelism, communicating processes, safety and liveness, fair execution .

6 Functional programs **(8 Hours)**: types and polymorphism, call-by-value, direct- and continuation-style semantics .

(f) Study Materials
The materials shall include textbooks, journal/conference papers, cloud platforms, and several digital resources.

(d) Mode of Study
Classes are held as a group discussion. Reading material which includes journal papers is distributed a week in advance, and students take it in turns to research and present new topics. The lecturer addresses questions to the students to encourage them to think about and understand the material. The lecturer should become aware of the students' proposed topics of research so that the discussion explores how the principles in the course apply to these topics. The students make presentations of their review paper for critique from both the students and the lecturer. The mode of delivery will be blended.

(g) Mode of Assessment
Progressive assessment will be based on the quality of presentations in class by each student (40%). The final assessment will be based on a scientific review paper (60%).

(h) Reading List

[1] Daniel P. Friedman, Mitchell Wand, Christopher T. Haynes. *Essentials of Programming Languages* 2008: MIT Press.

[2] John C. Reynolds. Theories of Programming Languages Cambridge University

Press, 1999

[3] JGlynn Winskel. The Formal Semantics of Programming Languages MIT Press, 1993.

[4] Abelson, Harold, Gerald Jay Sussman, and Julie Sussman. *Structure and Interpretation of Computer Programs* 1996: MIT Press. Available: `https://mitpress.mit.edu/books/structure-and-interpretation-computer-programs`

5.0.1 PIT 9102: Advanced Research Methods (4 CUs)

Course Code:	PIT 9102
Course Name:	Advanced Research Methods
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
TThis course will provide in-depth understanding of research through exploration of different research methods, methodologies, theories, research concepts and ethics. It will involve developing the students' ability to critically evaluate and review research articles in computing. It will also include qualitative and quantitative research, descriptive and other applicable research methodologies. The structure of the course aims to achieve a balance between theory and practice i.e., it acts as a critical and practical research forum where discussions and preparations for the PhD dissertation take place.

(b) Course Objectives
At the end of this course, the students will have been empowered to:

1 Report and structure a research problem within the computing field of concentration, to generate appropriate research questions

2 Critique scholarly articles in the computing field; conduct a comparative critical analysis of scholarship in their field; formulate a scientifically sound hypothesis and offer support for it through empirical evidence.

3 Apply computing and IT-related research methods in their research.

4 Communicate the results of their peer review; engage with research methods intelligently and with confidence.

(c) Learning Outcomes

A student who passes this course is expected to be able to:

a) Identify a research problem within your field of concentration, to generate appropriate research questions.

b) Critique scholarly articles in your field; conduct a comparative critical analysis of scholarship in their field; formulate a scientifically sound hypothesis and offer support for it through empirical evidence.

c) Understand and apply computing and IT research methods in their research.

d) Communicate the results of their peer review; engage with research methods intelligently and with confidence.

(e) Detailed Course Content
The course covers the following topics:

1 Introduction to Research: Definitions; Relevance; and Significance: Module One **(4 hours)**

Types of research (applied, basic, evaluation (summative and formative), action etc.) Introduction to research theories Introduction to theoretical and conceptual framework

2 Research Philosophy (e.g., Ontology, Epistemology, Methodology, Axiology) Module Two **(8 hours)**

Research Paradigms (e.g., Empricism, Positivism, Interpretivism, constructism etc.)

3 Problem Identification (gap analysis) e.g., using a problem tree, Module Three **(8 Hours)**.

Identifying research objectives and research questions Critiquing literature (Types of review i.e., systematic review, scoping review, integrative review, realistic review, narrative review etc.)

4 Research Designs /Types: Module Four **(8 hours)** Essentials; classifications (Basic Vs Applied; Descriptive Vs Analytical; Quantitative Vs Qualitative; Conceptual Vs Empirical; Exploratory Vs Explanatory Vs Causal; Laboratory/Experimental, Clinical/Historical); elements of a research plan; research process.

5 Research Methodologies, Research Methods, data collection tools and techniques Module Five **(12 hours)**

6 Scientific writing Module Five **(12 hours)**

Abstract, aim, literature reviews; Selection of overall methodological approach;

Selection of suitable data collection and analysis techniques; Interpretation and conclusion of the research; and Presentation of research findings. Presenting research discussion and conclusion sections

7 Sources of data and data collection methods Module Five **(8 hours)**

operationalization of concepts, constructs, study variables, design of data collection tools, data collection technique. Data management: data coding, data entry, data cleaning, quality control and assurance, retrieval; cleaning; analysis. Research Ethics/ Plagiarism. Referencing styles

(d) Mode of Study
Seminars/Tutorials, Directed Learning and Independent Learning, Blended learning lectures, Team/group work, Presentations

(g) Mode of Assessment
Progressive assessment shall be used which will include participation in class, presentations, and scientific review paper writing. Final assessment will be based on one group research paper including a presentation plus one individual research paper. The class attendance, presentations and scientific review of papers shall constitute (40%) and the individual research paper is (60%)

(h) Reading List

[1] Azari, R., Rashed-Ali, H. Research methods in building science and technology. Springer 2021.

[2] Badache, F., Kimber, L. R., Maertens, L. (Eds.). (2023). International Organizations and Research Methods: An Introduction. University of Michigan Press.

[3] Bhangu, S., Provost, F., Caduff, C. (2023). Introduction to qualitative research methods–Part I. Perspectives in Clinical Research

[4] Creswell, J. W. (2021). A concise introduction to mixed methods research. SAGE publications. Sage Publishers

[5] Creswell, J. W., Poth, C. N. (2016). Qualitative inquiry and research design: Choosing among five approaches. Sage publications.

[6] Cropley, A. (2019). Introduction to qualitative research methods. A research handbook for patient and public involvement researchers.

[7] Harrison, L. (2020). Quantitative designs and statistical analysis. In Doing Early Childhood Research (pp. 127-154). Routledge.

5.0.1 PCS 9102: Advances in Digital Security

Course Code:	PCS 9102
Course Name:	Advances in Digital Security
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
The course delves into the intricate landscape of digital security, exploring advanced concepts, techniques, and methodologies essential for safeguarding digital assets in contemporary cyber environments. With the proliferation of digital technologies and the increasing sophistication of cyber threats, this course equips students with a comprehensive understanding of the latest advancements in digital security. This course aids students to explore in depth selected areas in digital security. It helps them get the general knowledge as well as getting an in-depth knowledge of the current state of practice and potential challenges. It also guides them in making in depth reading so as to be able to critique recent research works as well as identify some existing research gaps.

(b) Course Objectives
The objectives of this course are to:

1 Equip students with the general state and potential challenges in security of computer systems.

2 Assist students explore the state of the art in selected aspects and emerging trends in digital security.

3 Assist students make deep analysis of the current literature in digital security and identify research gaps.

(c) Learning Outcomes
At the end of this course, students should be able to:

1 Comprehensively elaborate the typical security challenges in the digital world today including software development, network communications, machine learning, and embedded systems.

2 Explain ways of attack and techniques of defense on software, hardware, and data at rest and in transit.

3 Have an in-depth understanding of the current research trends and emerging technologies in the areas of digital security.

4 Comprehend and critique state of the art research findings in digital security

and privacy.

(e) Detailed Course Content

1 Module 1: Secure Software Development **(6 hours)** Secure coding practices; Static and dynamic code analysis; Secure software development lifecycle (SDLC); DevSecOps and continuous security integration

2 Module 2: Network Security **(6 hours)** Advanced intrusion detection and prevention systems; Secure routing protocols; Software-defined networking (SDN) security; Threat intelligence and information sharing

3 Module 3: Blockchain Security **(6 hours)** Consensus mechanisms and their security implications; Smart contract security vulnerabilities and auditing; Privacy-enhancing techniques in blockchain networks; Scalability and performance considerations in blockchain security

4 Module 4: Machine Learning in Digital Security **(12 hours)** Threat modeling and intelligence gathering; Machine learning and AI for threat detection, Malware Analysis; Security analytics and visualization; Incident response and digital forensics

5 Module 5: Internet of Things (IoT) Security **(10 hours)** Secure device authentication and access control, IoT communication protocols security, Firmware security and over-the-air (OTA) updates; Edge computing security; lightweight cryptography for IoT

6 Module 6: Cloud Security **(6 hours)** Virtualization security; Secure multi-tenancy; Data privacy and compliance in cloud environments; Cloud-native security solutions

7 Module 7: Cryptography Advancements **(6 hours)** Advanced cryptographic algorithms and protocols, homomorphic encryption, runtime encryption; Post-quantum cryptography; Cryptographic key management and distribution; Cryptanalysis techniques

8 Module 8: Emerging Technologies and Trends **(8 hours)** Quantum computing and its implications for digital security; Artificial intelligence and machine learning in cybersecurity; Biometric authentication and its challenges; Privacy-enhancing technologies (PETs)

(f) Study Materials
This class covers a great deal of information about security technologies and so no single textbook can cover it all. The materials shall include textbooks, journal/conference papers, and several freely available online resources.

(d) Mode of Study
The lecturer will chose an area and subject matter to be focused on over a period of time and ask students to do the reading. The lecturer will provide the main reading materials (like journal papers, books, technical reports). The students will do the reading; write their findings (like critique, technical report, etc). The students will make the write up and presentations in class.

The teaching will be highly student centered. It will involve teaching, online/class room discussions, demonstrations, group/individual projects and self guided research. A student will be expected to do self paced research in each of the modules.

(g) Mode of Assessment
Assessment will be by evaluating the students write ups and presentations. For each write up and presentations, the lecturer will award marks depending on the extent to which the objectives of the assignment has been met. The lecturer will also award marks on the extent to which the student demonstrates his/her mastery of the subject matter during presentations and final write up of a scientific review paper. Assessment shall be based on a test 10%, Case study 1 15%, Case study 2 15%, a term paper 20% and Final Exam 40%.

(h) Reading List
Reading materials will largely be got from the publications in journals and conferences of digital security. These include: IEEE Security and Privacy, Elsevier Computers and Privacy, Springer Lecture Notes in Computer Science, Computers & Security, and Journal of Cryptography among others.

[1] Simon Singh. The Code Book: The Science of Secrecy from Ancient Egypt to Quantum Cryptography The Code Book, 2000

[2] John R. Vacca. Cloud Computing Security: Foundations and Challenges. 2nd Edition CRC Press. ISBN 036756033X. 2021

[3] Souvik Pal, Vicente García Díaz, Dac-Nhuong Le IoT Security and Privacy Paradigm CRC Press. ISBN 9780367253844. 2020

[4] R. Bernardini Cryptography - Recent Advances and Future Developments. IntechOpen, 2021. doi: 10.5772/intechopen.87684.

5.0.1 PCS 9204: Machine Learning Theory and Algorithms

Course Code:	PCS 9104
Course Name:	Machine Learning Theory and Methods
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
This course will cover advanced theory and methods of machine learning relevant for the PhD research in this area. The goal of the course is to increase the understanding of the algorithms, mathematics and statistics techniques that underpin machine learning. The course will bring students to the frontiers of research in machine learning and to prepare students to undertake independent research and publish in this area.

(b) Course Objectives
The aims of the course are:

1 To present and contrast the statistical, computational and game-theoretic models for learning.

2 To present and rigorously analyze some of the most successful algorithms in machine learning that are extensively used today.

(c) Learning Outcomes
At the end of the course students will be able to:

1 To discuss and contrast the statistical, computational and game-theoretic models for learning.

2 To successful understand and analyse the extensively used machine learning algorithms.

(e) Detailed Course Content

1 Foundations of machine learning models **(16 Hours)**: Formal learning model, learning voa Uniform convergence, bias complexity trade off, VC-dimension, run time of learning.

2 Theory of ML Algorithms **(16 Hours)**: linear predictors, boosting, model selection and validation, convex learning problems, regularization and stability, stochastic gradient descent,support vector machines, Kernel methods, multiclass, ranking, and complex prediction problems, decision trees, nearest neighbor, neural networks.

3 Further learning models **(16 Hours)**: online learning, clustering, dimensionality reduction, generative models, feature selection and generation.

4 Advanced Theory **(16 Hours)**: rademancher complexities, covering numbers, proof of fundamental theorem of learning theory, multi class learnability, compression bounds, and PAC-Bayes.

(f) Study Materials
Students in this course will read and present research papers and textbook chapters on topics covered in this course. Readings will be assigned from notes, books, and online research papers.

(d) Mode of Study
Classes are held as a group discussions. Reading material which includes journal papers is distributed a week in advance, and students take it in turns to research and present new topics. The lecturer addresses questions to the students to encourage them to think about and understand the material. The lecturer should become aware of the students' proposed topics of research so that the discussion explores how the principles in the course apply to these topics. The students make presentations of their review paper for critique from both the students and the lecturer. The mode of delivery will be blended.

(g) Mode of Assessment
Progressive assessment will be based on the quality of presentations in class by each student (40%). The final assessment will be based on a scientific review paper (60%).

(h) Reading List

[1] Shalev-Shwartz, S., & Ben-David, S. Understanding machine learning: From theory to algorithms. Cambridge university press, 2014.

[2] Mohri, M., Rostamizadeh, A., & Talwalkar, A. Foundations of Machine Learning MIT Press, 2016

[3] Arora, S., Hazan, E., & Kale, S.. The multiplicative weights update method: a meta-algorithm and applications. Theory of computing, 8(1), 121-164, 2012

[4] Kearns, M. J., & Vazirani, U. An introduction to computational learning theory. MIT press, 1994

[5] Schapire, R. E., & Freund, Y. Boosting: Foundations and algorithms. Kybernetes, 2013

5.1 Year I Semester II

5.1.1 PSE 9201: Models of Software Systems

Course Code:	PSE 9201
Course Name:	Models of Software Systems
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	2

(a) Course Description
Scientific foundations for software engineering depend on the use of precise, abstract models for characterizing and reasoning about properties of software systems. This course considers many of the standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of software systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as composition mechanisms, abstraction relations, invariants, non-determinism, inductive definitions and denotational descriptions are recurrent themes throughout the course.

(b) Course Objectives
The aims of the course are to:

1 introduce various models and logics, including state machines, algebraic and trace models, and temporal logics.

2 describe and illustrate abstract formal models for certain classes of systems. to reason formally about the elementary properties of modeled systems.

3 provide an in depth understanding of various modeling techniques including state machines, Z, concurrency, Petri Nets and Unified Modelling Language (UML).

(c) Learning Outcomes
At the end of the course students will be able to:

1 understand the strengths and weaknesses of certain models and logics, including state machines, algebraic and trace models, and temporal logics.

2 to select and describe abstract formal models for certain classes of systems. to reason formally about the elementary properties of modeled systems

3 describe and relate different models of software systems; select and apply appropriate methodology to use in the final research work and dissertation.

(e) Detailed Course Content

1 Introduction and Foundations **(15 Hours)**: Introduction to modelling, Logic, Proof Techniques, Sets, Relations, Functions, Sequences and Induction.

2 State Machines (**10 Hours)**: State Machines, Variations, FSP, and LTSA, Reasoning about State Machines.

3 Z Techniques (**10 Hours)**: Introduction to Z, Z techniques, applications of and examples in Z, Refinements and Abstraction

4 Concurrency **(15 Hours)**: Introduction to Concurrency, Concurency Modelling Techniques, Reasoning about Concurrency, LTL and LTL in FSP.

5 Petri Nets and Unified Modelling Language (UML) **(10 Hours)**. Introduction to Petri Nets, Reasoning about Petri Nets, UML

(f) Study Materials
The materials shall include textbooks, journal/conference papers, cloud platforms, and several digital resources.

(d) Mode of Study
Classes are held as a group discussion. Reading material which includes journal papers is distributed a week in advance, and students take it in turns to research and present new topics. The lecturer addresses questions to the students to encourage them to think about and understand the material. The lecturer should become aware of the students' proposed topics of research so that the discussion explores how the principles in the course apply to these topics. The students make presentations of their review paper for critique from both the students and the lecturer.

(g) Mode of Assessment
Assessment will be by take-home assignments leading to presentations (40%) and a scientific review paper (60%). Students will be given tasks to read and write about then present in class. The lecturer will award marks for each write up of a scientific review paper.

(h) Reading List

[1] V. Gehlot A Tutorial Introduction to Colored Petri Nets Framework for Model-Driven System Design and Engineering. IEEE, 2021

[2] K. Jensen Coloured Petri Nets: A High Level Language for System Design and Analysis In High-level Petri Nets: Theory and Application. K. Jensen and G. Rozenberg (eds.) Springer-Verlag, 1991

[3] J. L. Peterson Software Engineering Mathematics. ACM Computing Surveys,

Sept 1977

[4] UML Walkthrough. J. Rumbaugh, I. Jacobson, and G. Booch In The Unified Modeling Language Reference Manual. Addison Wesley, 1999

[5] J. M. Spivey An Introduction to Z and Formal Specification SW Eng Journal, 1989.

[6] J. Woodcock and J. Davies Using Z: Specification, Refinement, and Proof. Prentice Hall, January 1, 1996.

5.0.1 PIS 9203: Presentations, Scientific Writing and Research Ethics (4 CUs)

Course Code:	PIS 9203
Course Name:	Presentations, Scientific Writing and Research Ethics
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
The course is intended to help students understand the principles of scientific writing, different scientific papers, the process of writing and publishing research papers, how to critique research papers and the practical writing skills. Given the amount of time that PhD students spend writing and preparing to present, students should invest in a systematic study of scientific writing and presentations. Additionally, ethics in research will be discussed. It is intended for PhD students in the fields of computing and Information technology, engineering and natural sciences.

(b) Course Objectives
At the end of this course, the students will have been empowered to:

1 Explain the correlation between the research aim, research methodology and research results and conclusion

2 Describe and plan clinical research including the choice of research methods

3 Perform analysis and describe research results verbally and graphically

4 Write a research proposal and subsequently a quality journal article

5 Appreciate ethics-related issues when writing a scholarly/scientific paper

6 Understand the prerequisites for choosing the market for publishing

(c) Learning Outcomes

By the end of this course, students should have:

1 Describe the importance of scientific writing,

2 Apply the knowledge to write scientific papers, and

3 Describe the prerequisites for publishing in first-class scientific journals.

(e) Detailed Course Content
The course covers the following topics:

1. Science and writing Module One **(15 hours)**

   Science and writing. Reports and scientific publications. The IMRAD format. Scientific journals. Why, what, when, with whom and where publish?

2. Structure of a scientific paper Module Two **(15 hours)**

   Structure of a scientific paper. The different parts of a scientific paper. Language and style. The publication process. Writing a paper. Dealing with editors, reviewers, and publishers.

3. Critical review of scientific papers Module Three **(15 hours)**

   Critical review of scientific papers by groups of participants. General principles of expository writing, pre-writing, and planning. Typical formats, structure and language for scientific writing, emphasis on scientific articles as published in (primary) international scientific journals. English grammar essential to scientific papers. Designing tables, figures, and graphs for scientific papers. Good style for readability. The refereeing and publishing process, what referees are looking for, how to deal with editors. Paragraphing, linking paragraphs to make the logic clear. Writing informative abstracts and crafting clear titles.

4. Ethics: Honesty and credibility in scientific writing Module Four **(15 hours)**

   Ethics: Honesty and credibility in scientific writing. Ethical issues in health-related research, the Helsinki Declaration, Belmont Document, Ethical regulations, Informed consent, Ethical Committee and Child Research.

(d) Mode of Study
Classes are held as a group discussion. Reading material which includes books and journal papers on scientific writing and ethics are distributed a week in advance, and students take it in turns to research and present. The students are also given reading material on how to make excellent presentations. The lecturer addresses questions to the students to encourage them to think about and understand the material. The classes will also include viewing of recorded seminar presentations by leading academics in the field.

(g) Mode of Assessment
Progressive assessment will be based on the quality of presentations in class by each student. The final assessment will be based on a scientific review paper. The class presentations will constitute 40/100 and the final assessment based on a scientific review paper 60/100

(h) Reading List

[1] Robert A. Day and Barbara Gastel How to Write and Publish a Scientific Paper 9th Edition 2020

[2] Wendy Laura Belcher Writing Your Journal Article in Twelve Weeks: A Guide to Academic Publishing Success 2nd Edition, 2019

[3] Loue Sana. Textbook of Research Ethics: Theory and Practice, 2024

[4] Hilary Glasman-deal. Science Research Writing: For Native And Non-native Speakers Of English, 2nd Edition, 2020

5.0.1 PCS 9207: Natural Language Processing

Course Code:	PCS 9207
Course Name:	Natural Language Processing
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	2

(a) Course Description
This course covers advanced topics of Natural Language Processing (NLP) which is a field in Artificial Intelligence. NLP covers apporaches and tools for natural language understanding, generation and machine translation. In this course, students will gain an in-depth understanding of fundamentals and recent advances in deep learning methods for NLP which include: language models, text classification, dependency parsing, topic modeling, word embeddings, transformers, coreference resolution, named entity recognition, and sentiment analysis and and downstream tasks (e.g., machine translation, text classification, question answering, and text generation). The course will have emphasis on student-led investigation in the use of advanced NLP techniques in the local contexts including speech and text translation for African languages.

(b) Course Objectives
The aims of the course are:

1 To study deep learning models with a focus on large language models and their

application to solve downstream natural language analysis problems.

2 To cover bias and ethical issues when developing Natural Language Processing systems.

3 To develop real-world Natural Language Processing Systems using deep learning models.

(c) Learning Outcomes
At the end of the course, students will be able to:

1 Have an understanding of deep learning and large language models and their application to solve challenging natural language analysis problems.

2 Discuss bias and ethical issues when developing Natural Language Processing systems.

3 Apply deep learning models to develop down stream real-world Natural Language Processing Systems using deep learning models.

(e) Detailed Course Content

1 Module One: Fundamental Algorithms for Natural Language Processing **(15 hours)**

- Review of machine learning, language modelling and neural networks fundamental concepts
- Computational frameworks for neural network implementation, backpropagation.
- Deep Learning models - Convolutional neural networks Recurrent neural networks (RNN): including LSTM, GRU, sequence-to-sequence RNN, bidirectional RNNs, Attention models, transformers, generative adversarial networks, and memory neural networks.

2 Module Two: Text Analysis and Understanding **(15 hours)**

- Review of natural language processing and analysis fundamental concepts.
- Word level semantics
- Text classification: sentiment analysis, author profiling, author identification, text categorization
- Language model
- Conditional language models: summarization

- Text Similarity: community question answering

3 Module Three: Large Language Models **(15 hours)**

- Review and capabilities of Language Models
- Modelling, training and fine tuning Large Language Models
- Reinforcement learning from human feedback
- Multilingual language modeling and adaptation of LLMs
- Evaluation of language generation
- Prompt engineering, evaluation & Retrieval-Augmented Generation (RAG)
- Evaluation of text generation models
- Harms of Large Language Models

4 Module Four: Bias and Ethical Issues in NLP **(15 hours)**

- Word Embeddings & Language Behavior as Ground Truth
- Language Variation and Emergent Bias, Exclusion/Discrimination/Bias
- NLP Applications Addressing Ethical Issues

(f) Study Materials
The materials shall include textbooks, journals and research papers from NLP conference papers (e.g., ACL, NAACL, and EMNLP). We will also use software like TensorFlow, an open-source software library for Machine Intelligence, and Keras, a Python Deep Learning library.

(d) Mode of Study
Classes are held as group discussions. Reading material which includes journal papers is distributed a week in advance, and students take it turns to research and presenting new topics. The lecturer addresses questions to the students to encourage them to think about and understand the material. The lecturer should become aware of the student's proposed research topics so that the discussion explores how the principles in the course apply to these topics. The students make presentations of their review papers for critique from the students and the lecturer. The mode of delivery will be blended.

(g) Mode of Assessment
Progressive assessment will be based on the quality of presentations in a class by each student. The final assessment will be based on a scientific review paper.

(h) Reading List

[1] Lewis Tunstall, Leandro von Werra, Thomas Wolf, Natural Language Processing with Transformers, Revised Edition O'Reilly Media, Inc, 2022

[2] Jacob Eisenstein Natural Language Processing 2018 https://github.com/jacobeisenstein/gt-nlp-class/blob/master/notes/eisenstein-nlp-notes.pdf

[3] Jurafsky, D. and Martin, J. Speech Language Processing, 3rd edition. MIT Press, 2017

[4] Prabhumoye, S., Mayfield, E., & Black, A. W. Principled frameworks for evaluating ethics in NLP systems. In Proceedings of the 2019 workshop on Widening NLP (pp. 118-121). Florence, Italy: Association for Computational Linguistics.

[5] Raymond S.T Lee Natural Language Processing. A Textbook with Python Implementation Springer 2024.

5.0.1 PCS 9208: Systems Security and Privacy (4 CUs)

Course Code:	PCS 9208
Course Name:	Systems Security and Privacy
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	1

(a) Course Description
This course aims at providing a general overview of Network Security, attacks, issues of Data Privacy and counter measures. Data privacy helps system users to control what information they choose to keep personal. It is an individual's prerogative to prevent their personal information from being used or shared without their consent even when the use might not lead to data breach or cybercrimes. The cryptographic and algorithmic background behind different attacks shall be handled and how possible intrusion detection systems can be implemented to defend the local network. For the part of systems security, the course focuses in providing foundations of authorization systems, approaches for designing effective systems and tools and techniques for detecting problems in conventional systems. In the contemporary world, there is increased awareness of privacy issues and data protection, given the increase in the digitalization of operations and practices in the private and public sectors. There is need to understand, apply, analyse and develop the law and different information systems and software programs to address

the data privacy concerns.

(b) Course Objectives
The objectives of this courses are:

1 Study the current trends and methods of networks and systems security

2 To cover advanced areas of networks and systems security need attention

3 To develop students skills in using and implementing advanced data privacy and security techniques.

(c) Learning Outcomes
On successful completion of the course, a student will be able to:

1 Articulate the current trends and methods of networks and systems security

2 Explain the areas of networks and systems security that need due attention

3 be able to apply and implement advanced data privacy and security techniques.

(e) Detailed Course Content
The course covers the following topics:

1 Security problems on a topology level Module One **(15 hours)**

- Security problems on a topology level –Zone model, Security classification, Segmentation Typical security problems of Ethernet, –Sniffing, ARP Interception, Man-in-the-Middle Attacks, Wireless LANs –Attacks and Counter measures, Up-to-date technology
- Security in Enterprise Networking Module Two (15 hours)
- Security in Enterprise Networking –Typical security problems in large networks, House of Security, Typical measures and their prioritization, VLANs and Security Aspects –VLAN-Hopping, VLANs with Authentification, Security of Routing Protocols –RIP, OSPF, EIGRP, BGP, WAN / Remote Access –GRE, IPsec, Attacks against VPNs, Security of Network Devices –Services, Functions, Modules, Access Control (RADIUS, TACACS+, Kerberos), 802.1x based Access Control

2 Transport Technologies Module Three **(15 hours)**

- Transport Technologies–Security Consideration, MPLS Security Functions, VPNs with MPLS, EoMPLS, L2-MPLS, L3-MPLS, Multicast –Securing Multicast-Traffic, Multicast vs. IPsec, SRTP

3 Data Privacy Module Four **(15 hours)**

- Data Privacy –Definition of privacy to acknowledge multiple definitions

shaped by different aspects e.g., history, culture, and personal experience, Consider privacy as a thorny and sensitive issue, where technology is not value-neutral, Conflict between privacy norms and technological advancement through historical and ethical lenses, Key differences among laws and regulations governing privacy and understand the implications, The harms associated with data collection and data usage, and the rise of ethics in human subjects research.

- De- and Re-Identification of Data –Understand the implementation challenges of anonymizing a dataset, Common technical measures of data privacy, specifically k-anonymity and differential privacy, Difference between anonymized and de-identified data, Price of Privacy–How algorithms differentiate based on otherwise protected attributes and why de-identification of the individual is not enough to protect people from harm, Comparison between the economic value of privacy at the individual and group level, and how some companies build their business model around privacy, How personalizing each of our views of the world leads to information silos.

(d) Mode of Study
Interactive lectures, class presentations and discussions, self-paced programming tasks / labs

(g) Mode of Assessment
Evaluation shall be based on assignments (both written and practical), projects and examination (it could be a take home or written examination). The assignments shall constitute 40/100 and Examination 60/100

(h) Reading List

[1] Divya Muthukumaran, Trent Jaeger, and Vinod Ganapathy; Leveraging 'Choice' in Authorization Hook Placement. . In 19th ACM Conference on Computer and Communications Security, 2012.

[2] Joseph Migga Kizza, Guide to Computer Network Security, Springer Cham 2020.

[3] Daya, B., Network security: History, importance, and future. University of Florida Department of Electrical and Computer Engineering, 2013

[4] Ali Sadiqui, Computer Network Security, Wiley 2020

[5] Liyanage, M., Abro, A.B., Ylianttila, M. and Gurtov, A., Opportunities and challenges of software-defined mobile networks in network security. IEEE security & privacy, 14(4), pp.34-44. 2016

[6] Binjubeir, Mohammed, Abdulghani Ali Ahmed, Mohd Arfian Bin Ismail, Ali

Safaa Sadiq, and Muhammad Khurram Khan. "Comprehensive survey on big data privacy protection." IEEE Access 8 (2019): 20067-20079.

[7] Malin, Bradley A., Khaled El Emam, and Christine M. O'Keefe. "Biomedical data privacy: problems, perspectives, and recent advances." Journal of the American medical informatics association 20, no. 1 (2013): 2-6.

[8] Mehmood, Abid, Iynkaran Natgunanathan, Yong Xiang, Guang Hua, and Song Guo. "Protection of big data privacy." IEEE access 4 (2016): 1821-1834.

[9] Habibzadeh, Hadi, Brian H. Nussbaum, Fazel Anjomshoa, Burak Kantarci, and Tolga Soyata. "A survey on cybersecurity, data privacy, and policy issues in cyber-physical system deployments in smart cities." Sustainable Cities and Society 50 (2019): 101660.

[10] Salleh, Khairulliza Ahmad, and Lech Janczewski. "Technological, organizational and environmental security and privacy issues of big data: A literature review." Procedia computer science 100 (2016): 19-28.

5.0.1 PCS 9202: Analysis and Design of Algorithms

Course Code:	PCS 9202
Course Name:	Analysis and Design of Algorithms
Course Credit:	4
Contact Hours:	60
Year of Study:	1
Semester:	11

(a) Course Description
This course presents advanced techniques for designing efficient computer algorithms, proving their correctness, and analyzing their running times. It delves deep into both theoretical and practical aspects of algorithm development, analysis, and optimization. Discussions include efficient algorithms for basic graph problems, solving optimization problems, and advanced mathematical techniques for designing and analyzing computer algorithms. Emphasize is placed on theoretical underpinnings of techniques used to solve problems arising in diverse domains. To study a variety of useful algorithms and analyze their complexity; by that experience to gain insight into recent advances and trends in algorithm design.

(b) Course Objectives
By the end of the course, students should

1 have a good understanding of how several elaborate algorithms work.

2 have a good understanding of how a smart choice of data structures may be used

to increase the efficiency of particular algorithms.

3 be able to analyse the space and time efficiency of complex algorithms.

4 be able to design new algorithms or modify existing ones for new applications and reason about the efficiency of the result.

(c) Learning Outcomes
On successful completion of the course, a student will be able to:

1 Understand how to use a variety of data structures.

2 Understand a variety of common algorithms and why some are more efficient than others.

3 Carry out time complexity analysis in a variety of scenarios.

4 Discuss intractable and undecidable problems.

(e) Detailed Course Content

1 Module 1: Algorithm Analysis **(4 hours)** Asymptotic notation (Big O, Omega, Theta); Worst-case, average-case, and best-case analysis; Amortized analysis

2 Module 2: Algorithm Design Techniques **(4 hours)** Divide and conquer; Greedy algorithms: Longest common subsequence, chain multiplication, minimum weight; Dynamic programming; Backtracking; Branch and bound; Randomized algorithms; triangulation, Huffman trees.

3 Module 3: Graph algorithms **(8 hours)** Graph representation; Traversal algorithms (BFS, DFS); Shortest path algorithms (Dijkstra's, Bellman-Ford, Floyd-Warshall); Minimum spanning trees (Prim's, Kruskal's); Network flow algorithms (Ford-Fulkerson, Edmonds-Karp); and applications to maximum matching.

4 Module 4: Complexity Theory **(8 hours)** P vs NP problem; NP-completeness and reductions; Approximation algorithms; Parameterized complexity; Limits of Computation: Tractable and intractable problems; Undecidability.

5 Module 5: Advanced Topics String algorithms **(10 hours)** Geometric algorithms; Parallel algorithms; Quantum algorithms; Approximation Algorithms: Vertex cover, TSP k-center approximations. PTASs and the knapsack approximation; matroid theory, linear programming; Markov chains, Fast Fourier Transform, expander graphs, multithreaded algorithms, number-theoretic algorithms

6 Module 6: Algorithm Optimization **(8 hours)** Space-time trade-offs; Profiling and benchmarking; Parallelization techniques; Efficiency considerations (e.g.,

memory management, cache-aware algorithms)

7 Module 7: Algorithm Engineering and Implementation **(10 hours)** Real-world applications of algorithms; Case studies of algorithmic problem-solving in various domains (e.g., bioinformatics, networking, machine learning); Data structures and their implementations

8 Module 8: Research Trends and Challenges **(8 hours)** Recent developments in algorithms research; Open problems and areas for future exploration

(f) Study Materials
The materials shall include textbooks, journal/conference papers, cloud platforms, and several digital resources.

(d) Mode of Study
The course will be fast-paced and will cover a number of advanced topics in algorithms. Classes are held as a group discussion. Reading material which includes journal papers is distributed a week in advance, and students take it in turns to research and present new topics. The lecturer addresses questions to the students to encourage them to think about and understand the material. The lecturer should become aware of the students' proposed topics of research so that the discussion explores how the principles in the course apply to these topics. The students make presentations of their review paper for critique from both the students and the lecturer.

(g) Mode of Assessment
Assessment will be by take-home assignments leading to presentation (40%) and a scientific review paper (60%). Students will be given tasks to read and write about then present in class. The lecturer will award marks for each write up of a scientific review paper.

(h) Reading List

[1] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. Introduction to Algorithms. *MIT Press* , Fourth Edition. 2022

[2] Soubhik Chakraborty, Prashant Pranav, Naghma Khatoon, Sandip Dutta. A Guide to Design and Analysis of Algorithms Nova Science Publishers. ISBN: 979-8-88697-386-0. 2022

[3] Jon Kleinberg, Eva Tardos Algorithm Design, Pearson. 2021

5.0.1 PCS 9206: Responsible Software Systems

Course Code:	PCS 9206
Course Name:	Responsible Software Systems
Course Credit:	4
Contact Hours:	45
Year of Study:	1
Semester:	II

(a) Course Description
This course provides essential knowledge of design and development of responsible software systems and research in Computer Science. The rapid adoption of digital systems and AI and machine learning systems necessitates the need for being aware of potential harms and benefits to people, environment and other actors. The goal of the course is to introduce students to advanced methodologies, techniques and best practices for detection, measurement, mitigation of bias and harms in AI and other software systems. The course puts emphasize best practices for developing, and deploying AI and other software systems with good intentions and fairly impact users and society— allowing organizations and individuals to engender trust and scale AI and software systems with confidence. The course covers issues of bias, fairness, transparency, explainability, safety, security, privacy, and accountability across the end-to-end AI life cycle and software development life cycle. The course also explores issues of data governance and regulation around AI and software systems.

(b) Course Objectives
The course aims are:

1 Introduce students to potential benefits and harms of software systems including security, AI, machine learning systems on people, the environment, and other stakeholders.

2 Discuss data governance and regulatory frameworks and their role in the development and deployment of responsible AI and software systems.

3 Provide an in depth coverage of issues surrounding responsible software development, including bias, fairness, transparency, explainability, safety, security, privacy, and accountability.

4 Illustrate and provide an understanding of strategies and approaches to detect, measure and mitigate issues of biases, fairness, privacy and security in software systems.

(c) Learning Outcomes
After completing this course the student should be able to:

1 Be aware of the principles for responsible and equitable software systems development Explain the potential benefits and harms of software systems including security, AI, machine learning systems on people, the environment, and other stakeholders.

2 Demonstrate understannding of role of data governance and regulatory frameworks in the development and deployment of responsible AI and software systems.

3 Anayse key issues surrounding responsible software development, including bias, fairness, transparency, explainability, safety, security, privacy, and accountability.

4 Implement strategies to detect, measure and mitiggate issues of biases, fairness, privacy and security in software systems.

(e) Detailed Course Content
The course covers the following indicative topics:

1. Module 1: Introduction **(10 hours)** Rationale for responsible software systems with case studies and examples from AI and security systems, potential harms and risks. Influence of software systems on society: applications and disasters, Technologies and practices, liability of software and AI systems, environmental and social concerns into the software design and development process

2. Module 2: Responsible software systems issues across the software and AI development life cycle **(10 hours)** Perspectives of different stakeholders in a software project, Stakeholder values and identify value tensions in a software project, potential benefits and potential harms of software for different stakeholders

3. Module 3: Ethical considerations in Software Systems **(5 hours)** Ethical questions during software design and development, development decisions taking ethical risks into account.

4. Module 4: Bias, Fairness, Explainability, and Accountability **(12 Hours)**. Case studies on Bias, Fairness, Explainability, and Accountability with examples from local contexts. Techniques and tools for Bias, Fairness, Transparency, Explainability, Safety, Security, Privacy, and Accountability across the software and AI development lifecycle. Implications systems powered based on Generative AI and Large Language Models.

5. Module 5: Security, Safety, and Privacy **(12 Hours)**. Case studies on Security, Safety and Privacy with examples from local contexts. Techniques and tools for monitoring and mitigating security and privacy in software and AI models.

6. Module 6: Regulatory frameworks for responsible software and AI systems **(11 hours)**. Policies, regulations, Industry standards, Responsible software systems

toolkits, data and algortihm governance frameworks. Implications on systems powered by Generative AI and Large Language models.

(d) Mode of Study
The course will be delivered using Lectures, Class presentations, Class discussions, Independent study, Case studies, Tutorials, Group projects, Practical demonstration and hands on sessions, and scenario-based Assignments.

(g) Mode of Assessment
Assessment shall be based on a assignment/project, case study 1, case study 2 (40%), a term paper for the final Exam (60%).

(h) Reading List

[1] Voeneky S, Kellmeyer P, Mueller O, Burgard W, eds. The Cambridge Handbook of Responsible Artificial Intelligence: Interdisciplinary Perspectives. Cambridge University Press; 2022.

[2] Schieferdecker, I. (2020). Responsible Software Engineering. In: Goericke, S. (eds) The Future of Software Quality Assurance. Springer, Cham.

[3] Software Engineering: A Practitioner's Approach by Roger S. Pressman and Bruce R. Maxim, Hardback, ISBN13: 978-0078022128

[4] Essentials of Software Engineering - With Access by Frank Tsui, Orlando Karam and Barbara Bernal. Paperback, ISBN13: 978-1284106008.

5.0.1 PCS 9209: Advances In Computer Vision & Image Processing

Course Code:	PCS 9209
Course Name:	Advances In Computer Vision & Image Processing
Course Credit:	4
Contact Hours:	45
Year of Study:	1
Semester:	II

(a) Course Description
This course focuses on image processing and computer vision. It covers the methods that allow a machine to learn and analyze images and video using geometry and statistical learning. The recent growth of digital imaging technologies, hardware advances, and machine learning models has led to many exciting recent developments in the field of image and video analytics. This course covers a range of topics, spanning all phases of a typical image processing and computer vision pipeline. From the basics of image formation and processing to recent deep learning methods addressing high-level visual recognition problems, such as image segmen-

tation and object detection. In addition, multiple-view geometry and applications of deep learning in computer vision for autonomous vehicles are covered.

(b) Course Objectives
The course aims to:

1 Expose students to the concepts and tools used in computer vision and image processing.

2 Explore the importance of image processing and transformation.

3 Help learners survey the most important features and characteristics of images for analytical purposes

4 Equip students with knowledge and skills to utilize machine learning to process, analyze and classify images.

(c) Learning Outcomes
After completing this course the student should be able to:

1 Identify and competently deploy tools for computer vision and image processing

2 Demonstrate understanding of the methods that allow a computer to 'perceive' and analyze images

3 Be able to undertake advanced research in computer vision and image analysis.

(e) Detailed Course Content
The course covers the following indicative topics:

1 Module 1: Introduction **(5 hours)** Introduction to Computer Vision and Basic Concepts of Image Formation: Introduction and Goals of Computer Vision and Image Processing, Image Formation Concepts

2 Module 2: Image representation and storage, image preprocessing and GreyScale and Color image transformations **(10 hours)** Radiometry, Geometric Transformations, Geometric Camera Models,Camera Calibration, Image Formation in a Stereo Vision Setup, Image Reconstruction from a Series of Projections, Image Transforms, Image Enhancement

3 Module 3: Spatial filtering, Image denoising, Low level features **(10 hours)** Image Filtering, Colour Image Processing, Image Segmentation

4 Module 4: Thresholding and region description, Image segmentation, Texture descriptors **(10 hours)** Texture Descriptors, Colour Features, Edges/Boundaries, Object Boundary and Shape Representations, Interest or Corner Point Detectors, Histogram of Oriented Gradients, Scale Invariant Feature Transform, Speeded up Robust Features, Saliency

5 Module 5: Traditional machine learning for images, Convolutional neural networks for images **(10 hours)** Linear Regression, Basic Concepts of Decision Functions, Elementary Statistical Decision Theory, Parameter Estimation, Clustering for Knowledge Representation, Dimension Reduction, Linear Discriminant Analysis, Artificial Neural Network for Pattern Classification, Convolutional Neural Networks, Autoencoders, Gesture Recognition, Motion Estimation and Object Tracking, Programming Assignments.

(d) Mode of Study
The study mode for this course will include Lectures, Class presentations, Class discussions, Independent study, Case studies, Tutorials, Group projects, and Practical demonstration and hands on sessions.

(g) Mode of Assessment
Assessment shall be based on a test 10%, Case study 1 15%, Case study 2 15%, a term paper 20% and Final Exam 40%.

(h) Reading List

[1] Computer Vision: A Modern Approach, D. Forsyth and J. Ponce, 2015, Second Edition, ISBN 9781292014081.

[2] Deep Learning: Algorithms and Applications, I. Goodfellow, Y. Bengio and A. Courville, 2017 (online version available at no cost for personal use)..

[3] A Guide to Convolutional Neural Networks for Computer Vision, S. Khan, H. Rahmani, S. Shah and M. Bennamoun, 2018 (online version available from a USC account)

[4] Computer Vision: Algorithms and Applications 2nd ed. 2022 — Deep Learning, Mobile Photography, Autonomous Navigation

5.1 Year II Semester I

5.1.1 PCS 9301: Thesis Proposal

Course Code:	PCS 9301
Course Name:	Thesis Proposal
Course Credit:	5
Contact Hours:	75
Year of Study:	2
Semester:	I

(a) Course Description
The purpose of the Thesis Proposal seminar is for doctoral students to have their

thesis proposal to be reviewed and discussed. The proposal is a synopsis providing a direction for the thesis. It is start of the academic formulation of a pragmatic research problem in relation to a field of knowledge that is to be presented by the doctoral student. The doctoral student should demonstrate conceivable theoretical and methodological approaches. Ethical considerations should be stated together with a discussion about planning the study's implementation. The doctoral student is expected to present their Thesis proposal to a panel of a number determined as per the regulations. The Graduate Research Office shall communicate with the Panel members well in advance.

(b) Course Objectives
The course through a panel aims to:

1 Review and discussed the student's Thesis proposal

2 Give constructive feedback in regard to the theoretical and methodological approaches in the proposal

3 Guide on the necessary Ethical considerations in the field of study

4 Provide guidance on the direction the study should take and suggest areas of improvement

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Describe the research problem and the gap in knowledge

2 Explain the different Computer Science methods to use to generate the required knowledge

3 Formulate a coherent research proposal with the budget and work plan that would be adequate for the work needed.

5.2 Year II Semester II

5.2.1 PCS 9401: Research Seminar I

Course Code:	PCS 9401
Course Name:	Research Seminar I
Course Credit:	3
Contact Hours:	45
Year of Study:	2
Semester:	II

(a) Course Description

The purpose of the Research Seminar I is to support the doctoral student by offering them an opportunity to present their work and later having a candid discussion providing different view points and allowing the student decide on the next course of action. The Research Seminar I is important as it provides for correction and development of the research analyses and argumentation. The doctoral student is expected to present their work to their doctoral committee which is set up as per the regulations. The Research Seminar I shall be initiated by the principal supervisor through the Graduate Research Office. Documentation for the halfway seminar is to be made available for the discussant and seminar chair no later than three weeks before the seminar. The Graduate Research Office shall communicate with the doctoral committee well in advance. Furthermore the Research Seminar I shall be announced by the Dean following a proposal by the principal supervisor.

(b) Course Objectives
The course through the Doctoral committee aims to:

1 Review and discussed the student's work at that stage

2 Give constructive feedback in regard to the theoretical and methodological approaches in the proposal

3 Guide on the necessary Ethical considerations in the field of study

4 Provide guidance on the direction the study should take and suggest areas of improvement

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Organize a public seminar, invite participants and coordinate the logistics necessary to have a successful presentation.

2 Make a presentation of the study coherently to a heterogenous audience.

3 Adequately respond to questions from faculty, staff and the general public on the topic being presented.

4 Acknowledge gaps in the work done and how those gaps can be covered in subsequent research work.

5 Document the proceedings of a seminar and present a report that would be succinct and yet comprehensive.

5.3 Year III Semester I

5.3.1 PCS 9501: Scientific Presentation at Conference

Course Code:	PCS 9501
Course Name:	Scientific Presentation at Conference
Course Credit:	2
Contact Hours:	30
Year of Study:	3
Semester:	I

(a) Course Description
The doctoral student is expect to submit an article to a conference that is in line with their field of study. This is helpful as it help the student to build their confidence in writing as well as presentation of their work. The student shall look for potential submission venues in consultation with their supervisor.

(b) Course Objectives
The course aims to:

1 Help the student present their work in a conference setting

2 Allow the student receive constructive feedback

3 Open up the student to other researcher and also grow their network

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Select acceptable and credible scientific conference

2 Prepare and submit a scientific manuscript and respond to reviewer's comments.

3 Prepare and make a scientific presentation to a diverse international audience.

4 Adequately respond to questions from a diverse of audience of scholars at an international forum.

5.4 Year III Semester II

5.4.1 PCS 9601: Scientific Paper Manuscript

Course Code:	PCS 9601
Course Name:	Scientific Paper Manuscript
Course Credit:	3
Contact Hours:	45
Year of Study:	3
Semester:	II

(a) Course Description
The doctoral student is expect to submit an article to improve the article they presented at the conference following the comments and suggestions they were given and submit it in a journal outlet that is in line with their field of study. This shall contribute to the requirements in partial fulfillment of the award for Doctor of Philosophy. The student shall look for potential submission venues in consultation with their supervisor.

(b) Course Objectives
The course aims to:

1 Support students produce a high quality scientific manuscript

2 Support students in the selection of the appropriate and credible Journal

3 Help the student track their progress in their PhD research

4 Meet the necessary requirement for the programme

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Demonstrate understanding of the Computer Science literature reviewe process and methods

2 Produce a scientific manuscript using commonly used tools such as LATEX

3 Demonstrate ability to outline and produce a high quality scientific manuscript

4 Demonstrate and understanding of the Computer Science publication processes.

5.5 Year IV Semester I

5.5.1 PCS 9701: Research Seminar II

Course Code:	PCS 9701
Course Name:	Research Seminar II
Course Credit:	3
Contact Hours:	45
Year of Study:	4
Semester:	I

(a) Course Description
The purpose of the Research Seminar II is to support the doctoral student by offering them an opportunity to present their work before they submit their Doctoral Thesis and later having a candid discussion providing different view points and allowing the student decide on the next course of action. The Research Seminar II is important as it provides for correction and development of the research analyses and argumentation. The doctoral student is expected to present their work to their doctoral committee which is set up as per the regulations. The Research Seminar I shall be initiated by the principal supervisor through the Graduate Research Office. Documentation for the halfway seminar is to be made available for the discussant and seminar chair no later than three weeks before the seminar.

(b) Course Objectives
The course through the Doctoral committee aims to:

1 Review and discussed the student's work at that stage

2 Give constructive feedback in regard to the theoretical and methodological approaches in the proposal

3 Guide on the necessary Ethical considerations in the field of study

4 Provide guidance on the direction the study should take and suggest areas of improvement

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Organize a public seminar, invite participants and coordinate the logistics necessary to have a successful presentation.

2 Make a presentation of the study coherently to a heterogenous audience.

3 Adequately respond to questions from faculty, staff and the general public on the topic being presented.

4 Acknowledge gaps in the work done and how those gaps can be covered in subsequent research work.

5 Document the proceedings of a seminar and present a report that would be succinct and yet comprehensive.

5.6 Year IV Semester II

5.6.1 PCS 9801: PhD Thesis

Course Code:	PCS 9801
Course Name:	PhD Thesis
Course Credit:	12
Contact Hours:	180
Year of Study:	4
Semester:	II

(a) Course Description
The PhD Thesis is for doctoral students is an original piece if research that must be carried out by doctoral students in order to earn their doctoral degree. It is meant to explain the contribution and conclusion that has been reached as a result of the research over the period of study.

(b) Course Objectives
The course through the Opponent and Panel aims to:

1 Discussed and examine the student's work

2 Give constructive feedback in regard to the theoretical and methodological approaches in the PhD Thesis

3 Guide on the necessary suggestions to improve the work

4 Provide a verdict indicating whether the doctoral student has passed or not

(c) Learning Outcomes
By the end of the course, the students should be able to:

1 Systematically organize and prepare an academic thesis inline with the acceptable standards of the Computer Science discipline and the University.

2 Make a presentation of the PhD thesis and adequately respond to questions from examiners and the general public on the topic being presented.

3 Adequately respond to the comments arising from the examination process.

6 Resources and Infrastructure

6.1 Infrastructure and Equipment

6.1.1 Lecture Space

The School of Computing and Informatics Technology is housed in the College of Computing and Information Sciences with 2,500 and 12,000 square meter buildings known as block A and B, respectively. Block A mainly accommodates offices for the administration and teaching staff. The ground floor has a video conferencing facility; on second floor there are two teaching labs, a lecture room and two seminar rooms used for teaching purposes as well. On fourth floor, there is a seminar room and a conference hall and the sixth floor has a testing centre. Block B has lecture rooms together with the rest of the general and specialized laboratories i.e. Software Systems Centre, Multimedia lab, Mobile Applications among others. The two buildings sufficiently cater for all the lecture and laboratory space requirements at the College of Computing and Information Sciences (CoCIS). Specifically, CoCIS has twelve lecture theaters each of 200 square meters (300 seat capacity) of circulation space where students are able to access other services such wireless Internet services.

6.1.2 Computer Laboratories and Software

The CoCIS buildings that house CIT, i.e. Block A and B, have general computing laboratories (for student hands-on training); teaching and specialized laboratories, that are shared amongst the four departments. The School has 7 laboratories each of 800 square meters (1000 seat capacity) and six small laboratories of total area 1200 square meters with a total of approximately 700 computers. All computers in the laboratories are pre-installed with various operating systems and computing applications with a focus on open source applications. The School has access to software for the practical aspects of the programme.

The School of Computing and IT has also put in place specialized research laboratories (e.g. the Multimedia Laboratory, Geographical Information Systems Laboratory, Mobile Computing Laboratory, Networking and Systems Laboratory, Software Incubation Laboratory, Computer Engineering Laboratory and e-learning Laboratory) and plans are under way to establish more laboratories using funds available under donor funded projects and internally generated funds.

6.1.3 E-Learning Platforms

Makerere University has an eLearning platform known as Muele (http://www.muele.mak.ac.ug) and it is expected that courses will be developed as interactive online modules on Muele. Students in the Department of Computer Science have adequate access to computers. Each student will be expected to have a personal computer. This creates a good environment for e-learning blended teaching. All courses in the new curriculum will be taught in a blended way. All course materials will be put on Muele. Staff will, as much as possible, make use of e-learning facilities like discussion forum and drop boxes for assignments. This will increase student activity/participation and reduce staff effort (e.g. staff will not need to dictate notes). This in turn will increase the material covered and taken in by the students.

6.1.4 Library Services

Makerere University library supports the College of Computing and Information Science library, which is located on the first level of Block B. The College Library is stocked with up-to-date information resources. The information resources in the College Library have been acquired through purchases made by Makerere University Library and the College of Computing & Information Sciences. Additionally, the University Library has dedicated space for graduate students and provides access to print books, print journals, electronic journal databases, a well-stocked reference section and connections to many online databases like the Uganda Scholarly Digital Library at http://dspace3.mak.ac.ug. The print collection is beefed up by the broad variety of electronic resources provided by the University Library and accessible online at http://muklib.mak.ac.ug. Through the document delivery service, users who fail to get access to full-text articles from the available databases can make requests for articles, which are delivered, to them at no cost. Library users can also access the Online Public Access Catalogue (OPAC) to get bibliographic information about the collections found in the College Library. Below is a list of all electronic databases that Makerere subscribes to;

1. Institute of Electrical and Electronic Engineers (IEEE)
2. Emerald Insight
3. Springer Verlag
4. Research4life (ARDI & HINARI)
5. Sage Publications
6. E-library (eBook database)
7. Science Direct

8. Association of Computing Machinery (ACM) Digital Library

6.2 Financial Resources

The project revenue and expenditure are provided in **Appendix B**.

6.3 Human Resource

The School of Computing and Informatics Technology has staff who can competently teach the course units of the programme. The list of staff members in the Department of Computer Science and other departments is in **Appendix A**.

Appendix A: Academic Staff List

Name	**Qualifications and Awarding Institution**	**Area of Specialization**	**Current Load per Week (hrs)**	**Proposed Load (hrs)**	**Staff Status**
Assoc. Prof. Engineer Bainomugisha	PhD CS (VUB) [1] MSc. CS (VUB) BSc. CS (Mak)[2]	Programming Language Engineering Cloud & Mobile Computing Secure Programming Distributed Systems AI	12	12	Full time
Dr. John Ngubiri	PhD. CS (RUN)[3] MSc. CS (Mak) PGD. CS (Mak) BSc. Educ (Mak)	Software Security Parallel Systems Process Modelling Algorithms	12	12	Full time
Dr. Rose Nakibuule	PhD. CS (Mak)[2] MSc. CS (Mak) BSc. CS and Math (Mak)	Computer Vision Image processing Artificial Intelligence Data Science	12	3	Full time
Dr. Michael Kizito	PhD. Informatics (GU)[6] MSc. CS (RUN) BSc. CS (Mak)	IT Governance Computer Security Digitalisation Health Informatics	12	3	Full time
Dr.Marriette Katarahweire	PhD. CS (Mak)[2] MSc. CS (VUB)[1] BSC. CS (Mak)	Computer Security Privacy Software Engineering	9	3	Full time
Dr. Joyce Nakatumba-Nabende	PhD. CS (TUE)[5] MSc. CS (Mak) BCS (MUST)	Data & Process Mining Business Process Management Process Modelling	12	3	Full time
Dr. Daudi Jjingo	PhD. Bioinformatics (Georgia)[7] MSc. Bioinformatics (Leeds) BSc. Biochemistry (Mak)	Bioinformatics of Infectious and Chronic Diseases Health Informatics	12	12	Full time
Dr. Peter Nabende	PhD. Math & Natural Sciences (RUG)[4] MSc. CS (Mak) BSc. Mech Eng (Mak)	Intelligent Systems Computational Linguistics Data Mining	12	12	Full time

Footnotes

[1]Vrije Universiteit Brussels, Belgium
[2]Makerere University, Uganda
[3]Radbound University Nijmegen, The Netherlands
[4]Rijks Universiteit Groningen, The Netherlands
[5]Technische Universiteit Eindhoven, The Netherlands
[6]University of Gothernburg, Sweden
[7]Georgia State University, USA

Appendix B: Projected Revenue & Expenditure

SN	Item	Rate	Amount (UGX)
A	**Revenue collection**		
A.1	Tuition fees(East African)	UGX 7,000,000 x 10 students	70,000,000
A.2	Tuition fees(International)	UGX 10,000,000 x 5 students	50,000,000
		Total Revenue	**120,000,000**
B	**Expenditure**		
B.1	Teaching Expenses	38%	45,600,000
B.2	ICT/specialized equipment	20%	24,000,000
B.3	Staff Development	5%	6,000,000
B.4	Administrative Expenses	3%	3,600,000
B.5	Office Expenses	3%	3,600,000
B.6	Library Materials	5%	6,000,000
B.7	Utilities/Furniture	1%	1,200,000
B.8	University Council	25%	30,000,000
		Total Expenditure	**120,000,000**