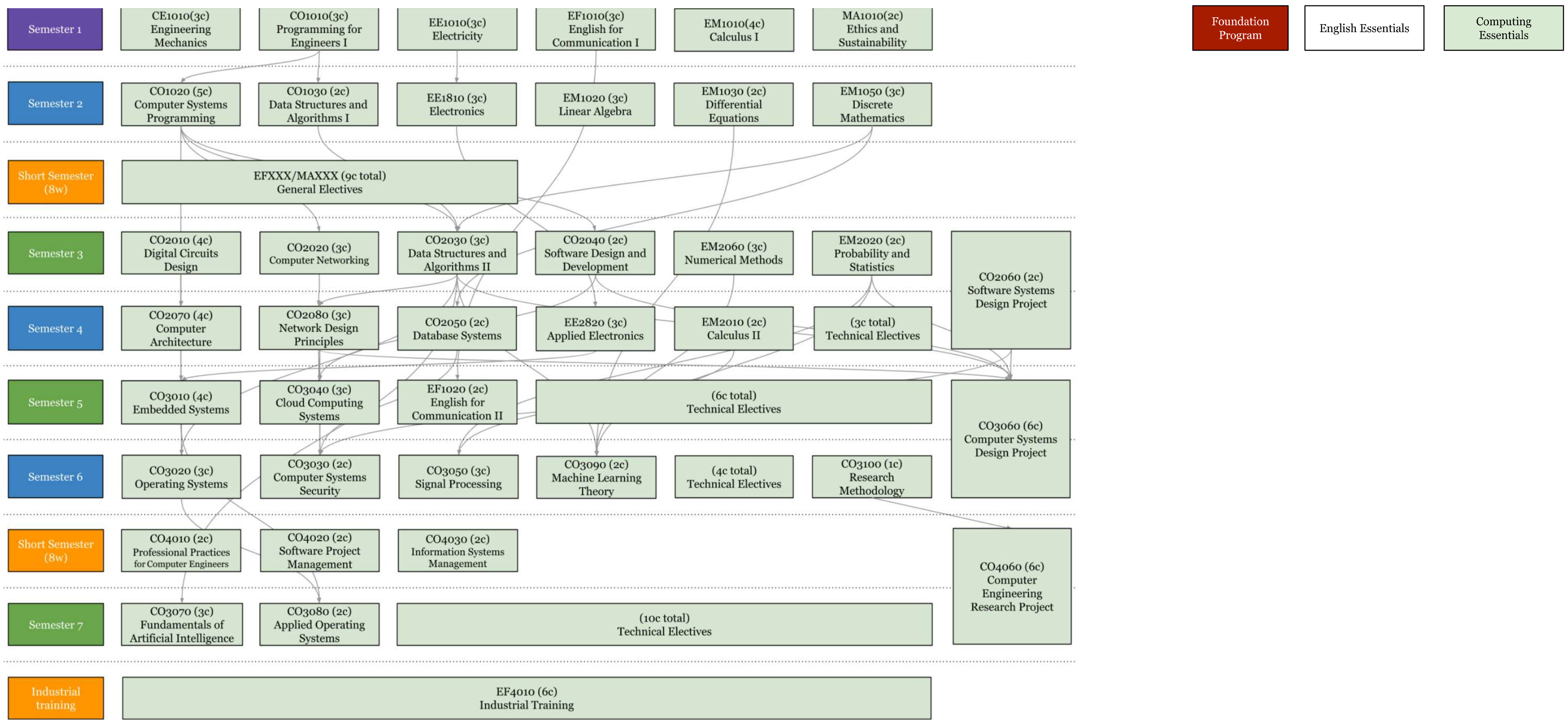
Course Structure - BScEngHons Degree Programme Specializing in Computer Engineering
[Effective from E/21]



Courses in the Computer Engineering Specialization

	Semester	Course Code	Course Name	Credits	Core/ Elective	Counted for CGPA?	Prerequisites
Year 1	1	CE1010	Engineering Mechanics	3c	Core	✔	-
		CO1010	Programming for Engineers I	3c	Core	✔	-
		EE1010	Electricity	3c	Core	✔	-
		EF1010	English for Communication I	3c	Core	✔	-
		EM1010	Calculus I	4c	Core	✔	-
		MA1100	Ethics and Sustainability	2c	Core	✔	-
	2	CO1020	Computer Systems Programming	5c	Core	✔	-
		CO1030	Data Structures and Algorithms I	2c	Core	✔	-
		EE1810	Electronics	3c	Core	✔	-
		EM1020	Linear Algebra	3c	Core	✔	-
		EM1030	Differential Equations	2c	Core	✔	-
		EM1050	Discrete Mathematics	3c	Core	✔	-
Short Semester 1 (8w)			**General Electives**	**9c**	**Electives**		**-**
Year 2	3	CO2010	Digital Circuits Design	4c	Core	✔	-
		CO2020	Computer Networking	3c	Core	✔	CO1020
		CO2030	Data Structures and Algorithms II	3c	Core	✔	CO1030 /CO1810
		CO2040	Software Design and Development	2c	Core	✔	CO1020
		CO2060	Software Systems Design Project (Continue to Semester-4)	2c	Core	✔	-
		EM2020	Probability and Statistics	2c	Core	✔	-
		EM2060	Numerical Methods	3c	Core	✔	-

	4	CO2050	Database Systems	2c	Core	✔	CO1020
		CO2060	Software Systems Design Project (continued from semester-3)	-	-	-	-
		CO2070	Computer Architecture	4c	Core	✔	CO1020, CO2010/EE2030
		CO2080	Network Design Principles	3c	Core	✔	CO2020, CO2030
		EE2820	Applied Electronics	3c	Core	✔	EE1810
		EM2010	Calculus II	2c	Core	✔	-
		CO5XXX	**Technical Electives***	3c	Electives	✔	As appropriate
Year 3	5	CO3010	Embedded Systems	4c	Core	✔	CO2010
		CO3040	Cloud Computing Systems	3c	Core	✔	CO2040, CO2060, CO2080
		CO3060	Computer Systems Design Project (Continue to Semester-6)	6c	Core	✔	CO2030, CO2040, CO2050, CO2060, EM2010, EM2020
		EF1020	English for Communication II	2c	Core	✔	-
		CO5XXX	**Technical Electives***	6c	Electives	✔	As appropriate
	6	CO3020	Operating Systems	3c	Core	✔	CO2030, CO2070
		CO3030	Computer Systems Security	2c	Core	✔	CO2050, CO2060, CO2080
		CO3050	Signal Processing	3c	Core	✔	EM2010, EM2020
		CO3060	Computer Systems Design Project (continued from Semester-5)	-	-	-	-
		CO3090	Machine Learning Theory	2c	Core	✔	CO2030, EM2020, EM2060
		CO3100	Research Methodology	1c	Core	✔	-
		CO5XXX	**Technical Electives***	4c	Electives	✔	As appropriate

Short Semester 2 (8w)		CO4010	Professional Practices for Computer Engineers	2c	Core	✔	-
		CO4020	Software Project Management	2c	Core	✔	-
		CO4030	Information Systems Management	2c	Core	✔	-
		CO4060	Computer Engineering Research Project(Continue to Semester-7)	6c	Core	✔	CO3100
Year 4	7	CO3070	Fundamentals of Artificial Intelligence	3c	Core	✔	CO2030
		CO3080	Applied Operating Systems	2c	Core	✔	CO3010, CO3020
		CO4060	Computer Engineering Research Project (continued from Short Semester-2)	-	-	-	-
		CO5XXX	**Technical Electives***	10c	Electives	✔	As appropriate
		Industrial Training (EF4010)		**6c**	Core	-	-
***Technical Electives (4/5/6/7)**		CO5010	Advanced Embedded Systems	3c	Elective	✔	CO2070
		CO5020	Advanced Computer Architecture	3c	Elective	✔	CO2070
		CO5030	Advanced Operating Systems	3c	Elective	✔	-
		CO5040	Compliers	3c	Elective	✔	CO2030
		CO5050	Programming Language	3c	Elective	✔	CO2030
		CO5060	Theory of Computation	3c	Elective	✔	EM1040
		CO5070	Parallel Computation and Algorithms	3c	Elective	✔	CO2070
		CO5080	Cyber Physical Systems	3c	Elective	✔	-
		CO5090	Advanced Algorithms	2c	Elective	✔	CO2030
		CO5210	Advanced Computer Communication Networks	3c	Elective	✔	CO2080
		CO5220	Optical Communication Networks	3c	Elective	✔	CO2080
		CO5230	Network Virtualization	3c	Elective	✔	CO2080
		CO5240	Cybersecurity	3c	Elective	✔	-
		CO5310	Applied Software Architecture	3c	Elective	✔	CO2040

	CO5320	Advanced Database Systems	3c	Elective	✔	CO2050
	CO5410	Applied Data Science	3c	Elective	✔	-
	CO5420	Artificial Neural Networks and Deep Learning	3c	Elective	✔	-
	CO5430	Image Processing	3c	Elective	✔	-
	CO5440	Data Engineering	3c	Elective	✔	-
	CO5450	Game Theory and Markov Decision Processes	3c	Elective	✔	EM2020
	CO5460	Computer Vision	3c	Elective	✔	-
	CO5470	Natural Language Processing	2c	Elective	✔	-
	CO5480	Data Warehousing & Big Data Analytics	3c	Elective	✔	CO2050
	CO5510	Formal Verification Tools and Techniques for Complex Reactive Systems	3c	Elective	✔	EM1050
	CO5520	Mathematics of Cryptography	3c	Elective	✔	-
	CO5530	Computational Bioengineering	3c	Elective	✔	-
	CO5540	Trends in Internet of Things	3c	Elective	✔	-

Other than the mentioned Technical Electives, students may take other Technical Electives offered in the Faculty with the departments' consent

Complementary Studies Courses	EF3010	The Engineer in Society	2	Elective		-
	EF3020	Social Project	2	Elective		-
	EF3030	Introduction to Music	2	Elective		-
	EF3040	Painting and Sculpture	2	Elective		-
	EF3050	Written English for Communication	1	Elective		-
	EF3060	Effective Communicating in English through Speech	1	Elective		-
	EF3070	Introduction to Digital Art	3	Elective		-
	EF3080	Mindfulness for Engineers	2	Elective		-
	MA5500	Business Communication	3	Elective		-
	MA5510	Circular Economy for Engineering	3	Elective		-
	MA5520	Marketing for Engineers	3	Elective		-
	MA5600	Economics for Engineers	3	Elective		-
	MA5610	Corporate Finance and Accounting for Engineers	3	Elective		-
	MA5620	Business Law and Intellectual Property	3	Elective		-
	MA5700	Environmental Economics	3	Elective		-
	MA5710	Project Management	3	Elective		-
	MA5720	Organizational and Industrial Psychology	3	Elective		-
	MA5800	Sustainable Technology and Economic Development	3	Elective		-
	MA5810	Procurement Management	3	Elective		-
	MA5820	Engineer as an Entrepreneur	3	Elective		-

Note 1: All assignments listed in the following course descriptions are in-course assignments.

Note 2: Respective teaching panels are provided with limited flexibility of up to two contact hours per one credit to enable, where deemed necessary, inclusion and utilization of other teaching-learning activities and/or delivery modes within the lecture hours specified in the course descriptors in recognition of the significance of adaptable course delivery and lecture hour allocation.

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Year 1
Semester 1

Semester:	1			
Course Code:	CE1010			
Course Name:	Engineering Mechanics			
Credit Value:	3 (Notional hours:150)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Practical hrs.	Tutorial hrs.	Independent Learning & hrs.
	35	10	5	100

Course Aim :

- To provide an exposure to the fundamentals of physics, which govern the behaviour of macroscopic elements so that the students will be able to model and analyze complex mechanical systems and structures, and experience the art of scientific problem solving

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **illustrate** the construction of a free body diagram of an element in a mechanical or a structural system
ILO2:**compute** internal forces in statically determinate and indeterminate structures, using the concepts of equilibrium, compatibility and stress-strain relation
ILO3:**describe** the behavior of a particle in inertial and moving frames by identifying the Einstein, Centrifugal, Coriolis, and Euler accelerations
ILO4:**derive** the governing differential equations of a mechanical or a structural system using fundamental laws in mechanics

Course Content:

Introduction:
Force systems: Forces and couples; equilibrium of rigid body

Analysis of simple structures:
Structures and components; loads and supports; internal and external forces; free-body diagrams; statically determinate structures; analysis of trusses; beams and shear force and bending moment diagrams; stress and strain; Hooke's law, and deformation of axially loaded members; statically indeterminate problems

Bending of beams:
Simple bending theory and its applications

Work and energy methods:

Work due to forces and couples; virtual displacements and virtual work; strain energy and potential energy; energy principles

Kinematics of Particle Motion:
Description of particle motion in 3D Inertial frames and in moving frames. The use of the euclidean group of translations in describing the relative motion of frames

Kinetics of Particle Motion :
Concept of Space-Time, mass and conservation of linear momentum and its relationship to Newton's Laws; The concept of force, meaning of kinetic energy, the notion of spatial angular momentum; conservation of spatial angular momentum

Newton's laws in Moving Frames:
The meaning of centrifugal, Coriolis, Euler, and Einstein forces. Application to the description of complex motion of systems that can be approximated as particles

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and practical classes

Assessment Strategy:

Continuous Assessment 50%	Final Assessment 50%		
Details: Tutorials 10% Laboratory practical classes 20% Mid semester examination 20%	Theory (%) 50%	Practical (%) -	Other (%) -

Recommended Reading:

- Cohenn, M. (2012). *Classical Mechanics: A Critical Introduction*. Hindawi Publications. Cairo, Egypt.
- Greenwood, D. T. (1997). *Classical Dynamics*. Dover Publications, United States of America.
- Tatum, B. *Classical Mechanics*, E-Book at: http://astrowww.phys.uvic.ca/~tatum/classmechs.html
- Hibller, R.C (2013) *Statics and Dynamics*, 13th Edition

Semester:	1				
Course Code:	CO1010				
Course Name:	Programming for Engineers I				
Credit Value:	3 (Notional hours 150)				
Prerequisites:	None				
Core/Optional	Core				
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Practical class hrs	Design hrs	Independent Learning & Assessment hrs.
	15	10	30	10	85

Course Aim:

- To develop logical thinking through algorithms and structured programming constructs so that the students will be able to build software applications to analyze and solve engineering problems.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Construct** algorithms to solve engineering problems
ILO2: **Use** structured programming constructs and build software applications
ILO3: **Apply** good programming practices

Course Content:*(Only main topics & subtopics)*

Basics :
Variables. Operators and precedence. Data types. Number systems and numerical precision.

Control Structures:
Conditions and loops.

Modularization :
Standard libraries and functions. User-defined functions.

Input/Output:
Standard input/output. File input and file output

Data Structures:
List and list comprehension. String processing and formatting. Stack and Queue. Dictionaries.

Object-Oriented Concepts:
Classes and Objects. Accessing variables and functions within objects.

Quality Assurance:
Good programming practices. Testing. Debugging. Exception and error handling.

Algorithms :
Developing algorithms and writing programs for the solutions of well-defined problems related to Engineering.

Numerical Computations:
Introduce concepts of numerical packages/libraries such as numpy and the use of mathematical software such as Matlab to solve problems such as those listed under item 8

Teaching /Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessment 60%	Final Assessment 40%		
Details: Online class participation 5% Practicals 35% Assignments and Projects 20%	Theory (%) 40%	Practical (%) -	Other (%) -

Recommended Reading:
- John DeNero (2017), *Composing Programs, a free online introduction to programming and computer science*, 10 Oct 2019, http://composingprograms.com
- Ron Reiter (2018), *Interactive Python tutorial*, 10 Oct 2019,https://www.learnpython.org/

Semester:	1			
Course Code:	EE1010			
Course Name:	Electricity			
Credit Value:	3 (Notional hours:150)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Practical hrs.	Tutorial hrs.	Independent Learning
	29	24	4	93

Course Aim:

- To equip the learners with fundamentals of physics of electricity which will enable them to model and analyze natural phenomena of electricity and perceive the art of scientific problem solving.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **model** electrical phenomena using fundamentals of field theory.
ILO2: **apply** fundamental laws in electric and magnetic fields to solve basic electromagnetic problems.
ILO3: **analyze** electrical circuits under steady state and transient conditions.
ILO4: **build** engineering systems based on fundamentals.
ILO5: **use** state of the art tools for analyzing electric/magnetic field applications and electrical circuits.

Course Content:

Introduction:
Field theory as a tool to understand the universe, Fundamentals of Fields, Introduction to field theory

Electrostatics:
Electric Charge and Coulomb's Law, Permittivity, Electric field, Gauss law, Electric flux, Electric potential, Energy stored in a static electric field, Dielectric polarization, boundary conditions, Capacitance

Magnetism:
Magnetic flux and Flux density (B), Permeability, Magnetic field intensity (H), Biot-Savart law , Ampere's law, Gauss law for magnetic fields, Magnetic force and torque, , Self and mutual inductance, Faraday's law of Induction, Lenz's law,

Stored energy in the magnetic field, Magnetic properties of materials, B-H curve, Reluctance and magnetic circuits, eddy current, hysteresis and iron losses

Linear Electrical Circuit Analysis:
Steady state analysis: Charge flow - ohm's law, current and current density (J), resistance and resistivity, impedance and admittance, Mesh and nodal analysis, Thevenin's theorem, Norton's theorem, Maximum power transfer theorem

Linear Electrical Circuit Analysis:

Transient analysis:
Analysis of RC, RL and RLC circuits under dc excitation

Advances in modeling techniques:
Recent developments in modeling electrical phenomena

Introduction to the state of the art analysis tools:
Modern tools for electrical and magnetic field analysis, electrical circuit analysis

Electrical Engineering Mini Project

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and practical classes

Assessment Strategy:

Continuous Assessment 60%	Final Assessment 40%		
Details: Tutorials - 10% Quizzes - 4% Assignment / Project - 26% Labs - 20%	Theory (%) 40%	Practical (%) -	Other (%) -

Recommended Reading:

- Hughes, E. and Smith, I.M. (1995), *Huges Electrical Technology*. Longman Scientific & Technical, Pennsylvania, USA.
- Mehta, V.K., (2006). *Principles of Electrical Engineering and Electronics.*
- Powell, R. G., (1990). *Electromagnetism.* MacMillan Press Ltd., London

<table>
<tr><td>Semester:</td><td colspan="3">1</td></tr>
<tr><td>Course Code:</td><td colspan="3">EF1010</td></tr>
<tr><td>Course Name:</td><td colspan="3">English for Communication I</td></tr>
<tr><td>Credit Value:</td><td colspan="3">3 (Notional hours:150)</td></tr>
<tr><td>Prerequisites:</td><td colspan="3">None</td></tr>
<tr><td>Core/Optional</td><td colspan="3">Core</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs.</td><td>Assignments hrs.</td><td>Independent Learning hrs.</td></tr>
<tr><td>10</td><td>70</td><td>70</td></tr>
</table>

Course Aim:

- To develop the competence in using English effectively to follow the engineering degree programme and to further their profession.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **listen** to a verbal communication in English and describe accurately its contents;
ILO2: **read** a written communication in English and describe accurately its contents;
ILO3: **explain** information coherently using English through writing and
ILO4: **explain** information effectively in English orally using appropriate terminology.

Course Content:

Listening Comprehension:
Listening comprehension on dialogues, short & long lectures, talks, documentaries; method of taking down notes for comprehension, tabulate information, paraphrase and summarize content through listening exercises.

Reading Comprehension:
Reading passages and articles from various disciplines to acquire reading skills such as skimming & scanning; reading comprehension, paraphrasing, improving vocabulary and critical analysis of content.

Writing:
Composing a structured discourse on general descriptions, processes, essays, graph descriptions and lab reports; writing with cohesion using relevant grammatical components.

Speech:
Effective use of the English language to communicate in different contexts such as dialogues, impromptu & prepared speeches, debates, discussions and presentations.

<table>
<tr><td colspan="4">Teaching /Learning Methods:
Classroom lectures and small group in-class activities</td></tr>
<tr><td colspan="4">Assessment Strategy:</td></tr>
<tr><td>Continuous Assessment
70%</td><td colspan="3">Final Assessment
30%</td></tr>
<tr><td>Details:
Assignments 70%</td><td>Theory (%)

30%</td><td>Practical (%)</td><td>Other (%)</td></tr>
<tr><td colspan="4">Recommended Reading:
● Glendinning, E.H. (2009) Technology I - Oxford English for Careers, Student's book.
● Eric H. Glendinning E.H. and Alison P. (2013) Technology II - Oxford English for Careers, Student's book.
● Ibbotson M. (2014) Cambridge English for Engineering - Professional English.
● Firsten R. and Killian P. (2002) The ELT Grammar Book: English Language Teaching Reference Guide</td></tr>
</table>

Semester:	1			
Course Code:	EM1010			
Course Name:	Calculus I			
Credit Value:	4 (Notional hours:200)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	48	06	12	134

Course Aim:

- To introduce mathematical concepts arising in the areas of calculus and functions of complex variables so that build confidence in students in solving related problems.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **analyze** concepts in limits, continuity, differentiability of real-valued functions of single and multiple variables and integration of single variable function.
ILO2: **determine** the convergence of sequences and infinite series, the power series expansion of real analytic functions.
ILO3: **analyze** lines, planes, curves and surfaces in 2D and 3D spaces
ILO4: **derive** the mathematical models of physical problems as differential equations
ILO5: **solve** first order separable, linear and exact differential equations and reducible forms.
ILO6: **analyze** limits, continuity, and differentiability of complex-valued functions, and determine holomorphic and harmonic functions.

Course Content:

Functions of a Single Variable:
Functions and Limits, Continuity and Differentiability of real valued functions, Intermediate value theorem, Rolle's theorem, Mean value theorem, Leibnitz theorem, and tangent line approximation, extreme values, integration of single variable function.

Sequences and Series:
Monotonic and bounded sequences, Convergence, divergence and oscillation of a sequence, Series and their convergence, Real power series and their convergence, Maclaurin and Taylor series approximation.

First order Ordinary Differential Equations:

Differential Equations as a mathematical model and Classification, Separable, Linear, Exact, Reducible forms.

Vector approach to geometry in space:
Vectors, Determinant, Vector equations of lines and planes and their geometry, Parametric representation of curves in planes, Curvature, radius and center of curvature, Derivatives of vector valued function in parametric form.

Functions of Several Variables:
Limit and continuity of functions of two and three variables, Partial derivatives and total differential, Chain rule and higher order partial derivatives.

Functions of Complex Variables:
Roots of unity and functions of complex variables, Mapping of complex variables, Derivatives of complex functions, Cauchy Riemann equation, Holomorphic functions, Harmonic functions.

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 50%	Final Assessment 50%		
Details: Assignments/Quizzes - 10% Tutorials - 10% Mid-semester - 30%	Theory (%) 50%	Practical (%) -	Other (%) -

Recommended Reading:

- Stewart, J. (2006). *Calculus* (5th edition), Thomson Brooks/Cole
- Fulks, W. (1978). *Advanced Calculus an Introduction to Analysis* (3rd edition), John Wiley & Sons, Inc.
- Dass, H.K. (2008). *Advanced Engineering Mathematics*. S. Chand Publishing
- Nagle, R.K., Saff, E,W. and Snider A.D. (2012). *Fundamentals of Differential Equations* (8th edition), Pearson Education
- E. Kreyszig, E.(2011). *Advanced Engineering Mathematics* (10th Edition), Wiley
- Franklin, P. (1960). *Differential Equations for Engineers*, Dover Publications
- Staff, E.B. and Snider A.D. (2013), *Fundamentals of Complex Analysis with applications to Engineering and Science* (3rd edition), Pearson Education

Semester	1		
Course Code:	MA1100		
Course Name:	Ethics and Sustainability		
Credit Value	2 (Notional hours: 100)		
Pre-requisites	None		
Core /Optional	Compulsory		
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Independent Learning (hrs)
	15	15	70

Aim(s):

- To impart knowledge on basic concepts of sustainability and ethics.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **explain** the concept of morality and how it relates to standard ethical practices in the Education and Engineering Profession.

ILO2: **reflect** ethical conduct as a student and an engineering professional in contributing to decision-making in engineering activities.

ILO3: **interpret** the sustainability concepts and practices in different industrial sectors.

assess the economic, social, and environmental impacts of development activities.

Course content:

Ethics and Morality:

Concept of morality; personal morality; common morality; core values.

Academic integrity:

Usage of information; citation and acknowledgement; plagiarism; impersonation.

Professional Ethics:

Engineers in an organization; introduction to IESL Code of Ethics.

Ethics and Sustainability:

Ethical considerations in decision making for sustainable development projects – application of IESL Code of Ethics.

Global environmental and social issues:

Global environmental issues with particular emphasis on global warming and resource limitation; Contribution from present development practices to these issues. Need for different approaches for development.

Concept of Sustainable Development:

Concept of sustainable development, three pillars of sustainability, the need for a sustainable approach to development, Sustainable development goals (SDGs).

Introduction to Tools and Concepts for sustainable development of Industries: Concepts of Life Cycle Thinking, design for sustainability, cleaner production, sustainable consumption and production, circular economy			
Teaching/Learning Methods: Lectures Student Based Activities			
Assessment Strategy			
Continuous Assessments 60%	**Final Assessment** 40%		
Small Group Activities 40% Quizzes 20%	**Theory** 40%	**Practical** -	**Other** -

Recommended Reading:

- Harris, C. E., Pritchard, M.S., Rabins, M.J. (2009) *Engineering Ethics: Concepts and Cases*, Wadsworth Cengage Learning, USA.
- Kelly, W. E., Luke, B., Wright, R.N. (2017). *Engineering for Sustainable Communities-Principles and Practices*, ASCE Press.
- Martin, M. W., Schinzinger, R. (2010). *Introduction to Engineering Ethics,* McGraw-Hill, USA.
- Robertson, M. (2017). *Sustainability Principles and Practice,* Routledge, UK.
- The Institution of Engineers Sri Lanka. (2017). Code of Ethics, The Institution of Engineers Sri Lanka.
- Whitbeck, C. (2011). *Ethics in Engineering Practice and Research,* Cambridge University Press.

Year 1
Semester 2

<table>
<tr><td>Semester:</td><td colspan="5">2</td></tr>
<tr><td>Course Code:</td><td colspan="5">CO1020</td></tr>
<tr><td>Course Name:</td><td colspan="5">Computer Systems Programming</td></tr>
<tr><td>Credit Value:</td><td colspan="5">5 (Notional hours 250)</td></tr>
<tr><td>Pre-requisites:</td><td colspan="5">None</td></tr>
<tr><td>Core/Optional:</td><td colspan="5">Core for Computer Engineering specialization</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs</td><td>Tutorial hrs</td><td>Practical class hrs</td><td>Design hrs</td><td>Independent Learning & Assessment hrs</td></tr>
<tr><td>22</td><td>19</td><td>36</td><td>32</td><td>141</td></tr>
</table>

Course Aims:

- To establish a solid foundation of computer programming for the disciplined practice of Computer Systems Engineering.
- To provide a good understanding about computer systems from a programmer's perspective.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** how computer programs are written, built (pre-processed, compiled, assembled and linked), stored in memory and executed in a computer system;
ILO2: **interpret** and **write** assembly language programs based on a specified ISA;
ILO3: independently use the C programming language to **write computer programs** with memory and I/O operations, build and run them in a Linux text-based environment;
ILO4: use debugging and testing techniques to **understand** the execution of computer programs and **identify** errors;
ILO5: **demonstrate** good practices in programming such as pre-planning, naming conventions, commenting, modularization and testing in order to write high quality and efficient code.

Course Content: *(Only main topics & subtopics)*

Overview of computer systems and the programming process:

Abstractions in software (from algorithms to machine code) and hardware (from silicon to microarchitecture), Von Neumann machine concept, organization of a computer system (application software, system software, instructions & microarchitecture, memory, peripheral hardware such as secondary storage and networking, firmware), the process of building and executing programs (pre-processing, compiling, assembling, linking, storing/loading, execution in a GNU/Linux environment).

Introduction to C programming syntax:
Comments, variables, data types, type casting, operators, expressions, flow control (conditions, loops, interrupting loop flow, program termination), statements & blocks, library functions, basic user inputs & outputs.

Structured programming:
Functions syntax, naming conventions, parameter passing by value and reference, recursion.

Error detection and prevention:
Syntax/semantic/logical errors, compile-time/run-time errors, assertions, debugging tools (GNU debugger), good practices in programming, testing to verify correctness using proper test cases.

Memory allocation and peripheral I/O:
Memory layout (stack, heap, global data, code/text), stack tracing for debugging, static memory allocation, arrays, string representation, string manipulation, pointers, structures, file input and output, network socket programming.

Assembly language programming:
Introduction to assembly syntax using a specified ISA, integer arithmetic and logic operations using register/immediate operands, branching and conditional execution, function calls, register conventions, stack operations, nested calls, accessing data memory.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 40 %	Final Assessment 60 %		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 20% Assignments 20 %	30%	30%	-

Recommended Reading:

- Randal E. Bryant, David R. O'Hallaron, Computer Systems: A Programmer's Perspective 3rd Edition, 2015
- Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Second Edition, 1990
- Jeffrey D. Ullman, Alfred V. Aho, Foundations of Computer Science C Edition, 1994
- David Patterson, John L. Hennessy, Computer Organization and Design: The Hardware/Software Interface

Semester:	2				
Course Code:	CO1030				
Course Name:	Data Structures and Algorithms I				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization stream				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	14	-	18	14	54

Course Aims:

- To introduce the notion of efficiently solving computational problems without resorting to naïve or brute-force techniques.
- To introduce fundamental algorithmic concepts such as divide and conquer, greedy algorithms and dynamic programming using linearly structured data.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **estimate** the performance of a given algorithm using empirical and mathematical techniques;
ILO2: **describe** different algorithmic techniques used for searching and sorting linearly structured data, and compare their performance.

Course Content: *(Only main topics & subtopics)*

Algorithm analysis:
Empirical measuring of algorithm performance, Running time vs. time complexity, asymptotic analysis (Big-O/Big-Omega/Big-Theta notations), time complexity of recursive algorithms, master theorem, space efficiency.

Search and sort strategies:
Linear search, concept of divide and conquer using binary search, efficiency of search (sorted vs unsorted linear data), analysis of sorting algorithms: bubble-sort; selection-sort (greedy algorithms); insertion-sort (dynamic programming); quick-sort and merge-sort (divide and conquer).

Linear data structures:

Introduction to abstract data types (ADT) as opposed to data structures, the list ADT, linked vs array based implementations, efficiency of list search and maintenance operations, stack and queue data structures and their applications, implementation using different programming languages.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50 %	Final Assessment 50 %		
Details: Practicals & quizzes 50%	Theory(%) 30%	Practical(%) 20%	Other(%)(specify) -

Recommended Reading:

- Introduction to Algorithms by Cormen, Leiserson, Rivest, Stein
- Algorithm Design Manual by S S Skiena

Semester	2				
Course Code	EE1810				
Course Name	Electronics				
Credits Value	3 (Notional hours =150)				
Pre-requisites	None				
Core/Optional	Core				
Hourly Breakdown	**Lecture**	**Tutorial**	**Practical**	**Assignment**	**Independent Learning and assessment**
	33	6	9	3	99

Course Aim:

- To introduce the operational characteristics, circuit design considerations and applications of fundamental devices in analog electronics.

Intended Learning Outcomes:

At the completion of the course students should be able to;

ILO1: **analyze** diode circuits in relevant applications,
ILO2: **analyze** BJT and FET circuits,
ILO3: **design** transistor amplifier circuits to meet requirement specifications,
ILO4: **design** logic circuits using semiconductor devices.

Course Content

Diodes:
Semiconductors, p-n junction, diodes, operation principle of diodes, ideal & piece-wise linear modeling of diodes, common diode circuits, diode logic circuits.

Bipolar Junction Transistors:
Terminal characteristics of BJT, operational principles, BJT amplifier and switching circuits, biasing circuits & amplifier configurations, dc/ac load line analysis, small signal analysis.

Amplifiers using BJTs:
Voltage gain, current gain, power gain, input resistance, output resistance, multi-stage amplifiers, coupling techniques, frequency response of amplifiers.

BJT Logic families:
Transistor inverter circuits, logic level definitions; switching characteristics of inverter, speed up method, Diode Transistor Logic-DTL; Transistor-Transistor

Logic-TTL, the different pair as a current switch, Emitter-Coupled Logic-ECL, Low voltage bipolar logic families.

Field Effect Transistors (FET):
Terminal characteristics, circuit models, MOSFET amplifier and switching circuits, dc/ac load line analysis.

MOS Logic Families:
NMOS logic design; Inverters, NOR, NAND, SOP, POS, complex gates; PMOS logic, CMOS logic: Inverter, NOR, NAND, SOP, POS, complex gates, Dynamic logic; Cascade buffers

Interfacing logic families:
Interface criteria, interfacing TTL - CMOS, TTL - ECL, CMOS – ECL.

Teaching/ Learning Methods:

Classroom lectures, tutorial discussions, assignments, and practical classes

Continuous Assessment 40%	**Final Assessment** 60%		
Details: Assignments 20% Mid Semester 20%	**Theory (%)** 60	**Practical (%)**	**Other (%)**

Recommended Reading:

- G. J. Ritchie (2003) Discrete and Integrated Transistor Circuit Techniques, CRC Press
- James M. Fiore (2019) Semiconductor Devices: Theory and Applications, New York

Semester:	2			
Course Code:	EM1020			
Course Name:	Linear Algebra			
Credit Value:	3 (Notional hours: 150)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	35	10	-	105

Course Aim:

- To encourage students to develop a working knowledge of the central ideas of linear algebra: vector spaces, linear transformations, orthogonality, eigenvalues, eigenvectors and canonical forms and the applications of these ideas in science and engineering.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Apply** the knowledge of matrices, Gaussian reduction and determinants to solve systems of linear equations.

ILO2: **Apply** the properties of vector spaces and to generalize the concepts of Euclidean geometry to arbitrary vector spaces.

ILO3: **Identify** linear transformations, represent them in terms of matrices, and interpret their geometric aspects.

ILO4: **Calculate** eigenvalues and Eigenvectors of matrices and linear transformations and apply the concepts in physical situations.

ILO5: **Prove** eigenvalue properties of real symmetric matrices and apply them in quadratic forms.

Course Content:

Matrix Algebra:

Operations, elementary matrices, inverse, partitioned matrices.

Determinants:

Introduction and properties.

Vector spaces:

Definition, subspaces, linear independence and spanning, basis, change of basis, normed spaces, inner product spaces, Gram-Schmidt orthonormalization.

Linear Transformations:

Introduction, matrix representation, operations of linear transformations, change of basis.

System of linear equations:

Gauss and Jordan elimination; LU factorization, least square approximations, ill-conditioned and overdetermined systems.

Characteristic value problem:

Computing eigenvalues and eigenvectors, Eigen-basis, diagonalization, matrix exponentials.

Real Symmetric matrices:

Properties, definiteness, quadratic forms, applications.

Teaching /Learning Methods:

Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 50%	Final Assessment 50%		
Details: Tutorials/Assignments/Quizzes 20% Mid Semester Examination 30%	Theory (%) 50%	Practical (%) -	Other (%) -

Recommended Reading:

- Gilbert Strang, Introduction to Linear Algebra, 5th edition, (2010), Cambridge Press.
- David C. Lay, S. R. Lay & J. Mcdonald, Linear Algebra and its Applications, 5th edition, (2012), Pearson.
- David Poole, Linear Algebra: A Modern introduction, 4th edition, (2005), Cengage.
- Thomas. S. Shores, Applied Linear Algebra and Matrix Analysis, (2007), Springer.

Semester:	2			
Course Code:	EM1030			
Course Name:	Differential Equations			
Credit Value:	2 (Notional hours: 100)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	24	6	-	70

Course Aim:

- To introduce analytical solving techniques for differential equations with constant coefficients and interpret the solutions.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Solve** higher order ordinary differential equations with constant coefficients.

ILO2: **Analyze** the solution of a second order ordinary differential equation with constant coefficients.

ILO3: **Apply** matrix methods and Laplace transform in solving systems of ordinary differential equations with constant coefficients.

ILO4: **Select** analytical solutions of first order linear partial differential equations using method of characteristics.

ILO5: **Classify** second order linear partial differential equations and solve the wave equation, the Laplace equation and the heat equation.

Course Content:

Second Order Ordinary Differential Equations:

Spring mass damper equation: forced oscillations and resonance.

Laplace Transform:

Definition, existence and properties; Laplace transform of standard functions, derivatives and integrals; solve ordinary differential equations with constant coefficients; discontinuous forcing functions; convolution.

Boundary Value Problems:

Boundary value problem of a second order differential equation with constant coefficients using direct calculation; Euler Bernoulli equation and Macaulay's Bracket method.

Systems of ODEs:
Converting higher-order differential equations to a system of first-order differential equations; eigenvalue eigenvector method; matrix exponential method.

First order linear partial differential equations:
Partial differential equations as a mathematical model and Classification; Method of characteristics.

Second order linear partial differential equations:
classification: hyperbolic, parabolic and elliptic equations; Fourier series; method of separation of variables: wave equation, heat equation, Laplace equation on rectangular domains with homogeneous boundary conditions.

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 50%	Final Assessment 50%		
Details: Tutorials/Assignments/Quizzes 20% Mid Semester Examination 30%	Theory (%) 50%	Practical (%) -	Other (%) -

Recommended Reading:

- R.K. Nagle, E.W. Saff, A.D. Snider, Fundamentals of Differential Equations, 8th edition, (2012), Pearson Education.
- E. Kreyszig, Advanced Engineering Mathematics, 9th edition, (2010), John Wiley &sons Inc.
- Jiří Lebl, Differential Equations for Engineers, Open Education Resource (OER) LibreTexts Project (https://LibreTexts.org).
- Walter A. Strauss, Partial Differential Equations, 2nd edition,(2007), John Wiley and Sons Inc.

Semester:	2			
Course Code:	EM1050			
Course Name:	Discrete Mathematics			
Credit Value:	3 (Notional hours: 150)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	35	10	-	105

Course Aim:

- To solve problems related to propositional and predicate calculus, mathematical models for computing machines and algorithms using fundamentals of number theory, algebraic structures, Boolean algebras and graph theory.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **Apply** the concepts of number theory and algebraic structures to solve advanced mathematical /physical problems.
ILO2: **Evaluate** statements in propositional and predicate logic and check the validity of an argument.
ILO3: **Solve** advanced mathematical and physical problems. Using graph theory and algorithms.

Course Content:

Fundamentals:
Set theory, relations and functions, axiomatic systems, ordinary Induction, invariants, strong induction.

Number Theory:
Divisibility, the greatest common divisor, Modular arithmetic, Fermat's Little theorem, RSA algorithm

Algebraic Structures:
Monoids, groups, rings and fields.

Logic and Proofs:
Propositional and predicate logic, proof methods and strategy.

Graph Theory:
Graphs, representation of a graph in a computer, isomorphic graphs, Eulerian and Hamiltonian graphs, planar graphs, graph coloring, trees, spanning trees, binary trees, tree searching, Hasse diagrams.

Algorithms:
Greedy algorithms, searching and sorting algorithms, algorithms to obtain minimum spanning tree and shortest path of a weighted graph, complexity of an algorithm.

Mathematical models for Computing Machines:
Finite state machines, finite state automata, Turing machines.

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 50%	Final Assessment 50%		
Details: Tutorials/Assignments/Quizzes 20% Mid Semester Examination 30%	Theory (%) 50%	Practical (%) -	Other (%) -

Recommended Reading:

- D. K. Joshi, Foundations of Discrete Mathematics,(1989/2015), Wiley-Inter Science.
- D. K. Joshi, Applied Discrete Structures,(2001/2014), New Age International.
- Thomas Koshy, Discrete Mathematics with Applications,1st edition,(2004), Elsevier Academic Press.
- Ian Anderson, A First Course in Discrete Mathematics, (2001), Springer-Verlag. London Limited.
- Kenneth H. Rossen Discrete Mathematics and Applications, (2002),McGraw-Hill Higher Education.

Year 2
Semester 3

Semester:	3				
Course Code:	CO2010				
Course Name:	Digital Circuits Design				
Credit Value:	4 (Notional hours 200)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	34	2	20	28	116

Course Aims:

- To introduce digital electronics with emphasis on practical design techniques for logic circuits, analysis of static and dynamic behavior of logic circuits and optimized circuit implementation with its principles in Boolean algebra.
- To introduce the design of combinational and sequential logic circuits with gate level implementation.
- To teach how simple combinational and sequential modules are used to build complete systems, reflecting real-world digital design.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **perform** Boolean manipulations, circuit minimization and synthesis of sequential and combinational circuits;
ILO2: **describe** static and dynamic behavior of digital circuits;
ILO3: **construct** the formal requirement specification starting from an informal requirement;
ILO4: **design** basic combinational and sequential circuits with considerations to common problems such as hazards, race conditions and instability in these circuits;
ILO5: **implement** combinational and sequential logic circuits using logic ICs, as well as using a hardware description language and programmable logic;
ILO6: **demonstrate** the conformance of a design to its specifications including temporal behavior.

Course Content: *(Only main topics & subtopics)*

Introduction to logic circuits design:
Purpose and role of logic circuits in computer systems, use of Boolean logic and basic logic gates in circuit design, levels of integration, overview of logic circuits design flow, digital electronic signals and different logic families.

Number systems and data representation:
Binary and hex number systems, binary representation of unsigned and signed decimals, binary arithmetic, character representation.

Boolean logic:
Boolean logic operations, Boolean algebra laws and theorems, Boolean expressions, sum-of-products and product-of-sums methods, simplifications of Boolean expressions, truth tables, Karnaugh maps, Quine Mc-Cluskey method, *"don't care"* combinations.

Basic logic circuits:
Physical logic gate implementations for basic and derived Boolean operations, high-impedance condition and tri-state logic, realizing Boolean expressions using two-level gate forms and multi-level gates, positive/negative/mixed-logic design conventions, physical properties of logic gates and design tradeoffs, interfacing different logic families, Hardware Description Languages and logic synthesis process, simulation and verification.

Modular design of combinational logic circuits:
Multiplexers, de-multiplexers, encoders, decoders, adders, subtractors, shifters, comparators, modular Arithmetic & Logic Unit.

Modular design of sequential logic circuits and memory elements:
Latches, gated/edge-triggered/master-slave operation, flip-flops, timing characteristics, registers, counters, shift-registers, serial-parallel conversion, timing diagrams, error detection and correction techniques, static memory, dynamic memory.

Synchronous sequential logic circuits design:
Analysis of synchronous circuits, Finite State Machine (FSM) models, state diagrams and state tables, FSM timing diagrams, state minimization, state assignment, assignment rules, next state and output equation realization.

Asynchronous sequential logic circuits design:
Analysis of asynchronous circuits, design procedure, flow tables,reduction of state and flow tables, race-free state assignment.

Programmable logic:
History of programmable logic, programmable logic architectures and their basic elements.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

<table>
<tr><td>Continuous Assessments
40 %</td><td colspan="3">Final Assessment
60 %</td></tr>
<tr><td>Details:

Practicals Assignments 40%</td><td>Theory(%)

40%</td><td>Practical(%)

20%</td><td>Other(%)(specify)

-</td></tr>
<tr><td colspan="4">Recommended Reading:

● Morris Mano, Digital Design, 3rd Edition
● William James Dally and R. Curtis Harting, Digital Design - A Systems Approach</td></tr>
</table>

Semester:	3				
Course Code:	CO2020				
Course Name:	Computer Networking				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	26	8	16	6	94

Course Aims:

- The goal of this course is to provide a fundamental view behind the general purpose computer networks: the principles upon which the Internet and most other computer networks are built; how those principles translate into deployed protocols; and hands-on experience solving challenging problems with network protocols.
- This course provides an introduction to fundamental concepts in the design and implementation of computer networks, their protocols, and applications.

Intended Learning Outcomes:

Upon successful completion of the course, the students should be able to:

ILO1: **explain** the layered network architectures, and **critique** the role of each layer and their interdependence;
ILO2: **explain** the concepts of error control, flow control and congestion control;
ILO3: **illustrate** how a packet is routed over the Internet;
ILO4: **describe** how to control access to a shared channel by multiple stations;
ILO5: **design**, **build**, and **describe** a client-server application;

Course Content: *(Only main topics & subtopics)*

Introduction to Networking
What is the internet, the network edge and core, packet-switched networks, network performance measurement, layered architecture and service models, networks under attack

Application Layer

Network applications and their requirements: web and HTTP, FTP, email, DNS, peer-to-peer applications, video conferencing, content distribution networks, and other emerging applications.

Network Application Development
Introduction to UDP and TCP, client-server model, socket programming and network applications.

Transport Layer
Transport layer services, connectionless transport: UDP, principles of reliable data transfer, connection-oriented transport: TCP, principles of congestion Control, TCP congestion control, evolution of transport-layer functionality.

Network Layer: Data Plane
Forwarding and routing: network data and control planes, network service models, router design principles, IP design principles, generalized forwarding and SDN, middleboxes: firewalls, NATs, DPIs and load balancers.

Network Layer: Control Plane
Routing algorithms, Intra-AS routing, exterior gateway protocols: role, design principles and practice, SDN control plane, ICMP, and network management.

Link Layer and LANs
Link layer services, error detection and correction, multiple access links and protocols

Retrospection
A comparative analysis: a day in the life of a web page request

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 70%	Final Assessment 30%		
Details: Practicals (quizzes, viva voce, programming projects) 30% Tutorials, Quizzes and Assignments 20% Mid Semester Evaluation 20%	Theory(%) 30%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- James Kurose and Keith Ross, Computer Networks, 8th Edition, 2021

Semester:	3				
Course Code:	CO2030				
Course Name:	Data Structures and Algorithms II				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO1030 or CO1810				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	21	6	24	12	87

Course Aims:

- To expand the notion of efficiently representing and solving non-trivial computational problems without resorting to naïve or brute-force techniques.
- To familiarize students with real world applications of Tree, Graph and Associative-arrayADT (Abstract Data Type) based data structures and algorithms.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** tree/graph/associative-array-based data structures and related algorithms used in practice, **estimate** and **compare** their performance;
ILO2: **critique** the suitability of a given data structure to efficiently represent a non-trivial computational problem;
ILO3: **apply** suitable data structures to efficiently represent non-trivial computational problems;
ILO4: **select** a suitable algorithm to efficiently solve a given non-trivial computational problem;
ILO5: **apply** suitable algorithms to efficiently solve non-trivial computational problems;

Course Content: *(Only main topics & subtopics)*

Trees
Tree ADT, linked implementation, tree traversal, efficiency of search and maintenance operations, binary search trees, balanced BSTs, AVL and red-black trees, binary heaps, priority queues, heapsort, other applications of tree data structures (abstract-syntax-trees, XML/JSON parsing, radix-trees, Huffman-trees, B-trees), using trees to represent computational problems.

Graphs

Graph ADT, graph types and properties, matrix and list based implementations, graph traversal (depth-first, breadth-first), efficiency of search and maintenance operations, topological sort, Eulerian and Hamiltonian cycles, spanning trees, Kruskal's algorithm, Prim's algorithm, greedy algorithms and local optima, shortest-path algorithms (Dijkstra's, A*, Floyd-Warshall), reachability, Kosaraju's algorithm, graph coloring, applications of graph data structures (in location maps, flow networks, social networks, games, etc.), using graphs to represent computational problems

Hashing

Associative-array (map/dictionary/set) ADT, the dictionary problem, tree implementations, hash table implementations, hash functions and codes, collision handling, efficiency of search and operations, associative-array applications (in programming languages, memoization, JSON, No-SQL databases), using hashing to efficiently solve computational problems.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 50%	30%	20%	-

Recommended Reading:

- Introduction to Algorithms by Cormen, Leiserson, Rivest and Stein
- Data structures and algorithms by Aho, Hopcroft and Ullman
- Algorithms by Sedgewick and Wayne
- Algorithm Design Manual by S S Skiena

Semester:	3				
Course Code:	CO2040				
Course Name:	Software Design and Development				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	15	5	12	8	60

Course Aims:

- To familiarize students with the fundamental principles of software engineering, and impart tools, techniques and best practices for designing software systems.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** modern software process models, and their key components;
ILO2: **compare** modern software process models, and their key components;
ILO2: **construct** a basic three-tier web application using modern tools and techniques.

Course Content: *(Only main topics & subtopics)*

Software Process

Goals of software engineering, challenges of large scale software projects, evolution of software process models, details of agile software development

Requirement Analysis

Identifying functional requirements and non-functional requirements, illustrating use cases.

Software Design

Design fundamentals and design qualities, object oriented design (OOD) concepts, introducing design patterns.

Software Testing

Blackbox vs glass-box testing, test case design, unit testing, integration testing, test frameworks.

Web Applications

HTTP and HTML, processing user input, producing dynamic output, client-side scripting.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details: Practicals & quizzes 60%	Theory(%) 40%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- Software Engineering, 10th Edition, Ian Sommerville, Pearson Education
- Lean Architecture: for Agile Software Development, 1st Edition, James O. Coplien and Gertrud Bjørnvig, Wiley
- Object-oriented reengineering patterns, Serge Demeyer, Stéphane Ducasse and Oscar Nierstrasz, http://scg.unibe.ch/download/oorp/

Semester:	3 & 4				
Course Code:	CO2060				
Course Name:	Software Systems Design Project				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	-	-	22	38	40

Course Aims:

- To provide the students guidance and opportunity to design and implement a non-trivial software system containing a database component, using modern technology.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **construct** a requirement specification for a non-trivial software design;
ILO2: **design** and **implement** a non-trivial software system based on specification;
ILO3: **construct** test-cases and **perform** testing on a specified software system;
ILO4: **demonstrate** good practices in software design and development.

Course Content: *(Only main topics & subtopics)*

Requirement analysis and elicitation
Identification and presenting of functional requirements and non-functional requirements, relevant tools.

Software systems design and development
Apply software and database design concepts to design a non-trivial software solution and implement it, user experience and user interfaces design, software deployment, good practices in software design and development (documentation, version control, code reusability, etc.), relevant tools

Software testing
Design test cases and perform: unit testing; integration testing; and acceptance testing, relevant tools.

Teaching/Learning Methods: Flipped classrooms, small group discussion classes, project-based learning.			
Assessment Strategy:			
ContinuousAssessment 70%	FinalAssessment 30%		
Details: Requirement analysis (oral/written) 30% Progress evaluations on design, implementation and testing (oral/written/online-documentation) 40%	Theory(%) -	Practical(%) -	Other(%)(specify) Final project evaluation (oral/written) 30%

Recommended Reading:

- Software Engineering, 10th Edition of Ian Sommerville (Link: https://iansommerville.com/software-engineering-book/)
- Lean Architecture: for Agile Software Development, 1st Edition, James O. Coplien and Gertrud Bjørnvig, Wiley
- Object-oriented reengineering patterns, Serge Demeyer, Stéphane Ducasse and Oscar Nierstrasz, http://scg.unibe.ch/download/oorp/
- Elmasri and Navathe, Fundamentals of Database Systems
- Raghu Ramakrishnan and Johannes Gehrke, Database Management Systems

Semester:	3			
Course Code:	EM2020			
Course Name:	Probability and Statistics			
Credit Value:	2 (Notional hours:100)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	24	4	4	68

Course Aim:

- To introduce basic concepts of probability and inferential statistics.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **Demonstrate** fundamental probability and statistical concepts.
ILO2: **Apply** standard discrete and continuous probability distributions and observe their role as the foundation for statistical inference.
ILO3: **Perform** estimation and testing of hypotheses on common measures in decision making.

Course Content:

Concepts of probability:
Discrete and continuous random variables, probability distributions, mean, expectation and variance, moment generating functions

Discrete probability distributions:
Bernoulli (Point binomial) Distribution, Binomial distribution, Poisson distribution, geometric distribution, Hypergeometric distribution.

Continuous probability distributions:
Uniform distribution, exponential distribution, normal distribution, Student-t distribution, Weibull distribution and Chi-squared distribution.

Sampling distributions:
The central limit theorem and normal approximation to the binomial distribution, sampling distribution of sample mean and sample variance.

Estimation and Confidence Intervals:
Estimation and calculation of Confidence Intervals for mean, difference of means and variance.

Test of Hypothesis:
Test of hypothesis for mean and difference of means

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 40%	Final Assessment 60%		
Details: Tutorials/Assignments/Quizzes 10% Mid Semester Examination 30%	Theory (%) 60%	Practical (%) -	Other (%) -

Recommended Reading:

- D.C. Montgomery and G.C. Runger Applied Statistics and Probability for Engineers, 6th edition,(2013), John Wiley and Sons Inc.
- Jay L. Devore, Probability and Statistics for Engineering and the Sciences, 8th edition, (2010), Cengage Learning.

Semester:	3			
Course Code:	EM2060			
Course Name:	Numerical Methods			
Credit Value:	3 (Notional hours:150)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	30	3	24	93

Course Aim:

- To apply and analyze numerical methods for modeling and simulation.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Demonstrate** the limitations and identify the need of approximation, of numerical methods.

ILO2: **Apply** and **derive** numerical methods to solve nonlinear equations and solve systems of linear equations.

ILO3: **Derive** and **apply** interpolation and integration methods and their errors.

ILO4: **Solve** ordinary differential equations and partial differential equations numerically

Course Content:

Preliminaries:

Floating point arithmetic, Big O notation, matrix norms, Review of programming

Error Analysis:

Numerical solutions to nonlinear equations:

Fixed point iteration, Bisection method, Newton-Raphson method

Numerical solutions to systems of linear equations:

Gaussian elimination, Jacobi method, Gauss-Seidel method

Interpolation:

Lagrange interpolating polynomial, Newton's interpolating polynomials, Spline interpolation

Numerical integration:

Trapezoidal rule, Simpson rule, Gaussian quadrature

Numerical solutions to ordinary differential equations:

Initial value problems: Euler method, Runge - Kutta methods;

Boundary value problem: Finite difference method, Adaptive step size mechanisms

Numerical solutions to partial differential equations:
Explicit and implicit finite difference methods, Basics of finite element methods

Computational labs:
Covering selected topics & appropriate problems from the respective fields

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 40%	Final Assessment 60%		
Details: Lab assignments, tutorials 40%	Theory (%) 60%	Practical (%)	Other (%)

Recommended Reading:

- Ackleh et al. Classical and Modern Numerical Analysis,1st Edition(2009) Chapman and Hall/CRC.
- Quarteroni et al. Scientific Computing with MATLAB and Octave,2nd Edition(2014) Springer.
- Strang. Computational Science and Engineering,1st Edition(2007), Wellesley-Cambridge Press
- Gockenbach. Partial Differential Equations: Analytical and Numerical Methods,2nd Edition (2002)SIAM,

Year 2
Semester 4

Semester:	4				
Course Code:	CO2050				
Course Name:	Database Systems				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	20	4	12	-	64

Course Aims:

- To familiarize students with basic theoretical and practical concepts of database management systems (DBMS) so that students will be able to use that knowledge to design and develop databases effectively.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** database concepts and database system life cycle;
ILO2: **select** an appropriate database modeling technique for a given problem;
ILO3: **construct** well-structured databases using data modeling and/or normalization;
ILO4: **describe** the design, build and optimizing of databases;
ILO5: **use SQL** from definitions to operations of databases.

Course Content: *(Only main topics & subtopics)*

Introduction to database systems
Information models and systems, database system evolution, file based systems, DBMS approach, database environment and components, DBMS functions, DBMS architecture, data independence, database system life cycle.

Data modeling
Conceptual models (ER/EER and UML), logical models (relational and object oriented models), relational mapping, NoSQL, Comparison of NoSQL data model with relational data model..

RDBMS concepts

Normalization (1NF, 2NF, 3NF and BCNF), object oriented extensions.

Database query languages
4GL environments; SQL (DDL, DML and DCL), triggers, views.

Database programming techniques
Embedded SQL, database programming with function/procedure calls (ODBC, JDBC), stored procedures, Object-relational mapping.

Introduction to indexing and transaction processing
Types of indexes, transactions, ACID properties, concurrency control, failure and recovery.

Database security
Security issues and threats, access privileges, relationship between database security and privacy, encryption.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 50%	50%	-	-

Recommended Reading:

- Elmasri and Navathe, Fundamentals of Database Systems
- Raghu Ramakrishnan and Johannes Gehrke, Database Management Systems

Semester:	4				
Course Code:	CO2070				
Course Name:	Computer Architecture				
Credit Value:	4 (Notional hours 200)				
Pre-requisites:	CO1020, CO2010 or EE2030				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	29	9	21	23	118

Course Aims:

- To provide a strong understanding on the role of microprocessors in computer systems, and to provide an insight into microprocessor design..

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** the fundamental concepts in ISA (instruction set architecture), microarchitecture, memory hierarchy, interfacing and multiprocessors;
ILO2: **critique** tradeoffs and decisions made in ISA, microarchitecture, memory hierarchy, interfacing and multiprocessors design;

Course Content: *(Only main topics & subtopics)*

Introduction to computer architecture
Review of Von Neumann machine concept and computer systems organization, history of computer technology and current trends.

Performance evaluation
Metrics of computer performance, response time vs throughput, CPU time vs elapsed time, clock rate, cycles per instruction, benchmarks, design tradeoffs.

Instruction Set Architecture
Review of programmer model and ISA, instruction encoding, operand types (immediate, register, memory), instruction types (data processing, data transfer and flow control), register conventions, addressing modes, software interrupts, comparison of CISC and RISC programmer models.

CPU organization

Implementation of the Von Neumann machine using a specified ISA, datapath and control, register file, arithmetic and logic unit, control unit, instruction fetching and decoding, execution of instructions in a single-cycle datapath, timing and clocking, critical path and performance considerations, implementation of a single-cycle CPU using Verilog HDL behavioral modeling.

Pipelined datapath and control
Introduction to pipelining and instruction level parallelism, datapath and control in a pipelined CPU using specified ISA, pipeline hazards and stalls, hazard mitigation techniques (data forwarding, code scheduling, branch prediction), clocking and performance considerations.

Memory sub-system
Memory layout, overview of memory technologies, latency and performance, memory hierarchy and principles of locality, caching and cache control, data blocks placement and address mapping, write policies, replacement policies, cache performance, multi-level caches, virtual memory and address translation using page tables, page faults, translation look-aside buffer, secondary storage technologies (disk and flash storage).

Interfacing and I/O
Overview of interfacing in a computer, bus interconnects (types, signals, synchronization, arbitration), crossbar switch networks, mesh and grid interconnects, I/O fundamentals, programmed vs interrupt driven I/O, direct memory access, systems-on-chip.

Multiprocessor systems
Parallel processing, shared-memory multiprocessors, uniform memory access and symmetric multiprocessors, cache coherence and bus snooping, non-uniform memory access, directory-based cache coherence, message passing multiprocessors, Flynn's classification

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments & quizzes 50%	50%	-	-

Recommended Reading:

- David Patterson, John L. Hennessy, Computer Organization and Design: The Hardware/Software Interface (ARM, MIPS and RISC-V) Editions

Semester:	4				
Course Code:	CO2080				
Course Name:	Network Design Principles				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2020, CO2030				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	17	10	32	4	87

Course Aims:

- To further explore fundamental concepts in the design and implementation of computer communication networks, their protocols and applications, with a special focus on main elements that work together to form the Internet.

Intended Learning Outcomes:

Upon successful completion of the course, the students should be able to:

ILO1: **design** complex and varied computer networks based on specified requirements, and **perform** troubleshooting of functional and performance issues of such networks;
ILO2: **appraise** networking fundamentals (theory) and practice;
ILO3: **critique** network design principles and evaluate current networking concepts and research directions.

Course Content: *(Only main topics & subtopics)*

Retrospection
Revising the layered architecture and overall operation of a network; a day in the life of a web page request**;** network troubleshooting analysis.

Network Design and Configuration: Principles and Practice
Ethernet/IEEE 802.3, multiple-access protocols (CSMA/CD), switched LANs: link-layer addressing and ARP, link-layer (L2) switches: basic and advanced functionality, VLANs, IP, forwarding and routing, subnetting and supernetting, VLANs vs subnets, network-layer (L3) switches, routers, routing principles, and network diagnostics: fundamentals and tools.

Network Design and Configuration: Campus Networks
Complex designs with switched LANs, link-layer (L2) switches, VLANs, network-layer (L3) switches, and routers.

Network Programming Project
Layered network application development: blocking and non-blocking calls, IO multiplexing, signal handling, asynchronous IO, IP header options (e.g., timestamping).

Retrospection
Reliability, flow-control, addressing, multiplexing/demultiplexing across layers: a comparative analysis; networking troubleshooting roundup.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 70%	Final Assessment 30%		
Details: Practicals (Network Design and Programming projects) 40 % Tutorials, Quizzes and Assignments 10% Mid Semester Evaluation 20%	Theory(%) 30%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- James Kurose and Keith Ross, Computer Networks, 8th Edition, 2021
- James Bernstein, Networking Made Easy: Get Yourself Connected (Computers Made Easy), 1st Edition, 2018
- Russ White and Denise Donohue, Art of Network Architecture, The: Business-Driven Design (Networking Technology) 1st Edition, 2014

Semester:	4				
Course Code:	EE2820				
Course Name:	Applied Electronics				
Credit Value:	3 (Notional hours: 150)				
Pre-requisites:	none				
Core/Optional	Core				
Hourly Breakdown	**Lecture**	**Tutorial**	**Practical**	**Assignment**	**Independent Learning & Assessment**
	32	7	6	6	99

Course Aim: This course is aimed at providing essential fundamental knowledge and skills to design and implement electronic circuits for common practical applications.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to:

ILO1: **describe** the characteristics of an operational amplifier.
ILO2: **explain** the operation of analogue electronic circuits based on operational amplifiers.
ILO3: **design** electronic circuits.
ILO4: **Implement** electronic designs.

Course Content:

Operational Amplifiers (OPAMP)
The ideal OPAMP, open-loop gain, input resistance and output resistance. Characteristics of real Op-Amps: open-loop transfer function, voltage gain, bandwidth, slew rate, power bandwidth, clipping, offset voltages and currents, rejection ratios.

OPAMP Applications
Linear applications: (Inverting and Non- Inverting amplifiers, Differential and Summing amplifiers, Integrators and Differentiators), Nonlinear applications (precision rectifiers, peak detectors, Schmitt-trigger comparator and logarithmic amplifiers).

Active Filters
Low-pass, high-pass, band-pass and band-stop sections, Butterworth, Chebyshev, Elliptic and Bessel functions, circuit realization of single pole and two-pole transfer functions; frequency and impedance scaling. Implementation of filters using OPAMPs.

Data conversion circuits
Analog to Digital converters: definitions, codes, LSB, MSB, linearity, differential linearity, offset and gain errors, missing codes; Counting converters: successive approximations, single-and-dual slope converters, flash converters, delta-sigma converters; Sample-and-hold circuits, sampling rate selection and setting, integrating an analog signal to a digital system.

Digital to Analog converters: definitions, codes, LSB, MSB, linearity, differential linearity, offset and gain errors; weighted resistor D/A converter; R/2R ladders and D/A converters; weighted current source converters; integrating a digital signal to an analog system.
Clock synchronizing the Analog to Digital and Digital to Analog conversion operations using system clock signals.

Oscillators

Basic concepts and definitions; Wien-bridge oscillator

Circuit modeling and simulation

Introduction to electronic Computer Aided Design (CAD) tools, dc analysis, ac analysis, transient analysis; simulation control options, built-in-solid-state device models, device parameter control libraries, Designing electronic circuits.

Logic Circuits

SOP and POS representation for logic functions, K-map representation, simplification of logic functions using K-map, minimization of logical functions, don’t care conditions.
Flip flops, latches, edge triggered flip flops, master slave flip flops. Flip flop applications in data storage, shift registers and counters.
Timing diagrams

Teaching /Learning Methods:

Lectures, Tutorials, Practical Work, and Assignments

Assessment Strategy:

Continuous Assessment	Final Assessment		
40%	60%		
Details: Assignments/Tutorials/Quizzes 25 %, Practical Work 15 %	Theory (%) 60	Practical (%)	Other (%)

Recommended Reading:

- Robert F. Coughlin, Frederick F. Driscoll, (2001) “Operational Amplifiers and Linear Integrated Circuits”, 6th Edition, Prentice Hall
- Maurizio Di Paolo Emilio, (2013) “Data Acquisition Systems – From Fundamentals to Applied Design”, Springer

Semester:	4			
Course Code:	EM2010			
Course Name:	Calculus II			
Credit Value:	2 (Notional hours: 100)			
Prerequisites:	None			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	24	6	-	70

Course Aim:

- To introduce, calculus of functions of several variables, vector valued functions and the use of integral theorems in any orthogonal curvilinear coordinates to solve engineering problems.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Sketch** level curves and level surfaces of functions of two and three variables, and sketch their surfaces and solids.

ILO2: **Compute** double and triple integrals of scalar functions over any given 2D and 3D regions.

ILO3: **Compute** gradient, divergence and curl of a given function using orthogonal. curvilinear coordinates and to solve related problems using cylindrical and spherical coordinates.

ILO4: **Evaluate** line, surface and volume integrals of continuous scalar and vector fields over a given domain and apply integral theorems.

Course Content:

Functions of several variables:

Sketching level curves and level surfaces of functions of two and three variables, sketching surfaces and volumes, limit, and continuity of functions of two and three variables; Tangent planes, gradient vector and directional derivative, scalar line integrals.

Double and Triple Integration:

Definitions of double and triple integrals, double and triple integrals over rectangular domains, double and triple integrals over any general domains; cylindrical and spherical polar coordinates, Jacobian and its properties, applications of double and triple integrals(change of coordinates).

Vector Fields and Vector Operators:

Scalar fields and vector fields, gradient, divergence and curl and their geometrical and physical interpretations.

Line, Surface and Volume Integrals:
Line integrals of vector valued functions and path independence of line integrals, simply connected domains and conservative vector fields, surface integrals of scalar fields and vector fields, area and volume elements in terms of orthogonal curvilinear coordinates; Surface integrals with orthogonal curvilinear coordinates,

Orthogonal curvilinear coordinates, Surface integrals and Integral Theorems: Green's Theorem on the plane, Stokes' theorem and divergence theorem, applications of integral theorems in terms of orthogonal curvilinear coordinates.

Teaching /Learning Methods:
Classroom lectures, tutorial discussions and in-class assignments

Assessment Strategy:

Continuous Assessment 40%	Final Assessment 60%		
Details: Tutorials/Assignments/Quizzes 10% Mid Semester Examination 30%	Theory (%) 60%	Practical (%)	Other (%)

Recommended Reading:

- James Stewart, Calculus, 5th edition, (2006), Thomson Brooks/Cole.
- Watson Fulks, Advanced Calculus and Introduction to Analysis, 3rd Edition,(1978), John Wiley & SonsInc.
- E. B. Saff and A. D. Sinder, Fundamentals of Complex Analysis with Applications to Engineering, Science, and Mathematics, 3rd edition,(2014), Pearson Education Ltd.

Year 3
Semester 5

Semester:	5
Course Code:	CO3010
Course Name:	Embedded Systems
Credit Value:	4 (Notional hours 200)
Pre-requisites:	CO2010
Core/Optional:	Core for Computer Engineering specialization

Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	29	-	40	22	109

Course Aims:

- To provide a broad understanding on developing embedded computer systems containing hardware and software components, and integrating using interfacing techniques.
- To provide practical experience in using current embedded systems technologies, tools, and industrial standards..

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** the characteristics of embedded systems and the operation of associated hardware and software technologies (controllers, peripherals, interfacing and communication);
ILO2: **identify** suitable hardware and software technologies for a specified embedded systems application, and critique design choices;
ILO3: **demonstrate** the application of specified hardware and software technologies in an embedded system.

Course Content: *(Only main topics & subtopics)*

Introduction to embedded systems
Embedded systems and their applications, characteristics and metrics: dependability (availability, reliability, safety, security); efficiency (energy, cost, resource utilization, size/weight, latency/throughput), event-driven architecture and state machines, embedded systems classifications and controller platform types, peripheral devices.

Microcontrollers
Features and applications of microcontrollers, architecture, instructions and addressing modes, memory organization of microcontrollers (program memory, data memory, EEPROM, banked and linear memory architectures), programming process and bootup, assembly and C language

in programming microcontrollers, debugging, general purpose I/O ports and pins, I/O pin configuration (input, strong drive, weak pullup/pulldown, open-drain, tri-state), using parallel I/O for peripheral interfacing (keypads, LCDs, etc.).

Interrupts
Interrupt system (implementation and usage), interrupt vectors and service routines, priority and nesting, interrupts vs. polling, data buffering.

Timing and waveform generation
Timer/counter device operation, timing accuracy, waveform generation, pulse-width-modulation, PWM applications

Data acquisition and control
Digital vs analog signals, analog-to-digital conversion (ADC) and digital-to-analog conversion (DAC), ADC and DAC characteristics (sampling rate, reference voltage, conversion time, precision, range, encoding method), ADC and DAC architectures, sensors and sensing physical qualities, actuators and control of physical quantity

Serial communication
Parallel vs serial I/O, half duplex and full duplex communication, asynchronous and synchronous communication, single-ended and differential signaling, standard protocols and applications (SPI, I^2C, UART, USART, RS232, RS485, USB, CAN), implementation details of a selection of representative communication protocols.

Mobile and networked embedded systems
Networked embedded systems, topologies, data and control flow, wired and wireless connectivity, low-power operation techniques, data security and persistent storage (EEPROM, Flash, SD card, etc.)

Industrial standards
Platform/interface independent communication, MQTT, IEEE-488 and IVI standards, SCADA, OPC UA, PLCs, industrial ethernet, MODBUS, PROFIBUS, PROFINET, ASi, implementation details of selected industry standard protocols

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments	Final Assessment
50%	50%

Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 50%	30%	20%	-

Recommended Reading:

- Microcontrollers and Microcomputers- Principles of Software and Hardware Engineering by Fredrick M. Cady
- Logic and Computer Design Fundamentals by M.M. Mano and C.R. Kime
- Industrial Communication Systems by Bogdan M. Wilamowski and J. David Irwin

Semester:	5				
Course Code:	CO3040				
Course Name:	Cloud Computing Systems				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2040, CO2060, CO2080				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	26	4	14	16	90

Course Aims:

- To provide a broad understanding on design and development of distributed networked software applications.

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Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **design** and **construct** distributed applications using modern tools and techniques, given a set of business and technical constraints;
ILO2: **analyze** a distributed application design to ensure graceful failure, minimizing data loss and downtime when underlying infrastructure or systems software fails;
ILO3: **use** appropriate techniques and tools to protect applications and data from accidental or malicious misuse by users;

Course Content: *(Only main topics & subtopics)*

Networked application preliminaries
Client-server vs peer-to-peer architecture, datagram vs. stream oriented sockets, data serialization: binary vs. text., synchronous (request-response) vs. asynchronous (message-oriented) application protocols, Deutsch's fallacies of distributed computing.

Request-response protocols
HTTP request structure and response structure, metadata and status codes, text serialization formats: JSON.

Concurrency

Concurrency model: processes, threads, coroutines (event driven I/O.), data races and mutual exclusion, race conditions and transactions, statelessness and idempotence, modeling stateful services with finite automata

Remote procedure calls
RPC abstraction and interface definition languages.
RPC failure modes.
Binary serialization formats: Protocol buffers.

Asynchronous coordination
Publish-subscribe protocols: MQTT, message brokers (topics and message routing), message delivery semantics (MQTT QoS): at least once, at most once, exactly once.

Distributed data storage
Streaming datastores: distributed commit logs, BLOB storage: distributed hash tables (key-value stores.), replicas and partitions (shards.), consistency models, Brewer's CAP theorem.

Application security
Threat models (STRIDE), abuse cases and common application vulnerabilities, protocols for web application access control (Oauth) and authentication (Webauthn.), security considerations for "IoT" devices (mutual authentication, root of trust.)

Provisioning and deployment
Cloud platforms: infrastructure as a service vs. platform as a service, infrastructure as code: declarative vs imperative provisioning tools, application packaging: dependency management and containers.

Operability and observability
Defining service level objectives, application logging, metrics and alerting, container orchestration: declarative deployment, rollback and self-healing, incident postmortem and root cause analysis.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%

Details: Practical assignments 30% Quizzes (programming, written, oral) 30%	Theory(%) 40%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- Designing Data-Intensive Applications -- Martin Kleppman. ISBN: 9781449373320 (1449373321)
- Distributed systems for fun and profit -- Mikito Takada.
- Course notes from Columbia University Course COMS 4113
- Building Secure and Reliable Systems -- Heather Adkins, Betsy Beyer, Paul Blankinship, Ana Oprea, Piotr Lewandowski, Adam Stubblefield.

Semester:	5 & 6
Course Code:	CO3060
Course Name:	Computer Systems Design Project
Credit Value:	6 (Notional hours 300)
Pre-requisites:	CO2060
Core/Optional:	Core for Computer Engineering specialization

Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	-	30	38	82	150

Course Aims:

- To provide the students with guidance and opportunity to work as a team to design and implement a real-world cyber-physical system using modern technology, containing a major distributed software component.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **identify** a real-world problem, develop a technological product as a solution, and ***devise*** a feasible project plan to implement the product;
ILO2: apply a breadth of engineering knowledge to **design, implemen**t and **test** a real-world cyber-physical system using industry standard tools and technologies;
ILO3: **justify** design decisions and technology choices with respect to dependability, efficiency and security;
ILO4: **build** devices and software with enhanced usability;
ILO5: **demonstrate** best practices in systems design and development;
ILO6: effectively and coherently **present** information (oral and written).

Course Content: *(Only main topics & subtopics)*

Product Design and Development
Product classification, product development process (concept development, requirement specification, market analysis), project planning, best practices in project management, related tools and technologies.

Cyber-Physical Systems Design

High-level architecture, distributed and networked software, embedded hardware (sensing, control, interfacing and processing), network communication, cloud deployment, related tools and technologies.

Computer Systems and Data Security
Information flow control, network security, hardware security, software applications security, related tools and technologies.

Computer Systems Testing
Test planning, test types, test case design, related tools and technologies.

User-Experience and Usability
User experience vs. user interfaces, best practices in UX design, usability studies, related tools and technologies.

Computer Aided Design and Manufacturing Technologies
Design tools (system design, software design, electronics design, 2D and 3D design), choice of materials, manufacturing tools and technologies.

Effective Presentation of Information
Best practices in oral presentation, online documentation and reporting, related tools and technologies.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 70%	Final Assessment 30%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Progress evaluations on design, implementation and testing (oral/written/online-documentation) 70%	-	-	Final project evaluation (oral/written) 30%

Recommended Reading:

- Cyber-Physical Systems: A Model-Based Approach by Walid M. Taha, Abd-Elhamid M. Taha, Johan Thunberg
- Software Engineering, 10th Edition by Ian Sommerville

Semester:	05				
Course Code:	EF1020				
Course Name:	English for Communication II				
Credit Value:	2 (Notional hours: 100)				
Pre-requisites:	None				
Core/Optional	Core				
Hourly Breakdown	**Lecture hrs.**	**Tutorial hrs.**	**Practical class hrs.**	**Individual/ Group Activities hrs.**	**Independent Learning & Assessment hrs.**
	8	-	-	22	70

Course Aim: To develop the learners' English Language skills to communicate and interact effectively, mainly through a student-centered approach.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to

ILO1: **Demonstrate** fundamental skills of effective communication.

ILO2: **Produce** formal written correspondence effectively to relevant authorities or establishments

ILO3: **Propose** solutions to current problems and communicate them skillfully to a selected audience.

Course Content:

Introduction to fundamentals of effective communication through building up self-confidence and personality. Congruence: Maintaining a balance between expectation and reality through discussions and role play

Communicating effectively and appropriately in familiar social situations. Interactions at the workplace, apologies, excuses, requests, telephone etiquette etc.

Enhancement of presentation skills: Guiding students to do effective presentations on technical and non-technical topics to different types of audiences

Official correspondence: Writing formal letters (letters of request, complaint, invitation, excuse etc.), Writing official e-mails, Introduction to report writing

Interpretation of visual information: Presenting information via charts, graphs etc., Writing compositions, Group presentations based on interpreting information

Teaching/Learning Methods:

- Student centered learning through presentations, interactive group work
- Classroom teaching
- Self-assessment

Assessment Strategy:

Continuous Assessment 60 %	Final Assessment 40 %		
Details: quizzes%, % mid-semester%, % other% (specify) group presentations, ………..20 % individual presentations, …...20% mock interviews, …………...20%	Theory (%) 40 %	Practical (%) -	Other (%) (specify) -

Recommended Reading:

- None

Year 3
Semester 6

Semester:	6
Course Code:	CO3020
Course Name:	Operating Systems
Credit Value:	3 (Notional hours 150)
Pre-requisites:	CO2030, CO2070
Core/Optional:	Core for Computer Engineering specialization

Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	-	20	10	90

Course Aims:

- To provide an understanding on the fundamental concepts in operating systems (OS) and their application in a computer system.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** the role of an OS as a resource manager and a service provider for application execution;
ILO2: **describe** basic OS concepts and abstractions (such as processes and threads, address spaces, files, input/output and information protection) and their implementation;
ILO3: **critique** the tradeoffs involved with realizing the OS concepts on actual hardware.

Course Content: *(Only main topics & subtopics)*

Introduction to Operating Systems
The role of an OS, history of OS, OS kernel, structure of a computer system

An overview of basic OS concepts
High level introduction to processes and threads, concurrency and deadlocks, memory management, file system, scheduling and resource management and information protection

Interrupts and exceptions
Introduction to interrupts, interrupt cycle, exceptions, hardware exception handling, stack frames

System calls
Role of system calls, classes of system calls, system call mechanism and calling conventions

Processes and threads
Introduction to processes and threads, process creation and termination, process/thread states, scheduling, implementation of processes and threads, user-level threads and kernel threads, context switch

Concurrency and synchronization
Critical region and race conditions, mutual exclusion using busy waiting, mutual exclusion using sleep and wake up, realization of mutual exclusion using synchronization primitives such as semaphores, mutexes and monitors, formal definition of a deadlock, deadlock modeling, deadlock detection and recovery, deadlock avoidance, deadlock prevention

Memory management
Memory hierarchy, fixed and dynamic memory partitioning, swapping, virtual memory, introduction to paging, page tables, speeding up paging, page replacement policies, virtual memory design and implementation issues, segmentation

File systems
File naming, file structure, file types, file access methods, file attributes, file operations, directories, directory organization, directory properties, directory operations, file system implementation, virtual file system, file system management and optimization

Input/output (I/O) management
I/O devices, device controllers, memory-mapped I/O, bus architectures, interrupts, I/O software, programmed I/O, interrupt-driven I/O, direct memory access (DMA), I/O management software: interrupt handlers, device drivers, device independent I/O software

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 50%	50%	-	-

Recommended Reading:

- Modern Operating Systems, Fourth Edition, Andrew S. Tanenbaum
- Operating System Concepts, 10th Edition, Silberschatz, Abraham, Peter B. Galvin, and Greg Gagne.

Semester:	6				
Course Code:	CO3030				
Course Name:	Computer Systems Security				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	CO2040, CO2060, CO2080				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	23	-	-	14	63

Course Aims:

- To provide a broad understanding about the importance of computer systems security, security vulnerabilities present at various levels in computer systems, and approaches to mitigate them.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **identify** security vulnerabilities in a given computer system;
ILO2: **assess** the impact of security vulnerabilities in a given computer system;
ILO3: **propose** viable solutions to well defined security issues in computer systems;

Course Content: *(Only main topics & subtopics)*

Introduction to Computer Systems Security
Importance of computer systems security (history, breaches and impact), basic concepts, threat models, common security goals.

Cryptography Basics
Introduction, modern cryptographic protocols (and their history, applications, depreciation), encryption, authentication, message authentication codes, hash functions, one-way functions, secret and public-key cryptography, secure channels, zero-knowledge proof, integration of cryptographic protocols into distributed systems and other applications.

Software Security
Importance of software security, authentication vs authorization and their importance, sandboxing.

Network Security

Importance, secure protocols (TCP/IP), firewalls, network segmentation, intrusion and detection.

Web Security
Importance of web security, SSL, HTTPS, basic authentication, oauth2, authorization and fine grain permission validation (OPA, XACML), SSO (SAML).

Hardware Security
Hardware security modules, side-channel attacks, hardware trojans

Advanced Topics
A selection of modern topics such as blockchain and cryptocurrency, privacy and secure communications, trusted computing, mobile security, operating systems security, ethical hacking, AI-driven security, data protection regulations (GDPR, POPI etc), compliance certifications.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 40%	Final Assessment 60%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments & quizzes 40%	60%	-	-

Recommended Reading:

- Introduction to Modern Cryptography (2nd Ed) by Katz and Lindell

Semester:	6					
Course Code:	CO3050					
Course Name:	Signal Processing					
Credit Value:	3 (Notional hours 150)					
Pre-requisites:	EM2010, EM2020					
Core/Optional:	Core for Computer Engineering specialization					
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**	
	29	5	10	12	94	

Course Aims:

- To provide an in-depth understanding of signal processing techniques and a broad exposure to their applications in computer engineering.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **analyze** linear time-invariant systems used in engineering;
ILO2: **apply** digital signal processing techniques in engineering design;
ILO3: **describe** the theory and applications of digital image processing techniques;
ILO4: **describe** the design and implementation of wireless and mobile communication systems.

Course Content: *(Only main topics & subtopics)*

Signal Analysis

Classification of signals: deterministic (periodic and aperiodic); random; continuous (analog); discrete-time; and digital signals, signal sources, mathematical representation of basic deterministic signals, transformation of the independent variable (time shift, time scaling, and time reversal).

Time Domain Processing of Signals

Introduction, convolution integral and convolution sum, autocorrelation and cross-correlation, implementing correlation using convolution, Fourier series – periodic signals, trigonometric Fourier series, exponential Fourier series, Fourier series of odd and even functions, half-range Fourier series, complex notation, amplitude and phase spectra, properties of Fourier series, Parseval's theorem, power spectral density.

Frequency Domain Processing of Signals

Fourier transform & inverse transform, energy spectral density, autocorrelation function, power spectral density and energy spectral density via autocorrelation, Laplace transform, bandwidth in relation to time constant, definition of dB, Bode plots with straight line approximation, Nyquist plots, resonance.

Digital Signal Processing
Sampling of continuous-time signals, discrete time signals, information theory - information content of signals, transmission of information, Hartley and Shannon's Law and its applications, Fourier transform of discrete time signals (DTFT), discrete Fourier series (DFS), discrete Fourier transform (DFT), fast Fourier transform (FFT), z-transform, z transform vs Fourier transform vs Laplace transform, filters, filter design: FIR filter design (inverse Fourier transform and windowing), IIR design (Butterworth, Chebychev, impulse method, etc.)

Image Processing
Human vision system, sampling and quantization, pixels and their relationships, adjacency, distance measures, image enhancement and restoration - spatial domain techniques; pixel point processing, pixel group processing, color systems, color to grayscale conversion.

Cellular and Wireless Network Principles
The cellular concept, wireless local area networks, wireless broadband access systems, wireless wide area networks, mobility management, WiMAX network architecture.

Mobile Networks
Global System Mobile (GSM) communication architecture, other cordless communications systems, Universal Mobile Telecommunications System (UMTS) architecture, modern technology: HSPA and LTE Architecture, 5G and beyond.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details: Practical Assignments & Quizzes 50%	Theory(%) 50%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- Signals and System by Alan Oppenheim, Alan Willsky, with Hamid
- Computer Networking: A Top-Down Approach, by Jim Kurose and Keith W. Ross
- Discrete-Time Signal Processing - 2nd Edition - Alan V. Oppenheim and Ronald W. Schafer
- Digital Signal Processing - A practical approach (2nd Edition) - E.C.Ifeachor and B.W. Jervis

Semester:	6				
Course Code:	CO3090				
Course Name:	Machine Learning Theory				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	CO2030, EM2020, EM2060				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	17	-	26	-	57

Course Aims:

- .To introduce students to the mathematical foundations of machine learning.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** the theory and applications of machine learning;
ILO2: **derive** learning algorithms from first principles and **quantify** their performance;
ILO3: **construct** systems to identify patterns from data, by **applying** suitable learning techniques;

Course Content: *(Only main topics & subtopics)*

Introduction
Biological motivations: the McCulloch and Pitts neuron, Hebbian learning, statistical motivations, Generalization: define learning from data, the power of machine learning methods, define a learning algorithm, state-of-the-art applications of machine learning theory.

Probability
Probability as representation of uncertainty in models and data, Bayes Theorem and its applications, law of large numbers and the Multivariate Gaussian distribution.

Optimisation
Convexity, 1-D minimisation, gradient methods in higher dimensions, constrained optimisation

Linear Algebra in machine learning

Using matrices to find solutions of linear equations, properties of matrices and vector spaces, eigenvalues, eigenvectors and singular value decomposition.

Supervised Learning
Regression analysis, classification using Bayesian principles, perceptron learning, support vector machines (SVM) and introduction to kernel methods, artificial neural networks (ANN) / multi-layer perceptrons (MLP), features and discriminant analysis.

Data handling and unsupervised learning
Principal components analysis (PCA), K-Means clustering, spectral clustering.

Regression and Model-fitting Techniques
Linear regression, polynomial fitting, kernel based networks

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 40%	Final Assessment 60%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments & quizzes 40%	60%	-	-

Recommended Reading:

- Bishop, Christopher M.. Pattern Recognition and Machine Learning.
- Mackay, David J. C.. Information Theory, Inference and Learning Algorithms

Semester:	6
Course Code:	CO3100
Course Name:	Research Methodology
Credit Value:	1 Cr (Notional hours 50)
Pre-requisites:	None
Core/Optional:	Core for Computer Engineering specialization

Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	1	-	14	14	21

Course Aims:

- The aim of the module is to guide the students to work as a team to identify a research problem related to computer engineering, and familiarize them with the scientific methodology of planning and carrying out a research project.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **formulate** a scientific question and **propose** potential solutions;

ILO2: **develop** a research project plan based on the scientific method.

Course Content: *(Only main topics & subtopics)*

Introduction
Introduction to research, research ethics, formulating a research question.

Review of existing work
Referring research articles, literature review.

Scientific method
Research project planning, scientific experiments, statistical methods, scientific writing, peer evaluation.

<table>
<tr><td colspan="4">Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.</td></tr>
<tr><td colspan="4">Assessment Strategy:</td></tr>
<tr><td>Continuous Assessments
70%</td><td colspan="3">Final Assessment
30%</td></tr>
<tr><td>Details:

Literature review (examiners and peer evaluation) 70%</td><td>Theory(%)

-</td><td>Practical(%)

-</td><td>Other(%)(specify)

Preliminary project proposal 30%</td></tr>
<tr><td colspan="4">Recommended Reading:

● How to Write a Better Thesis by David Evans, Paul Gruba, Justin Zobel</td></tr>
</table>

Short Semester 2

Semester:	Short				
Course Code:	CO4010				
Course Name:	Professional Practices for Computer Engineers				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	10	-	20	20	50

Course Aims:

- .To prepare the students for a career in computer engineering by providing exposure to professional practices and modern expectations in the domain.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **plan** their computer engineering education and career;
ILO2: **demonstrate** their portfolio of skills and knowledge related to the computer engineering profession;
ILO3: **appraise** the importance of professional conduct, ethics and relationships, and complexities therein.

Course Content: *(Only main topics & subtopics)*

Computer Engineering Profession
Education, career prospects, continuous professional development, certification and licensing, professional conduct and ethics, nature and role of professional societies, nature and role of engineering standards, economic impact of computer systems, employment contracts, intellectual property and legal issues, documentation, trade-off analysis, communication skills.

Portfolio Development
Importance of building a portfolio, developing and maintaining a portfolio.

Group Dynamics and Psychology

Dynamics of working in teams/groups, individual cognition, dealing with problem complexity, interacting with stakeholders, dealing with uncertainty and ambiguity, conflict resolution, dealing with multicultural environments.			
Teaching/Learning Methods: Flipped classrooms, small group discussion classes, project-based learning.			
Assessment Strategy:			
Continuous Assessments 70%	Final Assessment 30%		
Details: Practicals & quizzes 70%	Theory(%) 30%	Practical(%) -	Other(%)(specify) End of course evaluation (oral/written/portfolio)
Recommended Reading: ● *None*			

Semester:	Short				
Course Code:	CO4020				
Course Name:	Software Project Management				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	None				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	22	-	6	10	62

Course Aims:

- To familiarize students with techniques and tools available to plan, predict, execute, monitor and finalize software projects.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** software project management best practices;
ILO2: **describe** complexities involved in managing a software project.

Course Content: *(Only main topics & subtopics)*

Introduction to Project Management
Project goals and objectives, project assumptions and forecasts, project deliverable, project plan/budget development and management, cost/benefit analysis.

Project life cycle and organization
Software measurement and estimation techniques,scheduling and tracking using project management tools, implementation of plans, and measurement process.

Team structures
Team processes including responsibilities for tasks, meeting structure and work schedule, roles and responsibilities in a software team, team conflict resolution, risks associated with virtual teams (communication, perception, and structure), and factors affecting teams.

The role of risk in the life cycle

Risk identification and management, risk categories including security, safety, market, financial, technology, people, quality, structure and process, risk analysis and evaluation, risk tolerance (e.g., risk-averse, risk-neutral, risk-seeking), risk planning.

Project Quality management
Quality metrics, quality models and characteristics, value and costs of quality, software process quality vs. product quality.

Application quality requirements
Criticality of the system, dependability and integrity levels, software quality management techniques (static, people-intensive techniques, dynamic techniques), quality measurement.

Process improvement models
Concept of process improvement, improvement models, CMM, CMMI, CQI, ISO9000, PDCA.

Project Management topics
Communication management;plan communication, reporting performance, time management; WBS, project scheduling, precedence diagrams, tools for project management, project scope management (project scoping, requirements development and management)

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50 %		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments & quizzes 50%	50%	-	-

Recommended Reading:

- Software Project Management, Bob Hughes, Mike Cotterell and Rajib Mall.

<table>
<tr><td>Semester:</td><td colspan="5">Short</td></tr>
<tr><td>Course Code:</td><td colspan="5">CO4030</td></tr>
<tr><td>Course Name:</td><td colspan="5">Information Systems Management</td></tr>
<tr><td>Credit Value:</td><td colspan="5">2 (Notional hours 100)</td></tr>
<tr><td>Pre-requisites:</td><td colspan="5">None</td></tr>
<tr><td>Core/Optional:</td><td colspan="5">Core for Computer Engineering specialization</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs</td><td>Tutorial hrs</td><td>Practical class hrs</td><td>Design hrs</td><td>Independent Learning & Assessment hrs</td></tr>
<tr><td>20</td><td>-</td><td>-</td><td>20</td><td>60</td></tr>
</table>

Course Aims:

- To introduce the complexities related to designing, developing, commissioning and maintaining information systems (IS) for a large scale business.
  .

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** the composition, lifecycle and the resources required to develop and manage an information system;
ILO2: **analyze** a given information system and **assess** its impact on business.

Course Content: *(Only main topics & subtopics)*

Relationship between IS and Business
Introduction to IS, aligning IT (information technology) with the core competencies and strategies of the firm, assess the impacts of IT on the organizations competitive position, role of IS in defining and shaping competition.

IS Planning and Budgeting
Translate strategic and IT objectives into operating principles for IS planning, managing the information systems function, structuring the IS organization, hiring, retaining, and managing IS professionals, managing a mixed set of internal and external resources, determining staffing skills allocation models.

Acquiring Information Technology Resources and Capabilities

Acquiring infrastructure capabilities, sourcing information systems and services, sourcing information systems applications, financing and evaluating the performance of information technology investments and operations.

Risk Management
Managing business continuity, managing security and privacy, using IS/IT governance frameworks.

Case study

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details: Practical assignments, case studies, quizzes 50%	Theory(%) 50%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- Information Systems for Business and Beyond by David T. Bourgeois, Biola University, James L. Smith, Shouhong Wang, Joseph Mortati

Semester:	Short				
Course Code:	CO4060				
Course Name:	Computer Engineering Research Project				
Credit Value:	6 (Notional hours 300)				
Pre-requisites:	CO3100				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	4	26	-	120	150

Course Aims:

- To provide the students, as a team, the opportunity to plan and execute a project that involves a major computer engineering research component, and report on the findings.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **devise** a research proposal and a project plan;
ILO2: **evaluate** scientific literature related to a research problem;
ILO3: **investigate** methods to achieve project aims and objectives and **justify** design decisions;
ILO4: effectively and coherently **report on** the findings of the project (oral and written).

Course Content: *(Only main topics & subtopics)*

Research planning and management
Developing a research problem, devising a project plan, reference management, managing data, reading and critically assessing literature.

Empirical research
Design and conducting of experiments, experimental evaluation, statistical methods.

Research writing
Standard structures for writing research, writing process, appropriate writing styles, common fallacies when writing research.

Publishing research
Publication process, peer-review, ethics in publications, being a reviewer.

Presenting Research
Delivering a research presentation, poster presentations

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 70%	Final Assessment 30%		
Details: Project proposal and literature review 15% Progress evaluations: (oral/written/online-documentation) 30% Evaluation by the supervisor 25%	Theory(%) -	Practical(%) -	Other(%)(specify) Final project evaluation (oral/written) 30%

Recommended Reading:

- How to Write a Better Thesis by David Evans, Paul Gruba, Justin Zobel

Year 4
Semester 7

Semester:	7				
Course Code:	CO3070				
Course Name:	Fundamentals of Artificial Intelligence				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2030				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	38	-	14	-	98

Course Aims:

- To impart a working knowledge of the foundations of modern Artificial Intelligence and enable students to use them in designing intelligent systems.

Intended Learning Outcomes:

ILO1: <u>apply</u> concepts and algorithms at the foundation of modern Artificial Intelligence to identify potential applications in real-life product design, commercial/trade and scientific problems;
ILO2: <u>analyze</u> and <u>formulate</u> the problem for solving using Artificial Intelligence fundamentals and concepts;
ILO3: <u>develop</u> prototype solutions to the formulated problem and validate them.

Course Content: *(Only main topics & subtopics)*

Introduction
Introduction to Artificial Intelligence: What is AI? Foundations and History of AI; Mapping the Current state of AI; Intelligent Agents: Agents and Environments; Rationality; Structure of Agents.

Search
Solving Problems by Searching: Problem solving, basic search algorithms, uninformed search strategies, informed (heuristic) search strategies, Heuristic Functions. Adversarial Search: Game Theory, Minimax Search, Alpha-Beta pruning, Heuristic Alpha-Beta search.

Optimization

Search in Complex Environments: Local Search & Optimization problems, Search with Non-Deterministic actions, Search in Partially observable environments, Online search problems. Constraint Satisfaction Problems.

Knowledge, Reasoning and Planning
Knowledge Representation: Logic, Propositional Logic, First Order Logic, Knowledge Engineering, Logical Inference: Inference in First order Logic.

Uncertainty
Quantifying Uncertainty: Probability theory; Probabilistic Reasoning: Bayesian Networks; Probabilistic Reasoning Over time: Markov Models.

Machine Learning, Neural Networks and NLP
Introduction to the general areas of Machine Learning, Reinforcement Learning, Neural Networks and Natural Language Processing.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details: Practical assignments and quizzes 60%	Theory(%) 40%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- S. Russell and P. Norvig *Artificial Intelligence: A Modern Approach* Prentice Hall, 2020, Fourth Edition.

Semester:	7				
Course Code:	CO3080				
Course Name:	Applied Operating Systems				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	CO3010, CO3020				
Core/Optional:	Core for Computer Engineering specialization				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	21	-	6	12	61

Course Aims:

- To provide a broad understanding on the advanced concepts of applied operating systems such as real-time operating systems, virtualization and security.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** specialized operating system concepts such as real-time operating systems, virtualization and security;
ILO2: **critique** the tradeoffs involved with realizing specialized OS concepts on actual hardware

Course Content: *(Only main topics & subtopics)*

Real Time Operating Systems

- **Introduction to Real-Time Systems**
  Definition of a real-time system, functional and non-functional requirements of a real-time system, examples of real-time systems.
- **Basic concepts of Real-Time Operating Systems (RTOS)**
  The purpose of RTOS, RTOS components, concept of tasks, task scheduling, inter-task communication.

Virtualization

- **Fundamentals of Virtualization**
  History of virtualization, requirements for virtualization, types of hypervisors, techniques for efficient virtualization.
- **Memory Virtualization**

Virtual memory considerations for virtual machines, shadow page tables, hardware support for nested page tables, reclaiming memory.

- **I/O Virtualization**
  I/O MMUs, device domains, single-root I/O virtualization.
- **Operating Systems in Cloud Computing**
  Clouds as a service, virtual machine migration, checkpointing.

Operating Systems Security
Importance of operating system security, secure environment, access control, malware and defenses.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 40%	Final Assessment 60%		
Details: Practical assignments & quizzes 40%	Theory(%) 60%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- "Real Time Systems" by Jane W. S. Liu
- "Modern Operating Systems" by Andrew S. Tanenbaum

Semester:				
Course Code:	EF4010			
Course Name:	Industrial Training			
Credit Value:	6 (Notional hours: 960)			
Prerequisites:	-			
Core/Optional	Core			
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Practical hrs.	Independent Learning & Assessment hrs.
	5	-	960 (24 weeks)	-

Course Aim: To provide an industrial exposure for the students to acquire knowledge, develop professional skills, and demonstrate the requisite work ethics and attitudes for achieving success in their career opportunities and a smooth transition from an academic environment to an industrial/ research environment

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **Describe** the background, Management structure, Standard Operating Procedures, Occupational health and safety procedures of the organization.

ILO2: **Explain** how Engineering Principles are applied in real industrial situations, practical issues arise and possible solutions in such applications and Quality assurance standards and practices.

ILO3: **Describ**e Ethical practices, Professionalism, Social aspects and Sustainability practices in industrial/ research environments.

ILO4: **Demonstrate** the training experience through a daily diary, formal report, oral presentation and viva.

Course Content:

Introduction to the Industrial Training Programme :
Overview of the industrial training programme including its importance, parties involved and their responsibilities, schedules of training programme, procedures of arrangement of training, reporting for training and documentary work, behavior during the training period

Guidelines for demonstration of the knowledge and experience gained through training :
Maintenance of daily diary, report writing, effective presentations

Industry exposure through training in industrial/ research organizations :
Understanding the background of the organization, Management structure and

operational procedures, application of engineering fundamentals, issues and possible actions, quality assurance practices, health and safety practices, ethical practices, professional ways to handle situations, social and sustainability practices, effective communication

Teaching /Learning Methods: In-plant training

Assessment Strategy:

Continuous Assessment 10%	Final Assessment 90%		
Details: Mid Training Presentation - 10%	Theory (%)	Practical (%)	Other (%)
	-	90%	-

Recommended Reading:

- Collins, S., Ghey, J. and Mills, G. (2004). *The Professional Engineer in Society*. India:Jessica Kingsley.
- Iesl.lk, (2019). IESL Code of Ethics. [online] Available at: https://iesl.lk/index.php?option=com_content&view=article&id=20:code-of ethics&catid=14&lang=en&Itemid=138 [Accessed: 10 June 2019].

Technical Electives

<table>
<tr><td>Semester:</td><td colspan="5">4/5/6/7</td></tr>
<tr><td>Course Code:</td><td colspan="5">CO5010</td></tr>
<tr><td>Course Name:</td><td colspan="5">Advanced Embedded Systems</td></tr>
<tr><td>Credit Value:</td><td colspan="5">3 (Notional hours 150)</td></tr>
<tr><td>Pre-requisites:</td><td colspan="5">CO2070</td></tr>
<tr><td>Core/Optional:</td><td colspan="5">Optional (Technical Elective)</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs</td><td>Tutorial hrs</td><td>Practical class hrs</td><td>Design hrs</td><td>Independent Learning & Assessment hrs</td></tr>
<tr><td>30</td><td>-</td><td>-</td><td>30</td><td>90</td></tr>
</table>

Course Aims:

- The aim of the module is to expose students to techniques and methodology in embedded system design with hands-on experience in design, simulation and implementation of real-world non-trivial embedded systems using Electronic Design Automation (EDA) tools.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **appraise** the techniques and methods of embedded systems design;
ILO2: **propose** and **implement** optimizations on non-trivial embedded systems, and **evaluate** the impact;
ILO3: **demonstrate** competence in using EDA tools for embedded systems design.

Course Content: *(Only main topics & subtopics)*

Introduction to Embedded Systems
Embedded systems overview, Design challenges and optimizing design metrics, Processor/IC/design technologies, Embedded system design tradeoffs and design productivity gap, Microprocessor and microcontroller architectures.

Custom Single-purpose Processors: Hardware

Combinational and sequential logic, Custom single-purpose processor design, Register transfer level customization and its optimization methods, Standard single-purpose processors.

General-purpose Processors: Software
General-purpose architecture and operations, programmer's view of the architecture, Embedded systems programming, Application specific instruction-set processors, Selecting microprocessors, General purpose processor design.

Embedded System Modeling: State Machine and Concurrent Process Models
Models vs. languages, text vs. graphics, Finite-state machine models and finite-state machines (FSM) with datapath models (FSMD), Hierarchical/concurrent state machine models (HCFSM) and the Statecharts language, Program-state machine model (PSM), Concurrent processes and communication and synchronization among processes, Dataflow model.

Design Technologies of Embedded Systems
Design automation and synthesis – logic, RTL and behavioral, Reusability and Intellectual Property (IP) cores, Design process models.

Hardware/Software Co-design of Embedded Systems
System synthesis and hardware/software co-design, hardware/software co-simulation for verification.

Operating Systems for Embedded Systems
Types of OS/software construction methods and their merits/demerits, Requirements placed on embedded OS, real-time embedded OS – requirements and scheduling.

Design Example
User's perspective, Designer's perspective, Informal and formal specifications, Design and implementation.

System on a Chip (SoC)
Design of a SoC incorporating CPU and peripherals, implementation and testing on FPGA hardware.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments	Final Assessment
60%	40%

Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 60%	40%	-	-

Recommended Reading:

- Embedded System Design: A Unified Hardware/Software Approach by Frank Vahid and Tony Givargis

Semester:	4/5/6/7				
Course Code:	CO5020				
Course Name:	Advanced Computer Architecture				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2070				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	28	-	16	18	88

Course Aims:

- The aim of the module is to expose students to advanced concepts in computer architecture and allow them to assess their impact.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **explain** advanced concepts in computer architecture and **evaluate** their impact on efficiency and dependability;

ILO2: **use** hardware description languages to implement advanced CPU features and test them.

Course Content: *(Only main topics & subtopics)*

Instruction Level Parallelism (ILP) - Advanced Concepts

Concepts, challenges and limitations of instruction level parallelism, pipeline hazards and hardware level solutions, overcoming dependency boundaries with dynamic scheduling, superscalar processors, multiple issue processors, performance improvement of multi-issue processors with instruction level parallelism, static and dynamic branch prediction, in-order vs out of order execution, speculative execution mechanisms, thread level parallelism.

Memory Hierarchy Design - Advanced Concepts

Review of caches, improving performance of caches: reducing miss penalty/rates and hit time, reducing cache miss penalty and miss rate via parallelism, prefetching, virtual memory protection, shared-memory architectures: symmetric and distributed, performance of shared-memory architectures.

Interfacing and Communication - Advanced Concepts
Types and characteristics of I/O devices, handshaking, buffering, buses (types of buses, synchronous and asynchronous buses, bus masters and slaves, bus arbitration, bus standards), programmed I/O, interrupt driven I/O, interrupt structures (vectored and prioritized, interrupt overhead), direct memory access.

Special Purpose Processors
Processor customization based on applications (application specific integrated circuits: ASIC, application specific instruction-set processors: ASIP, field programmable gate arrays: FPGA, systems-on-chip: SoC), networks-on-chip: NoC (flow control, routing, router design), graphics processors (CUDA language, traditional GPUs, modern GPGPUs), reliable and secure processor architectures (ACID properties, basic cryptography, secure processors (Intel SGX), side-channel attacks), low power design, computer architectures for AI and ML.

Hardware Description Languages and Simulation
Using a hardware description language (HDL) to model a RISC processor, introduction to hardware simulators, hardware testing and verification using HDL simulation tools.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- David Patterson, John L. Hennessy, Computer Organization and Design: The Hardware/Software Interface (ARM, MIPS and RISC-V) Editions

Semester:	4/5/6/7				
Course Code:	CO5030				
Course Name:	Advanced Operating Systems				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	-	-	30	90

Course Aims:

- The aim of the module is to expose students to advanced concepts in operating systems and the complexities arising when implementing them.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **explain** advanced concepts in operating systems, and **evaluate** their impact on managing resources in a computer system efficiently and dependably;

ILO2: **implement** advanced operating system features and test them.

Course Content: *(Only main topics & subtopics)*

Introduction to operating system design
Introduction to monolithic, layered, microkernel based designs.

Introduction to microkernel
Microkernel abstractions (using L4), system calls and usages. Debugging support.

Microkernel based systems
History of microkernel, user-level page-fault handlers, device drivers, interrupts.

Managing virtual memory
Page tables structures, Translation lookaside buffer (TLB), caches, 64bit address spaces, IPTs, GPTs, name spaces, naming and protection.

Process management

Processes verses threads, protection verses execution, context switching, IPC.

File systems
Files verses virtual memory, single address space operating systems, blocking verses non-blocking operations.

Threads
Implementations issues, kernel verses user-level threads, scheduling, thread local storages, stack, threads verses events.

System calls
Implementation issues, security, argument passing.

I/O handling
Device drivers, user-level drivers, DMA, IO address spaces.

Security
Access control, Turing completeness, decidability, ACL verses capabilities

Research topics
Virtual machine monitors, separation kernels, Exokernels, verifications, full virtualisation verses para-virtualisation.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- "Modern Operating Systems" by Andrew S. Tanenbaum

Semester:	4/5//6/7				
Course Code:	CO5040				
Course Name:	Compilers				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2030				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	33	-	8	16	93

Course Aims:

- To provide a strong understanding of the role of the compilers and basics of compiler implementation.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **<u>Describe</u>** the basic phases of a modern compiler.
ILO2: **<u>Apply</u>** the knowledge of compiler theory to **<u>implement</u>** a complete compiler for a simple programming language.

Course Content: *(Only main topics & subtopics)*

Programming languages and their evolution
Inception and evolution of programming languages, programming language design & implementation, economy of programming languages, structure of a compiler.

Lexical analysis
Role of the lexical analyzer, regular languages, regular specification, finite automata (FA), converting regular specification into non-deterministic finite automata (NFA), converting and NFA to deterministic finite automata (DFA), implementation of FA.

Parsing
Parsing process, context-free grammars, derivations, ambiguity, top-down parsing and bottom-up parsing, recursive descent parsing, predictive parsing, shift-reduce parsing, handles, recognizing handles.

Semantic analysis

Symbol table design and implementation, scope, type checking, static and dynamic typing, self-typing.

Optimization

Intermediate code, local optimization, global optimization, dataflow analysis, constant propagation, loops, ordering, liveness analysis, register allocation, cache management.

Code generation

Runtime organization, activations, activation records, globals and heap, alignment, code generation process, temporaries, object layout.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details: Assignments and quizzes 50%	Theory(%) 50%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- Keith D. Kooper and Linda Torczon. Engineering a Compiler. Second Edition.
- Dick Grune, Kees van Reeuwijk, Henri E. Bal. Modern Compiler Design, Second Edition.

Semester:	4/5/6/7				
Course Code:	CO5050				
Course Name:	Programming Languages				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2030				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	27	-	-	36	87

Course Aims:

- The aim of the module is to familiarize the students on the design and implementation of different types of programming languages and the theoretical background of them.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **compare** different types of programming languages and **explain** their underlying similarities and differences.

Course Content: *(Only main topics & subtopics)*

Introduction
Design of Languages, Imperative and Declarative paradigms, Syntax and semantics, Data and procedural abstraction, Static and dynamic typing, Modularity, Programming tools.

Imperative Languages
Assignment operator, Sequential control structure, Imperative programming.

Object Oriented Languages
Classes, Inheritance, Polymorphism, Dynamic dispatch, object oriented programming.

Functional Languages
Higher order functions, Referential transparency, Lambda Calculus, Strict and lazy evaluation, Functional Programming.

Logical Languages
Facts and rules, Inference, logical programming.

Concurrent Languages
Processes, Nondeterminism, Concurrent control structure, Inter-process communication, Concurrent programming.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- Pierce, Benjamin C. Types and programming languages. MIT press, 2002.
- Scott, Michael Lee. Programming language pragmatics. Morgan Kaufmann, 2000.

Semester:	4/5/6/7				
Course Code:	CO5060				
Course Name:	Theory of Computation				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	EM1050				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	37	-	-	16	97

Course Aims:

- To give students an appreciation of the fundamental questions of computer science, namely, computability and complexity in the context of abstract computing machines.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Describe** automata theory, computability theory and computational complexity theory.
ILO2: **Appraise** the role of the aforementioned theories in computational problem solving.

Course Content: *(Only main topics & subtopics)*

Preliminaries

Trees and graphs, Set notations, relations, inductive proofs.

Finite Automata, Regular Expressions and Properties of Regular Sets

Finite state systems, Non-deterministic finite automata, Regular expressions, Two-way finite automata, Applications of finite automata, Properties of Regular Sets: the pumping lemma, closure properties and decision algorithms, Minimization of finite automata.

Context-Free Grammars (CGF) and Properties of Context-Free Languages (CFL)

Introduction to context-free grammars, Derivation trees, Normal forms: Chomsky and Greibach, Inherently ambiguous context-free languages, Context-Free Languages: the pumping lemma, closure properties and decision algorithms.

Pushdown Automata

Informal description of pushdown automata, pushdown automata and context-free languages.

Turing Machines
Introduction to Turing Machines and the Turing machine model, Computable languages and functions, Techniques for Turing machine construction and modifications, Church's hypothesis, Turing machines as enumerators, Restricted Turing machines equivalent.

Undecidability
Decidable and undecidable problems, Properties of recursive and recursively enumerable languages, Universal Turing machines and an undecidable problem, Rice's theorem and more undecidable problems, Undecidability of Post's correspondence problem, Greibach's theorem, Introduction to recursive function theory, Oracle computations.

Complexity Theory
Linear speed-up, tape compression, and reductions in the number of tapes, Hierarchy theorems, Relations among complexity measures, Translational lemmas and nondeterministic hierarchies, Properties of general complexity measures, Axiomatic complexity theory.

Intractable Problems
Polynomial time and space, Some NP-complete problems, The class co-NP, PSPACE-complete problems, Complete problems for P and NSPACE(log n), The P = NP question for Turing machines with oracles: limits on the ability to tell whether P = NP.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Assignments and quizzes 50%	50%	-	-

Recommended Reading:

- Introduction to the Theory of Computation by Michael Sipser, Third Edition.

Semester:	4/5/6/7				
Course Code:	CO5070				
Course Name:	Parallel Computation and Algorithms				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2070				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	-	12	18	90

Course Aims:

- The aim of the module is to familiarize students with advanced concepts on parallel processing techniques and parallelization at algorithm level.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **explain** advanced concepts on parallel processing in hardware and parallelization of algorithms;

ILO2: **evaluate** the impact of parallel processing techniques.

Course Content: *(Only main topics & subtopics)*

Computer Architecture - Advanced Concepts

Superscalar architectures, branch prediction, prefetching, speculative execution, scalability, short vector instruction sets.

Parallel Computation

Parallel processing, parallel machine models (SIMD, MIMD, numeric and non-numeric applications), instruction level parallelism, pipelined processors, pipelining and operation overlapping.

Multiprocessing

Systolic architectures, interconnection networks (hypercube, shuffle-exchange, mesh, crossbar), shared memory systems, cache coherence, memory models and memory consistency, Distributed and shared memory systems (PVMs, multi-tasking and multi-threading).

Design of high performance processing units
VLSI WSI architectures for parallel computing, performance evaluation.

Parallel Algorithms
Characteristics and applications for parallel and real-time systems, specification techniques, parallelizability of algorithms, parallelisation of matrix computation, the finite element method and optimization techniques

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- David Patterson, John L. Hennessy, Computer Organization and Design: The Hardware/Software Interface (ARM, MIPS and RISC-V) Editions

Semester:	4/5/6/7
Course Code:	CO5080
Course Name:	Cyber Physical Systems
Credit Value:	3 (Notional hours 150)
Pre-requisites:	None
Core/Optional:	Optional

Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	-	-	30	90

Course Aims:

- The aim of the module is to expose students to the concepts of Cyber Physical Systems (CPS). The students will appreciate the multidisciplinary nature in modeling and developing CPS.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **model** CPS mathematically ;
ILO2: **integrate** sensors and actuators to CPS;
ILO3: **apply** coordinate transformations for CPS;
ILO4: **develop** static and dynamic controllers.

Course Content: *(Only main topics & subtopics)*

Introduction to Cyber Physical Systems

Modelling physical systems

Hybrid systems

Control theory

Modelling computational systems

Coordinate transformation

Project to develop a cyber physical system

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical Assignments 40%	40%	-	-

Recommended Reading:

- Cyber Physical Systems, A Model Based Approach, Walid M.Taha et.al. Springer, 2021

Semester:	4/5/6/7				
Course Code:	CO5090				
Course Name:	Advanced Algorithms				
Credit Value:	2 (Notional hours 100)				
Pre-requisites:	CO2030				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	19	-	-	22	59

Course Aims:

- To explore a variety of techniques that apply broadly in the design of efficient algorithms, and study their uses in a wide range of application domains and computational models.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **analyze** a given non-trivial computational problem, and **justify** the selection of an appropriate algorithmic technique in order to develop a solution;

ILO2: **plan** an efficient algorithmic solution for a given non-trivial computational problem, and **evaluate** the solution.

Course Content: *(Only main topics & subtopics)*

Introduction
Introduction to the course and topics

Advanced solutions to data structure problems
Fibonacci heaps as priority queues, shortest path problem, minimum spanning tree problem.

Network flow problems
Maximum flow, minimum cost flow, minimum cost circulation.

Linear programming
Formulation of problems as linear programs, duality, simplex, interior point and ellipsoid algorithms.

Dealing with intractability
Approximation techniques, fixed-parameter algorithms.

Dealing with large data sets
Compression, streaming algorithms, compressed sensing.

Computational geometry
Geometry and dimensions, range trees, sweep algorithms, Voronoi diagrams.

Online algorithms
Ski rental problem, river search problem, paging, adversaries, randomization, k-server problem.

External-memory algorithms
Accounting for the cost of accessing data from slow memory, cache-oblivious algorithms.

Parallel algorithms
Circuit model, PRAM model, work-efficient algorithms.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 40%	Final Assessment 60%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 40%	60%	-	-

Recommended Reading:

- Advanced Algorithms and Data Structures by Marcello La Rocca

<table>
<tr><td>Semester:</td><td colspan="5">4/5/6/7</td></tr>
<tr><td>Course Code:</td><td colspan="5">CO5210</td></tr>
<tr><td>Course Name:</td><td colspan="5">Advanced Computer Communication Networks</td></tr>
<tr><td>Credit Value:</td><td colspan="5">3 (Notional hours 150)</td></tr>
<tr><td>Pre-requisites:</td><td colspan="5">CO2080</td></tr>
<tr><td>Core/Optional:</td><td colspan="5">Optional (Technical Elective)</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs</td><td>Tutorial hrs</td><td>Practical class hrs</td><td>Design hrs</td><td>Independent Learning & Assessment hrs</td></tr>
<tr><td>30</td><td>2</td><td>15</td><td>11</td><td>92</td></tr>
</table>

Course Aims:

- The aim of the module is to augment students' knowledge in networking with the study of some of the important and selected topics in networking so that they will be capable of taking up research on networking.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **explain** advanced concepts on computer networks and associated complexities and challenges;

ILO2: **demonstrate** the use of modern tools and techniques for analyzing and managing networks.

Course Content: *(Only main topics & subtopics)*

An overview of communication networks

Network applications and their requirements, network design and network application design: challenges and issues, the five-layer network architecture, and the OSI reference models, An illustration of how the layers work together.

Multimedia network applications and protocols

Multimedia network applications and classification, RTSP, techniques for multimedia (removing jitter, recovering from packet loss, content distribution), networks, and dimensioning networks; protocols (RTP, RTCP, SIP, and H.323), multimedia traffic and QoS.

Quality of service

QoS in IP networks; IP type of service; Providing multiple classes of service; scheduling and policing; Differentiated Services (DiffServ); Providing QoS, guarantees; Resource reservation; Call admission; Call setup; Integrated Services (IntServ); RSVP.

Broadcast and multicasting routing
Broadcast routing algorithms; IGMP; Multicast routing algorithms; Multicast routing in the Internet.

Multi-protocol label switching (MPLS) and Generalized MPLS
An overview of MPLS; Label encapsulation; Label distribution protocols; MPLS & ATM, GMPLS.

Wireless and mobile networks
Cellular Internet Access; WiMAX; Mobility management: addressing and routing to a mobile node; Mobile IP; Mobility in cellular networks; Mobility and the impact on higher layer protocols.

Network security
Security services; Operational security: firewalls, intrusion detection systems (IDS), intrusion prevention systems (IPS); Secure network protocols.

Network management
An overview of network management; Network management infrastructure; The Internet-standard management framework; Structure of management information (SMI); Management information base (MIB); SNMP; Security and administration.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- L. L. Peterson and B. S. Davie. Computer Networks: A Systems Approach.

Semester:	4/5/6/7				
Course Code:	CO5220				
Course Name:	Optical Communication Networks				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2080				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	7	-	16	97

Course Aims:

- To provide an in-depth understanding of the concepts, architectures, algorithms, protocols, and research issues in major optical networking technologies.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **<u>Explain</u>** the role and the common design and implementation issues of optical networks.
ILO2: **<u>Describe</u>** the various optical networking technologies, architectures, and protocols available.
ILO3: **<u>Describe</u>** the trends, challenges, and research issues in optical communication networks.

Course Content: *(Only main topics & subtopics)*

An overview of communication networks

Network applications and their requirements, network design and network application design: challenges and issues, the Internet architecture, optical network characteristics in terms of 'transmission' and 'switching', the Internet and optical networks, the optical layer, An overview of optical transmission systems and networks in local, access, metro, and wide-area networks.

Optical transmission fundamentals and issues

Optical fibers and characteristics of optical transmission, benefits and challenges/drawbacks of optical transmission, optical transmission system, multiplexing techniques for increasing the transmission capacity on an optical fiber, evolution of optical fiber transmission systems, wavelength division multiplexing (WDM) networking evolution, WDM optical network constructions, WDM optical transmission and enabling technologies, designing WDM networks.

IP traffic over WDM optical networks
Client layers of the optical layer, architectural choices for next-generation transport networks, technologies for IP-over-WDM and wavelength routed networks, overlay and integrated models for IP/WDM networks.

Synchronous optical networks (SONET) / Synchronous digital hierarchy (SDH)
Multiplexing, SONET frame structure, SONET elements, SONET layers, network survivability.

WDM optical networks: optical circuit switching (OCS)
Introduction, OCS node architectures and components, wavelength-selective and wavelength-convertible networks, routing and wavelength assignment, virtual topology design and reconfiguration, network survivability, traffic grooming, network control and management.

WDM optical networks: optical packet switching (OPS)
OPS basics: slotted networks and unslotted networks, OPS node architectures and components, header and packet format, contention resolution in OPS networks, OPS networks: challenges and other issues.

WDM optical networks: optical burst switching (OBS)
OBS networks: introduction, OBS node architectures and components, burst assembly and scheduling, signaling protocols, contention resolution in OBS networks, OBS and quality of service OBS networks: challenges.

Optical access networks
Challenges in access networks, available access techniques; a comparison between different access mechanisms, optical access networks: FTTx solutions, deployment scenarios, and Passive Optical Networks (PON), PON components, PON topologies, ethernet PON (EPON), WDM-PON, other types of PON such as APON, BPON, and GPON.

Other technologies, trends, and challenges
A brief description and discussion on other optical transmission technologies such as Light-trails, a discussion on the current trends and recent research efforts in optical networks, a discussion on the challenges ahead in optical networking.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments	Final Assessment
50%	50%

Details:	Theory(%)	Practical(%)	Other(%)(specify)
Assignments and quizzes 50%	50%	-	-

Recommended Reading:

- Optical WDM Networks by B. Mukherjee.
- Optical Networks: A Practical Perspective by R. Ramaswami, K. N. Sivarajan, and G. H. Sasaki.
- WDM Optical Networks: Concepts, Design, and Algorithms by C. Siva Ram Murthy and M. Gurusamy.

Semester:	4/5/6/7				
Course Code:	CO5230				
Course Name:	Network Virtualization				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2080				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	35	2	6	10	97

Course Aims:

- To provide an in-depth technical-treatment of key recent advances in computer networking so that students will be able to step into the industry and/or research with state-of-the-art knowledge and technological know-how.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **identify** key recent advances in computer networks and the problems they aim to solve with in-depth technical knowledge;

ILO2: **devise** solutions for computer networking problems using appropriate recent approaches.

Course Content: *(Only main topics & subtopics)*

Overview of Networking Trends

Recent standards, industry & research activities, trend-indicators, goals of this course.

Data Center Networks (DCN)

Introduction, overview of data centers-virtualization-cloud computing and related technologies: Network Function Virtualization (NFV) and Software Defined Networking (SDN), architectures and topologies, data center Ethernet, data center network routing and transport issues, application delivery in data centers, wireless and optics in data center networks, case study of a commercial data center network.

Carrier Ethernet

Carrier Ethernet vs. carrier Internet Protocol (IP) networks, enterprise vs. carrier Ethernet, options to connect two data centers, metro Ethernet and services, Provider Bridge (PB), Provider Backbone Bridge (PBB), Provider Backbone Bridge- Traffic Engineering (PBB-TE), use in multi-tenant data centers/clouds, carrier Ethernet and Packet-Optical Transport Systems (P-OTS).

Network Virtualization
Virtualization in computing: overview, different levels of network virtualization, data center networks- virtual bridging, combining bridges, data center interconnection and local area network (LAN) extension, multi-tenant isolation and network virtualization in cloud data centers, router virtualization.

Software Defined Networking (SDN)
Introduction, advantages of orchestration, centralization of policy, and disaggregation of hardware/software, evolution of SDN, Software Defined Anything (SDx), OpenFlow, elements of SDN, SDN orchestrators/controllers, key SDN related software, Open Services Gateway initiative (OSGi) Framework, overview of Software Defined Wide Area Networking (SD-WAN), overview of software defined multi-cloud networking.

Network Function Virtualization (NFV)
Introduction, evolution of NFV, relationship to SDN and cloud computing, use-cases, service provisioning using (1) NFV and (2) NFV and SDN, architectures, European Telecommunications Standards Institute (ETSI) NFV Industry Specification Group (ISG) specifications, proof-of-concepts, design and performance considerations, NFV business models.

Application of Recent Advances in Networking: Big Data
Big data fundamentals, overview of analytics, application of advances in networking (high-speed networks, virtualization, SDN, NFV) for big data, big data for networking.

Network Management
Introduction to recent network management protocols.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Project, Practical assignments and quizzes 60%	40%	-	-

Recommended Reading:

- IEEE, IETF, and other standards documents; Industry whitepapers; Technical/research papers.

Semester:	4/5/6/7				
Course Code:	CO5240				
Course Name:	Cybersecurity				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	33	-	20	4	93

Course Aims:

- To provide a broad understanding of the latest online threats, and hands-on experience of the practical skills needed to defeat those.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **critically assess** existing systems using the theories, techniques, and software tools that are available in the field of cybersecurity;
ILO2: **analyze** and document the core issues in building secure and effective systems; evaluating the strengths and weaknesses of the systems, and propose solutions;
ILO3: **evaluate** the implication of ethical issues and norms in privacy and security;
ILO4: **master** defenses against different threats.

Course Content: *(Only main topics & subtopics)*

Introduction to Cyber Attacks and Countermeasures

Real-time Cyber-Threat detection & Mitigation

Enterprise and Infrastructure Security: Planning, operations and management

IT Forensics

Ethical Hacking

Penetration Testing

Blockchain

Teaching/Learning Methods: Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 70%	Final Assessment 30%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Assignments & quizzes 30% Practicals/Labs/Project 40%	30%	-	-

Recommended Reading:

- Stallings, William, and Lawrie Brown. "Computer security: principles and practice, global edition." 2017.
- Wm. Arthur Conklin, Greg White, Chuck Cothren, Roger Davis, and Dwayne Williams, “Principles of Computer Security: CompTIA Security+ and Beyond, Fifth Edition”, McGraw Hill, 2018.

Semester:	4/5/6/7				
Course Code:	CO5310				
Course Name:	Applied Software Architecture				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2040				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	31	-	12	16	91

Course Aims:

- The aim of the module is to learn the art of structuring software systems. Understand differences between diverse architectural styles used in practice. Know the use of different architectural patterns and styles to serve specific technical and business contexts.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **describe** different types of software systems developed in the industry;
ILO2: **describe** different architectural styles and their applicability in different contexts;
ILO3: **select** a suitable high-level structure for software based on the context;
ILO4: **justify** the relevance of a particular architectural pattern for a given problem context;
ILO5: **design** high-level architectures for software systems.

Course Content: *(Only main topics & subtopics)*

Introduction to applied software architecture
Role of an architect,modern trends of software architecting: agile architecture, building to change over building to last.

Basic of software architecture: principles of software design
Separation of concerns, single responsibility principle, do not repeat yourself,minimize upfront design, common architectural styles in practice.

Web application architectures

Architectural style (client-server style) and its variants, reasons for adaption, alternative styles (RIA, smart-clients, rich-clients) and their key principles, technology trends (HTML5, RESTful, hybrid).

Service oriented architectures:
Key principles (autonomy, distribution, coupling, contracts, policy), industrial case-studies.

Enterprise architectures
Architectural styles (message bus, integration patterns), key considerations (business, data,applications, technology), industrial case studies.

Product architectures
Products vs. bespoke applications, specialized needs of product engineering (design, flexibility, branding, marketing, support).

Mobile application architectures
Application types (native, web, hybrid)and technology platforms, design considerations (portability, UX, constraints, capabilities, security, network, deployment/marketing).

Cloud architectures
Evolution and history of cloud computing, cloud patterns (scalability, big-data, failure-handling, distribution), cloud and 'XaaS' models (IaaS, PaaS, SaaS).

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Tutorials/practical 50%	50%	-	-

Recommended Reading:

- Martin Fowler, Patterns of Enterprise Application Architecture
- Ralph Johnson , Design Patterns: Elements of Reusable Object-Oriented Software
- David Garlan and Mary Shaw, An Introduction to Software Architecture (http://www.cs.cmu.edu/afs/cs/project/able/ftp/intro_softarch/intro_softarch.pdf)

Semester:	4/5/6/7				
Course Code:	CO5320				
Course Name:	Advanced Database Systems				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2050				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	32	6	12	2	98

Course Aims:

- The aim of this course is to provide in-depth theoretical and practical concepts of database management systems so that students will be able to use that knowledge to develop multi-user database systems and databases for complex data types.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **select** appropriate query execution plan and then optimize the database according to the requirements;
ILO2: **apply** transaction processing and distributed database concepts for developing multi-user database applications;
ILO3: **judge** whether relational data model is sufficient for a given database application and if not, **propose** alternative data model;
ILO4: **compare** relational data models with other data models.

Course Content: *(Only main topics & subtopics)*

Data storage and indexing structures

Storage and file structures, indexed, hashed and signature files, Btrees, sparse and dense indexes, variable length records.

Query Optimization and database tuning

Translating SQL to relational algebra, Algorithms for relational algebra operations, Query optimization: rule based and cost based approaches, Database design and tuning in relational databases, Partitioning, Sharding, and Peformance monitoring.

Transaction Processing

Transactions, ACID properties, SQL support for transactions, Transcation management in NoSQL databases, Concurrency control, Serialization, Failure and recovery.

Database security and privacy
Security issues, Access control: granting and revoking privileges, Multilevel security, Encryption, Auditing to protect data, Protecting privacy.

Distributed Databases
Distributed database concepts: data fragmentation, replication and allocation; distributed query processing, distributed transaction model, concurrency control, homogeneous and heterogeneous environments, cloud-based distributed databases.

Object databases and Object-relational databases
Current trends of database technology; Object databases : Object identity, Object structure, Type constructors, Encapsulation, Type and Class Hierarchies and Inheritance; Object-relational databases.

Other data models
Big data and NoSQL databases: handling large volumes of data and big data processing frameworks, Hadoop and MapReduce; Document and Column based databases, Graph databases, Cloud databases: database-as-a-service platforms, Comparison of other data models with relational models.

Data models for advanced applications
Active, temporal, multimedia and deductive databases.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- Ramez Elmasri and Shamkant B. Navathe, Fundamentals of Database Systems Raghu
- Ramakrishnan and Johannes Gehrke, Database Management Systems

Semester:	4/5/6/7				
Course Code:	CO5410				
Course Name:	Applied Data Science				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	2	14	12	92

Course Aims:

- The aim of this course is to provide students with in-depth theoretical and practical concepts of statistical analysis, visualization and problem solving in data science so that they will be able to use that knowledge and skills to design, implement and deploy data science pipelines to solve problems.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **conduct** statistical analysis using R;
ILO2: **select** appropriate visualization techniques for a given data set and **design** interactive dashboards;
ILO3: **design** a data science project architecture and **deploy** it in a specific setting.

Course Content: *(Only main topics & subtopics)*

Introduction to R
Basics, variables, control structures, functions.

Data manipulation
Data structures, data manipulation libraries, data visualization.

Exploratory data analysis
Summary statistics: mean, median, and standard deviation, Hypothesis testing: t-test and ANOVA, Plots: histograms, scatterplots, box plots, and correlation plots.

Data preprocessing

Data transformation: normalization and standardization, Data imputation, Handling outliers, Data sampling, Regular expressions.

Data visualization
Design principles, Interactive dashboards, Data visualization tools, and business intelligence platforms, Data visualization for storytelling

Data science project deployment
Project life cycle and architecture, Model deployment, Monitoring, and maintenance, project deployment case studies.

DevOps for data science
Agile development methods, continuous integration, and deployment.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 60%	40%	-	-

Recommended Reading:

- Hadley Wickham and Garrett Grolemund, R for Data Science
- Ben Root, Data Visualization with Python and Matplotlib
- Kieran Healy, Data Visualization: A Practical Introduction
- Carl Osipov, MLOps Engineering at Scale

Semester:	4/5/6/7				
Course Code:	CO5420				
Course Name:	Artificial Neural Networks and Deep Learning				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	31	-	4	24	91

Course Aims:

- The aim of this course is to impart a working knowledge of the theory and practice of Artificial Neural Networks and Deep Learning and enable students to use them in designing intelligent systems. The students will learn how to build prototype intelligent systems/solutions in product design, commercial/trade and scientific applications.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **apply** theories and techniques of Artificial Neural Networks and Deep Learning to identify potential applications in real-life product design, commercial/trade and scientific problems;

ILO2: **analyze** and formulate the problem for solution using Artificial Neural Networks and Deep Learning;

ILO3: **develop** prototype solutions to the formulated problem and validate them;

Course Content: *(Only main topics & subtopics)*

Artificial Neural Networks (ANN) and Deep Learning (DL):
Introduction Neural Networks basics, Introduction to Deep Learning, Shallow Neural Networks, Deep Neural Networks

Optimizing ANN based solutions
Scaling neural networks in practical applications, optimization algorithms and programming frameworks, hyper parameter tuning, batch normalization

Structuring a Machine Learning project
ML project workflow, solution evaluation

Convolutional Neural Networks(CNNs)
Foundations of CNN, object detection, case studies

Sequence Models
Recurrent Neural Networks, natural language processing

Use cases and Recent Advancements in ANN and DL
Transfer Learning, Transformer Networks , Trending topics in ANN and DL

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 60%	40%	-	-

Recommended Reading:

- S. Russell and P. Norvig *Artificial Intelligence: A Modern Approach* Prentice Hall, 2020, Fourth Edition.

Semester:	4/5/6/7				
Course Code:	CO5430				
Course Name:	Image Processing				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	28	6	8	14	94

Course Aims:
The aim of the module is to:

- Clearly describe the major steps in creating a digital image; sampling and quantization and relationship of spatial and grayscale resolution with the image size.
- Given an image, decide and perform the best image enhancement operations in the correct sequence, to achieve a certain target outcome.
- Segment an image into object and background regions using the required processing routines.
- Use existing image processing routines effectively by manipulating different input parameters to achieve a certain result, based on the input image.
- Where applicable, develop routines to perform different image processing tasks on an image.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to:

ILO1: **use** existing image processing packages to enhance and process images;
ILO2: **extract** the required features from the processed images;
ILO3: **develop** image processing software by incorporating the algorithms and techniques introduced in the course

Course Content: *(Only main topics & subtopics)*

Introduction to image processing
Background, applications, elements of a digital image processing system -Image acquisition, Storage, Processing, Transmission and display.

Fundamentals

Human vision system, sampling and quantization, pixels and their relationships, adjacency, distance measures.

Digital image processing techniques
Image enhancement and restoration- Spatial domain techniques; Pixel point processing, pixel group processing.

Digital image processing techniques
Fundamentals of Fourier Transform, Frequency domain techniques;Frequency domain representation, frequency domain filtering.

Image restoration, geometric transformations

Image analysis
Segmentation, Feature extraction, Morphological processing, Image compression and transmission, coding systems for various applications, handling of error, image coding systems, Run-length, Huffman, bit plane encoding.

Color image processing
Definitions, color systems, color to grayscale conversion.

Pattern recognition in image processing
Feature space, classification algorithms, minimum distance classifier, Mahalanobis distance, other measures.

Teaching/Learning Methods:

Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- Digital Image Processing, R. C. Gonzalez & R. E. Woods
- Digital Image Processing, Gregory A. Baxes
- Remote Sensing and Image Interpretation, T. M. Lillesand and R. W. Kiefer
- Remote Sensing Digital Image Analysis, J. A. Richards
- Digital image processing using MATLAB, Gonzalez, Woods, and Eddins

Semester:	4/5/6/7				
Course Code:	CO5440				
Course Name:	Data Engineering				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	28	-	-	34	88

Course Aims:

- The aim of this course is to impart a working knowledge of the theory and practice of Data Engineering and enable students to use them in designing knowledge discovery systems. The students will learn how to build prototype Machine Learning based systems/solutions in product design, commercial/trade and scientific applications.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **apply** theories and techniques of Data Engineering to identify potential knowledge discovery applications in real-life product design, commercial/trade and scientific problems;
ILO2: **analyze** and formulate the problem for solution using Data Engineering;
ILO3: **develop** prototype solutions to the formulated problem and validate them.

Course Content: *(Only main topics & subtopics)*

Introduction

Machine Learning Systems Engineering

Machine Learning data life cycle in production

Machine Learning Modelling in production

Deploying Machine Learning models in production

Recent topics in Data Engineering

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 60%	40%	-	-

Recommended Reading:

- I. Kononenko and M. Kukar, Machine Learning and Data Mining, Elsevier.
- Géron, A. (2022). Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow. " O'Reilly Media, Inc.".

Semester:	4/5/6/7				
Course Code:	CO5450				
Course Name:	Game Theory and Markov Decision Processes				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	EM2020				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	10	-	10	100

Course Aims:

- To introduce basic game theoretic methods in formal verification, algorithmic analysis of the games, and formal-mathematical analysis of the games.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Describe** different game theoretic models, algorithms and proof techniques to analyze the game models;
ILO2: **Apply** the game theoretic results in formal analysis and prove correctness of reactiv systems;
ILO3: **Design** new algorithms for new game models with new classes of specifications.

Course Content: *(Only main topics & subtopics)*

Introduction to game theory

Mixed Strategies, Expected Payoffs, Nash Equilibrium and Nash's Theorem

2-Player Zero-Sum Games, and The Minimax Theorem

Linear Programming, Simplex Algorithm, LP Duality Theorem

Computing Solutions for General Finite Strategic Games
Dominance and iterated strategy elimination, Nash Equilibria.

Games in Extensive Form, Games of Perfect Information

Games on Graphs
Parity Games: Memoryless determinacy, NP and coNP complexity, Classical algorithm and mean-Payoff Games

Simulation
Bisimulation, and other Ehrenfeucht-fraisse games

Markov Decision Processes and Stochastic Games

Selfish Network Routing, Congestion Games, and the Price of Anarchy

Auctions and Mechanism Design
Auctions as Games, Bayesian Games, Vickrey auctions, social choice theory, the VCG Mechanism, and Market Equilibria, Matching Markets, unit-demand auctions, and VCG; and a Formal Framework of Mechanism Design.

Reachability and safety games
Attractors and how to use them to solve these games, Polynomial time algorithm, Memoryless determinacy, PTIME-completeness. Linear time algorithm, Mu-calculus formula, Symbolic algorithm.

Buchi and coBuchi Games
Quadratic algorithm, Memoryless determinacy, Mu-calculus formula and symbolic algorithm.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- M. Maschler, E. Solan and S. Zamir, Game Theory
- Myerson, R.B. Game Theory: Analysis of Conflict
- K. Leyton-Brown and Y. Shoham, Essentials of Game Theory

- N. Nisan, T. Roughgarden, E. Tardos, and V. Vazirani, Algorithmic Game Theory
- Y. Shoham and K. Leyton-Brown, Multi-agent Systems: algorithmic, game-theoretic, and logical foundations

Semester:	4/5/6/7				
Course Code:	CO5460				
Course Name:	Computer Vision				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	-	-	30	90

Course Aims:

The aim of the module is to expose students to higher-order image processing operations that generate attributes of images or video streams through analysis. Together with recent advancements in deep learning techniques students will be able to use computer vision algorithms to develop engineering and automation applications.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** computer vision algorithms suitable for different engineering applications;
ILO2: **select** appropriate computer vision algorithms and techniques for a given engineering problem;
ILO3: **demonstrate** the competence of combining various image processing algorithms to develop vision-based engineering applications.

Course Content: *(Only main topics & subtopics)*

Introduction to image processing and computer vision

Linear algebra and probability review

Use of deep learning for computer vision

Visual recognition: Edge detection, Feature extraction, Image segmentation

Object classification and detection

Motion estimation, optical flow and tracking

Depth estimation

Project to develop/improve an engineering application

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details: Practical assignments 60%	Theory(%) 40%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- Richard Szeliski, Computer Vision: Algorithms and Applications, 2021

<table>
<tr><td>Semester:</td><td colspan="5">4/5/6/7</td></tr>
<tr><td>Course Code:</td><td colspan="5">CO5470</td></tr>
<tr><td>Course Name:</td><td colspan="5">Natural Language Processing</td></tr>
<tr><td>Credit Value:</td><td colspan="5">2 (Notional hours 100)</td></tr>
<tr><td>Pre-requisites:</td><td colspan="5">None</td></tr>
<tr><td>Core/Optional:</td><td colspan="5">Optional</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs</td><td>Tutorial hrs</td><td>Practical class hrs</td><td>Design hrs</td><td>Independent Learning & Assessment hrs</td></tr>
<tr><td>20</td><td>4</td><td>8</td><td>4</td><td>64</td></tr>
</table>

Course Aims:

- The aim of this course is to provide in-depth theoretical and practical concepts of human language processing and analysis so that students will be able to use that knowledge to develop real-word applications in information retrieval, machine translation and text summarization.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **define** the problem clearly in the context of NLP and select appropriate steps to develop solution to the NLP problem;
ILO2: **apply** NLP tools and techniques such as tokenization and stemming to a given problem;
ILO3: **apply** NLP techniques to solve real-world problems in information retrieval, machine translation and text summarization.

Course Content: *(Only main topics & subtopics)*

Introduction to NLP
Basics of Natural Language Processing, Applications.

Natural Language Processing
Language identification, tokenization, stemming, lemmatization, part-of-speech tagging, named entity recognition and syntax parsing.

Language Modeling
n-gram model, smoothing techniques, evaluation of language models.

Text Classification and Sentiment Analysis

Machine Learning algorithms used in text classification, sentiment analysis.

NLP Applications
Machine translation, text summarization, natural language generation, dialogue systems, Ethical and social issues related to NLP.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals & quizzes 50%	50%	-	-

Recommended Reading:

- Daniel Jurafsky and James H. Martin, Speech and Language Processing
- Chris Manning and Hinrich Schütze, Foundations of Statistical Natural Language Processing

Semester:	4/5/6/7				
Course Code:	CO5480				
Course Name:	Data Warehousing & Big Data Analytics				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	CO2050				
Core/Optional:	Optional (Technical Elective)				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	8	12	2	98

Course Aims:

- The aim of this course is to provide students with in-depth theoretical and practical concepts of data warehousing and big data systems so that they will be able to use that knowledge to design, implement data intensive software systems.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **select and design** appropriate data models and schemas for data warehousing and big dat systems;
ILO2: **apply** data integration and transformation tools to combine data from various sources;
ILO3: **use** query optimization and monitor performance in a data warehouse or big data system.

Course Content: *(Only main topics & subtopics)*

Introduction
Basics of data warehousing, Role of data warehouses, Data warehousing architecture, Tools and techniques used in data warehousing, data warehouses vs databases.

ETL processes
Extract, transform and Load processes, ETL tools, design and implementation of ETL pipelines, Data marts and lakes.

Data Modeling and schema design
Data modeling for data warehousing, dimensional modeling, star and snowflake schemas, fact and dimension tables, data mart design.

Big Data Analysis
Basics of big data and challenges: volume, velocity, variety, and veracity, Processing and analyzing big data, big data processing platforms: Hadoop, Spark and MapReduce.

Data integration and transformation
Data integration and transform from multiple sources; loading, cleaning, transforming and quality control.

Query optimization and performance turning
Indexing strategies: distributed, columnar, and inverted, Partitioning: horizontal, vertical and range, and Materialized views, Performance monitoring.

Cloud-based data warehousing
Cloud-based data warehousing platforms, benefits and challenges.

Data security and privacy
Techniques used for secure and protect data in a data warehouse: encryption, access control, and auditing.

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- Ralph Kimball and Margy Ross, The Data Warehouse Lifecycle Toolkit
- Nathan Marz and James Warren, Big Data: Principles and best practices of scalable real-time data systems
  Krish Krishnan, Data Warehousing in the Age of Big Data

Semester:	4/5/6/7
Course Code:	CO5510
Course Name:	Formal Verification Tools and Techniques for Complex Reactive Systems
Credit Value:	3 (Notional hours 150)
Pre-requisites:	EM1050
Core/Optional:	Optional

Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	31	4	6	14	95

Course Aims:

- To impart a working knowledge of formal methods used in rigorous verification of reactive systems and enable students to use them in designing systems.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Demonstrate** practical skills in design, specification and analysis of prototype distributed systems ;

ILO2: **Model** various classes of systems using the formalisms introduced;

ILO3: **Select** specific analysis/proof techniques and Prove properties of systems using appropriate formalisms.

Course Content: *(Only main topics & subtopics)*

Introduction, Modelling software/hardware systems

Techniques and tools for formal modelling and analysis of complex reactive systems for correctness and reliability. The Fundamental Model, State Spaces, Transition System Specification, Representing the Program, Transition Specifications, Scheduling and Fairness, Hierarchy and Realisability.

Finite state machines (FSMs) and Statecharts

Basic definitions, operational semantics. Categories of FSMs. Extended FSMs. Modelling concurrent systems with communicating FSMs, hierarchical FSMs, Statecharts.

Binary decision diagrams

General concepts. Fast canonical form algorithm. Optimisations.

Petri nets

Basic notions, definitions and classification. Modelling distributed systems with Petri nets, Petri nets analysis. Checking structural and behavioral properties.

Floyd/Hoare logic
Transition Diagrams, Floyd Inductive Assertions, Total Correctness, Extended Inductive Assertions, Hoare Logic.

Modelling distributed and concurrent systems with process algebra
Algebra CCS: syntax, semantics, modelling technique, The notion and properties of bisimilarity relation, Verifying reactive concurrent systems with CCS, Hennesy-Milner logic and temporal properties. The notion of fixed point and Tarski's fixed point theorem. Peterson's algorithm.

Owicki-Gries, ESC/Java
Parallel While Programs, Interference Freedom, Completeness and Compositionality.

CCS, bisimulation equivalence
Calculus of Communicating Systems - Introduction, CCS – Combinators, Flow Graphs, Composition, Restriction, Relabelling.

Temporal logic
Runs/Executions/Paths, LTL – Linear Time Temporal Logic, Satisfaction by transition system, Reachability Problem, Verification Using Automata, Branching Time Logic, Computation Tree Logic – CTL, Automata Over Finite/Infinite Words, Nondeterminism, Deterministic Buchi Automata, Generalized Buchi Automata.

Temporal logic continued
The automata framework. The Cost of Verification, Verification Using Automata.
Correctness in SPIN
Promela and SPIN.

CCS, modal logic, wrapping up, formal methods in industry

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 50%	Final Assessment 50%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments 50%	50%	-	-

Recommended Reading:

- D. Peled, Software Reliability Methods, Springer-Verlag 2001.
- Christel Baier and Joost-Pieter Katoen, Principles of Model Checking, The MIT Press, 2008.
- Klaus Schneider, Verification of Reactive Systems: Formal Methods and Algorithms, Springer, 2004.
- G. Holzmann, The SPIN Model Checker: Primer and Reference Manual, Addison-Wesley, 2003.
- René David and Hassane Alla, Discrete, Continuous, and Hybrid Petri Nets, Springer, 2nd ed. 2010.
- K. Jensen and G. Rozenberg, Eds. High-level Petri Nets. Berlin: Springer-Verlag, 1991.

Semester:	4/5/6/7				
Course Code:	CO5520				
Course Name:	Mathematics of Cryptography				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	15	-	-	105

Course Aims:

To appreciate the underlying mathematics used in cryptography.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **describe** the various mathematical concepts and techniques used in cryptography;
ILO2: **apply** the mathematical theories behind cryptographic algorithms and cryptanalysis for various applications;
ILO3: **demonstrate** the application of mathematical theories and techniques used in cryptography using mathematical software;

Course Content: *(Only main topics & subtopics)*

Introduction to Algebraic Structures, Groups, Rings and Fields

Modular Arithmetic, Euclidean and Extended Euclidean Algorithms

Finite Abelian Groups, Fermat Little Theorem, Euler phi Function, Euler Theorem and Their Applications

Exponentiation and Discrete Logarithm

Prime Numbers and Primality Testing

Linear Congruence, Chinese Remainder Theorem and Quadratic Congruence

Galois fields and Elliptic Curves **Mathematics of Lattice Structures**
Teaching/Learning Methods: Flipped classrooms, small group discussion classes, project-based learning.
Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details: Tutorials/ Assignments/ Practicals 60%	Theory(%) 40%	Practical(%) -	Other(%)(specify) -

Recommended Reading:

- An Introduction to Number Theory with Cryptography, James S. Kraft, Lawrence Washington
- Cryptography & Network Security, Behrouz Forouzan

Semester:	4/5/6/7				
Course Code:	CO5530				
Course Name:	Computational Bioengineering				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	31	-	22	6	91

Course Aims:

- The aim of this course is to impart a working knowledge of the theory and practice of Artificial Neural Networks and Deep Learning and enable students to use them in designing intelligent systems. The students will learn how to build prototype intelligent systems/solutions in product design, commercial/trade, and scientific applications.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

ILO1: **Understand** the impact of bioengineering solutions in a global, economic, environmental, and societal context;
ILO2: **Demonstrate** a working knowledge of contemporary issues in computational biology & bioengineering;
ILO3: **Apply** the techniques, skills, and modern engineering tools necessary for bioinformatics and bioengineering practice;
ILO4: **Develop** prototype solutions for real engineering applications.

Course Content: *(Only main topics & subtopics)*

Introduction to Bioengineering
Introduction to Bioengineering, Biosystems Engineering and Biomedical Engineering

Introduction to Cell & Life

Introduction to Molecular Biology & Biotechnology

Introduction to Biomedical Computation and Instrumentation

Introduction to Computational Biology

Introduction to Bioinformatics

Case Studies & Project

Teaching/Learning Methods:
Flipped classrooms, small group discussion classes, project-based learning.

Assessment Strategy:

Continuous Assessments 70%	Final Assessment 30%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practical assignments & Quizzes 30% Project 40%	30%	-	-

Recommended Reading:

- Zvelebil, Marketa J., and Jeremy O. Baum. Understanding Bioinformatics. Garland Science, 2007. ISBN: 9780815340249.
- Watson, James D., Tania A. Baker, et al. Molecular Biology of the Gene. Benjamin Cummings, 2013. ISBN: 9780321762436.
- Alberts, Bruce, Alexander Johnson, et al. Molecular Biology of the Cell. Garland Science, 2007. ISBN: 9780815341055.

Semester:	4/5/6/7				
Course Code:	CO5540				
Course Name:	Trends in Internet of Things				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional:	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	26	6	6	20	92

Course Aims:

- Develop the theoretical knowledge and practical skills to design and engineer Internet of Things (IoT) technologies. By combining with recent advancements in deep learning techniques, blockchain, and embedded AI students will be able to develop innovative IoT applications and services.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** IoT technologies suitable for different engineering applications;
ILO2: **select** appropriate IoT techniques, and hardware for a given engineering problem;
ILO3: **demonstrate** the competence of combining various technologies to **develop** IoT applications and services.

Course Content: *(Only main topics & subtopics)*

Introduction to IoT

IoT Applications

IoT Frameworks, Architectures, and Design Considerations

Sensors and components
Connectivity
Protocols
Frameworks and architectures

Edge Computation and Embedded IoT

Machine/Deep Learning for IoT **Blockchain** **Project to develop/improve an engineering application**
Teaching/Learning Methods: Flipped classrooms, small group discussion classes, project-based learning.
Assessment Strategy:

Continuous Assessments 60%	Final Assessment 40%		
Details:	Theory(%)	Practical(%)	Other(%)(specify)
Practicals, assignments 40% Project 20%	40%	-	-

Recommended Reading:

- The Internet of things : enabling technologies, platforms, and use cases, Pethuru Raj and Anupama C. Raman
- Internet of Things: A Hands-on Approach, A. Bahga and V. Madisetti

Complementary Studies Courses

Semester:	6/8/Short				
Course Code:	EF3010				
Course Name:	The Engineer in Society				
Credit Value:	2 (Notional hours:100)				
Pre-requisites:	None				
Core/Optional	Optional				
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Practical class hrs.	Assign ment hrs.	Independent Learning & Assessment hrs.
	25	-	-	10	65

Course Aim:

- To introduce roles and responsibilities of the engineer, the safety and sustainability in engineering practices, the impact of engineering on the environment and the society, and the professional code of conduct in engineering.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to:

ILO1: **demonstrate** social, cultural, global, and environmental responsibilities as an engineer;
ILO2: **explain** ethical issues and problems that arise in professional environment;
ILO3: **interpret** the significance of engineering practice in safety and sustainability;
ILO4: **explain** regulatory and statutory requirements for engineering practice. .

Course Content:

- Evolution of industry and its future: historical development, industrial and technological revolutions, and emerging trends
- Energy sources and the impact of their use on the society
- Environmental issues, assessing industrial impact on the environment, and on society.
- Sustainable development and engineering sustainability issues in engineering safety, engineering accidents, safety in design, and the human factor in safety.
- The workforce and human relations, Issues of fundamental rights and human rights
- Legal liabilities and legal responsibilities to society.
- Professional code of conduct

Teaching /Learning Methods:

Classroom lectures, and assignments

<table>
<tr><td colspan="4">Assessment Strategy:</td></tr>
<tr><td>Continuous Assessment

50%</td><td colspan="3">Final Assessment

50%</td></tr>
<tr><td>Details:
Assignments 50%</td><td>Theory (%)

50%</td><td>Practical (%)

-</td><td>Other (%)

-</td></tr>
<tr><td colspan="4">Recommended Reading:
Central Environmental Authority Sri Lanka, Man and Environment 1995, ISBN 955-9012-08-8
Constitution of the Democratic Socialist Republic of Sri Lanka, 1978
Weerasooriya, Wickrama, A text book on commercial law: business law, 2010, ISBN: 9789558969113</td></tr>
</table>

<table>
<tr><td>Semester:</td><td colspan="5">5/6/7/8</td></tr>
<tr><td>Course Code:</td><td colspan="5">EF3020</td></tr>
<tr><td>Course Name:</td><td colspan="5">Social Project</td></tr>
<tr><td>Credit Value:</td><td colspan="5">2 (Notional hours:100)</td></tr>
<tr><td>Pre-requisites:</td><td colspan="5">None</td></tr>
<tr><td>Core/Optional</td><td colspan="5">Optional</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture hrs.</td><td>Tutorial hrs.</td><td>Practical class hrs.</td><td>Assign ment hrs.</td><td>Independent Learning & Assessment hrs.</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>60</td><td>40</td></tr>
</table>

Course Aim:

- To develop self-learning skills to acquire knowledge based on a project which includes a social objective.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to:

ILO1: **extract** relevant information from authentic sources on a selected topic which includes a social objective;
ILO2: **analyze** the information gathered to identify the social impact related to the selected topic;
ILO3: **communicate** scientific and technical information in verbal and written forms.

Course Content:

- Identifying a social issue through research based on data and evidence.
- Proposing solutions to the identified issue based on analyzed information, and estimating the solutions' impact and effectiveness.
- Implementing selected solutions and carry out a post-analysis on their impact and effectiveness.

Teaching /Learning Methods:

Assignments, group work, project-based learning

Assessment Strategy:

Continuous Assessment	Final Assessment
70%	30%

Details:	Theory (%)	Practical (%)	Other (%)
Project Proposal (written / presentation) 40% Progress evaluations (written / viva / presentations at multiple stages) 30%	-	-	Presentation/report 30%
Recommended Reading *None*			

Semester:	6/8				
Course Code:	EF3030				
Course Name:	Introduction to Music				
Credit Value:	2 (Notional hours:100)				
Pre-requisites:	None				
Core/Optional	Optional				
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Practical class hrs.	Assignment hrs.	Independent Learning & Assessment hrs.
	18	-	20	04	58

Course Aim:

- To provide a basic understanding about music and its history around the world.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to:
ILO 1: **describe** the specified important developments in the history of music;
ILO 2 : **describe** basic concepts related to music.

Course Content:
- Classical Indian and Western systems.
- Important musicians including great composers of both systems and their work.
- Musical instruments of Western and Indian systems.
- Trends in Sri Lankan music.
- Practical in instrumental or vocal music
- Self study assignments

Teaching /Learning Methods:

Classroom lectures, practicals and assignments

Assessment Strategy:

Continuous Assessment	Final Assessment
40%	60%

<table>
<tr><td>Details:
Classroom activities 10%
Assignments 30%</td><td>Theory (%)

60%</td><td>Practical (%)

-</td><td>Other (%)

-</td></tr>
<tr><td colspan="4">Recommended Reading
None</td></tr>
</table>

Semester:	5/7				
Course Code:	EF3040				
Course Name:	Painting and Sculpture				
Credit Value:	2 (Notional hours:100)				
Pre-requisites:	None				
Core/Optional	Optional				
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Practical class hrs.	Assign ment hrs.	Independent Learning & Assessment hrs.
	16	-	24	04	56

Course Aim:

- To provide the basic knowledge of painting and sculpture.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to:

ILO 1: **explain** the basic concepts used in painting and sculpture;
ILO 2: **describe** the traditional Sri Lankan painting and sculpture;
ILO 3: **apply** the fundamentals of computer graphics.

Course Content:

- Introduction to painting and sculpture
- Understanding human body and nature painting & sculpture
- Main traditions of the west and the east
- Traditional Sri Lankan painting and sculpture
- Aesthetic, social and anthropological aspects of painting & sculpture
- Computer graphics
- Painting and sculpture assignments

Teaching /Learning Methods:

Classroom lectures, practicals and assignments

Assessment Strategy:

Continuous Assessment	Final Assessment
40%	60%

Details: Practical assignments and quizzes 40%	Theory (%) 40%	Practical (%) 20%	Other (%) -
Recommended Reading *None*			

Semester:	5/7				
Course Code:	EF3050				
Course Name:	Written English for Communication				
Credit Value:	1 (Notional hours 50)				
Pre-requisites:	None				
Core/Optional	Optional				
HourlyBreakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	14	-	-	2	34

CourseAim:

- The objective of this course is to develop the learners' written English skills enabling them to correspond effectively in formal English and technical writing skills.

IntendedLearningOutcomes:

On successful completion of the course, the students should be able to:

ILO1: **describe** the structure of scientific publications;
ILO2: **compose** scientific articles along with title abstract and reference management;
ILO3: **write** formal documents using the proper formats and organizing patterns;
ILO4: **demonstrate** critical thinking, creativity, and confidence in written communication.

Course Content:

Scientific Publications
Basic features of a scientific paper, using relevant search engines to find research articles, formulate the title of a research project/paper, how to write the abstract, organize references using reference generators.

IMRaD
Learn how to write the four main chapters of a research project report

Email Writing
Acquire appropriate rudiments in language, and formatting for effective communication

Formal Letter Writing
Acquire appropriate formatting, organizing, and set phrases to communicate messages effectively

Memo Writing
Acquire appropriate formatting and organizing to build the ability to effectively communicate within an organization

Writing a Personal Statement
Acquire necessary skills to analyze capabilities and competencies of oneself to write an essay to highlight one's skills

Curriculum Vitae
Acquire necessary skills to organize, and present information in an effective format to apply for career opportunities

Teaching/LearningMethods:
Classroom lectures, group activities and assignments

AssessmentStrategy:

Continuous Assessment 60 %	Final Assessment 40 %		
Details: Scientific Writing (30%) Communication Skills (30%)	Theory (%) 40%	Practical (%) -	Other(%) (specify)

Recommended Reading:

- How to Write and Publish a Scientific Paper - 6th Edition, by Robert A. Day and Baraba Gastel, Cambridge University Press

Semester:	6/8/Short				
CourseCode:	EF3060				
CourseName:	Effective Communication in English through Speech				
CreditValue:	1 (Notional hours 50)				
Pre-requisites:	None				
Core/Optional	Optional				
HourlyBreakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**IndependentLearning& Assessment hrs**
	5	-	10	10	25

CourseAim:

- To develop the learners' English Language speaking skills to communicate and interact effectively, mainly through a student centered approach.

IntendedLearningOutcomes:

On successful completion of the course, the students should be able to

ILO 1: **demonstrate** creativity, personality, and confidence in speaking;
ILO2: **demonstrate** the necessary skills to deliver a presentation;
ILO3: **demonstrate** formal oral communication;
ILO4: **demonstrate** speaking skills to speak effectively before an audience;
ILO5: **demonstrate** interview skills to face an interview successfully

CourseContent:

Ice breaker –
Initiating the process of speech through introducing themselves through a unique approach which encourages the students to talk about their life and experience. Builds self-confidence, confidence in speaking in the target language, creativity, self-exploration, and personality.

Technical Presentation –
Enhance technical presentation skills, creativity, communication skills, and confidence in speaking. Slide preparation, use of visual aids, organization, time management, and body language are also emphasized.

Speech Evaluation –
Being able to evaluate a speech done by another speaker while identifying positive and negative features and critically analyzing the content. Enables the students to improve their speaking skills by observing, analyzing, and giving suggestions for improvement for a speech done by another speaker.

Impromptu Speech
(Different types of speeches such as agree/disagree, advantage/ disadvantage, experience) –

create awareness about different types of speeches and how to organize them. Enhances the ability to talk about different topics using different organizational patterns. Creativity and confidence in speaking emphasized.

Interview Skills –
Ability to prepare and face an interview in an effective and professional manner. Acquire the necessary rudiments of language, skills, and attitudes to answer questions at an interview with confidence.

Teaching/LearningMethods:

- Classroom lectures, group activities and assignments

AssessmentStrategy:

ContinuousAssessment 40 %	FinalAssessment (Viva Voce) 60 %		
Details: Assignments (Ice breaker speech, Technical presentation - individual/group) 40%	Theory(%) -	Practical(%) 60%	Other(%)(specify)

Recommended Reading

None

Semester:	5/6/7/8/Short				
Course Code:	EF3070				
Course Name:	Introduction to Digital Art				
Credit Value:	3 (Notional hours 150)				
Pre-requisites:	None				
Core/Optional	Optional				
Hourly Breakdown	**Lecture hrs**	**Tutorial hrs**	**Practical class hrs**	**Design hrs**	**Independent Learning & Assessment hrs**
	30	-	16	14	90

Course Aim:

- To introduce the basics of digital art techniques.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

ILO1: **use** desktop publishing and graphic design tools;
ILO2: **use** multimedia packages for web designs, presentations etc;
ILO3: **make** video clips using digital animation.

Course Content:*(Only main topics & subtopics)*

- Desktop publishing tools / graphic design
- Introduction to digital animation
- Web design. Linking web design to graphic design and digital animation.
- Multimedia presentation
- Impact of digital revolution on the society
- Group report and project presentation

Teaching/Learning Methods:
Lectures, practical assignments.

Assessment Strategy:

Continuous Assessment 50 %	Final Assessment 50 %

Details:	Theory(%)	Practical(%)	Other(%)(specify)
Tutorials, assignments, quizzes 30% Project report 20%	-	-	- Project presentation individual contribution 35 % Project presentation group contribution 15 %

Recommended Reading

None

Semester:	6/8				
Course Code:	EF3080				
Course Name:	Mindfulness for Engineers				
Credit Value:	2 (Notional hours:100)				
Pre-requisites:	None				
Core/Optional	Optional				
Hourly Breakdown	Lecture hrs.	Tutorial hrs.	Practical class hrs.	Assign ment hrs.	Independent Learning & Assessment hrs.
	11	04	30	-	55

Course Aim:

- To develop mindfulness as a lifestyle among young engineers.

Intended Learning Outcomes:
On successful completion of the course, the students should be able to;

ILO1: **identify** basics of mindfulness, advantageous and different stages of it;

ILO2: **describe** medical, physiological backgrounds of mindfulness and recent developments;

ILO3: **relate** the use of basic tools of mindfulness;

ILO4: **apply** knowledge of mindfulness for solving problems.

Course Content:

Introduction to mindfulness:
What is mindfulness, definitions, advantages of being mindful; creative thinking ability, problem solving skills, clear and quick decision making, improved interpersonal-skills, stress and anger control, be happy etc. and different stages of mindfulness.

Basic tools to develop mindfulness:
Mind-body-friendship, mindful-sitting, mindful-walking, mindfulness in day-to-day activities.

Medical and physiological background of mindfulness:
How brain and nerve system function, mindfulness practice and consequent structural/functional changes in brain and nerve system, immune system etc.

Recent developments in mindfulness practice:
Recent developments in mindfulness practice, mindfulness as a preventive method to society in general, prevention of alcohol usage, prevention of drug addiction and living with epidemic or any other illness.

Lifelong development of mindfulness practice:

Appreciation of mindfulness practice and how to develop it as a lifestyle.

Teaching /Learning Methods:

Classroom lectures, practical and discussions

Assessment Strategy:

Continuous Assessment	Final Assessment		
60%	40%		
Details:	Theory (%)	Practical (%)	Other (%)
Tutorials 20% Practical 40%	40	-	-

Recommended Reading:

- Zinn, J. K. (2010). *Where you go There you are*. 10th anniversary edition, Hachette Books, New York, USA.
- Williams, M, Penman, D. (2011). *Mindfulness: An Eight-week plan for finding peace in a frantic world*. Rodale Inc., NY.
- Zinn, J. K. (2013). *Full Catastrophe Living: Using the Wisdom of Your Body and Mind to Face Stress, Pain and Illness*. 2nd edition, Bantam Books, NY.
- Nyanaponika Thera. (2001). *The Power of Mindfulness.* BPS Inc, Kandy, Sri Lanka.
- Shapiro, S. L., &Carlson, L. E. (2017). *The Art and Science of Mindfulness*. 2nd edition, American Psychological Association, Washington DC.

Semester	5		
Course Code:	MA5500		
Course Name:	Business Communication		
Credit Value	3 (Notional hours: 150)		
Pre-requisites	None		
Core /Optional	Optional		
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Independent Learning (hrs)
	14	31	105

Aim(s):

- To provide the necessary tools to develop communication skills for effective business operations and professional conduct as engineering managers.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **analyze** audience and related modes of communication for different situations.
ILO2: **demonstrate** communication skills in writing and presenting.
ILO3: **apply** communication skills in negotiating and conducting business meetings.
ILO4: **use** effective communication strategies for conflict handling and counseling.
ILO5: **demonstrate** communication skills in facing and conducting interviews.

Course content:

Understanding Your Audience:
Understanding yourself, perception, and getting to know your audience.

Different Communication Modes for Business Situations:
Communication choices in businesses; techniques of communications; nonverbal communications; listening and critical thinking.

Effective Writing for Business:
Letters, memorandums; proposals; reports; resumes; text; and emails.

Business Presentations:
Preparation for presentations; presenting; use of presentation aids.

Conducting Business Meetings:
Agenda; the role of the chair and members; meeting minutes.

Business Negotiations:
Laying the groundwork, mutual gain and win-win situations; complex issues and ethics.

Communications in Handling Stress, Conflict and Counseling:

Controlling stress through communication, conflict handling, and decision making; manager as a counselor.

Interviewing Skills: Facing interviews; conducting interviews.

Teaching/Learning Methods:

Lectures

Student Based Activities

Assessment Strategy

Continuous Assessments 50%	**Final Assessment** 50%		
Small Group Activities 30% Individual reports and presentation 20%	**Theory** 50%	**Practical** -	**Other** -

Recommended Reading:

- Luecke R. and Munter, M. (2003). *Harvard Business Essentials: Business Communication*. Harvard Business School Press.
- Malhotra, D. (2016). *Negotiating the Impossible: How to Break Deadlocks and Resolve Ugly Conflicts.* Pearson.
- Thill, J. V. and Courtland, L. B. (2017). *Excellence in Business Communication.* Pearson Education.

Semester	5			
Course Code:	MA5510			
Course Name:	Circular Economy for Engineering			
Credit Value	3 (Notional hours: 150)			
Pre-requisites	None			
Core /Optional	Optional			
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Assignments (hrs)	Independent Learning (hrs)
	12	28	10	100

Aim(s):

- To introduce the concept of circular economy and discuss the necessary involvement of Engineering Managers for the effectiveness of its application in engineering processes.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **explain** the differences between a circular economy and a linear economy.
ILO2: **explain** the basic concepts of a circular economy.
ILO3: **create** circular economic business models for different processes.
ILO4: **analyze** material recovery indicators for a circular economy.

Course content:

Introduction to Circular Economy:
Linear economy and waste of resources, green economies, regenerative economies, the Circular Economy.

Basic Principles of a Circular Economy:
The concepts of design out, regeneration, zero waste, 3R: reduce, reuse, and recycle; 6 R, 10R and evolution of R principles.

Models of Circular Economy:
Circular supply chain**,** engineering inputs at different levels of a circular economy

Indicators of material recovery:
Developing indicators for a circular process in engineering activities.

Challenge Project:
Building a circular economic model for any engineering activity and presenting the model.

Teaching/Learning Methods:

Lectures
Student Based Activities

Assessment Strategy

<table>
<tr><th>Continuous Assessments
50%</th><th colspan="3">Final Assessment
50%</th></tr>
<tr><td rowspan="2">Small Group Activities 30%
Challenge Project 20%</td><td>Theory</td><td>Practical</td><td>Other</td></tr>
<tr><td>50%</td><td>-</td><td>-</td></tr>
</table>

Recommended Reading:

- De Angelis, R. (2018). *Business Models in the Circular Economy_ Concepts, Examples and Theory.* Palgrave Macmillan ISBN 978-3-319-75126-9
- Machado, C. and Davim, J. P. (2020). *Circular Economy and Engineering.* Springer, Switzerland. ISBN 978-3-030-43043-6
- Mao, J., Li, C., Pei, Y., Xu, L. (2018). *Circular Economy and Sustainable Development Enterprises.* Springer, Singapore. ISBN 978-981-10-8524-6
- Scott, J. T. (2015). *The Sustainable Business*, 2nd Edition. Greenleaf Publishing, UK. ISBN-13: 978- 1-907643-52-1

Semester	5			
Course Code:	MA5520			
Course Name:	Marketing for Engineers			
Credit Value	3 (Notional hours: 150)			
Pre-requisites	None			
Core /Optional	Optional			
Hourly Breakdown	Lectures (hrs)	Small-Group Discussions (hrs)	Assignments (hrs)	Independent Learning (hrs)
	22	11	24	93

Aim(s):

- To introduce marketing concepts and their applications.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **describe** basic marketing terminology and concepts.
ILO2: **explain** the characteristics of consumers' and businesses' buyer behavior.
ILO3: **analyze** market segmentation, targeting and positioning for a product or a service.
ILO4: **analyze** branding, pricing, promotions and marketing channels for a product or a service.
ILO5: **develop** a marketing plan using the elements of the marketing mix.

Course content:

Introduction to Marketing:
Scope of marketing; needs; wants and demands; elements of the marketing mix; collecting and analyzing market data.

Buyer Behavior:
Consumer buyer behavior; business buyer behavior

Segmentation Targeting and Positioning:
Analyzing marketing environment; bases of segmentation; selecting target segments; positioning the product.

Products and Services:
Goods and services; differentiating products; product life cycle; branding; building brand equity.

Pricing:
Considerations in setting an initial price; adapting the price.

Promotions:
Promotions mix; 5 M's in advertising; sales promotions; public relations; personal selling

Marketing Channels: Selecting marketing channels; retailing and wholesaling; franchising; managing channel conflict. **Marketing Plan:** Prepare and present a marketing plan for a product.
Teaching/Learning Methods: Lectures Student Based Activities

Assessment Strategy

Continuous Assessments 50%	**Final Assessment** 50%		
	Theory	**Practical**	**Other**
Small Group Activities 30% Quizzes 20%	50%	-	-

Recommended Reading:

- Amstrong. G. Kotler, P.T., Harker, M., Brennan, R. (2017). *Marketing an Introduction,* (4th Edition), Pearson Education Limited.
- Ishikawa, A., Tsujimoto, A. (2008). *Creative Marketing for New Business Development,* World Scientific Publishing Co. Pte. Ltd, Singapore.
- Kotler, P.T., Amstrong. G. (2017). *Principles of Marketing* (17th Edition). Global, Pearson Education Limited.

<table>
<tr><td>Semester</td><td colspan="4">6</td></tr>
<tr><td>Course Code:</td><td colspan="4">MA5600</td></tr>
<tr><td>Course Name:</td><td colspan="4">Economics for Engineers</td></tr>
<tr><td>Credit Value</td><td colspan="4">3 (Notional hours: 150)</td></tr>
<tr><td>Pre-requisites</td><td colspan="4">None</td></tr>
<tr><td>Core /Optional</td><td colspan="4">Optional</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture (hrs)</td><td>Small-Group Discussions (hrs)</td><td>Assignments (hrs)</td><td>Independent Learning (hrs)</td></tr>
<tr><td>20</td><td>16</td><td>18</td><td>96</td></tr>
</table>

Aim(s):

- To introduce necessary macroeconomics and microeconomics principles for engineering decision-making.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **describe** the key ideas that define the economic way of thinking.
ILO2: **analyze** how demand and supply determine prices.
ILO3: **explain** the relationship between a firm's output and costs.
ILO4: **analyze** the impact of government interventions in markets.
ILO5: **analyze** the effect of international trade on the microeconomies of organization
ILO6: **appraise** economic effects on engineering projects

Course content:

- **Basic Economic Concepts:** Scarcity; thinking on the margin; opportunity cost; the power of trade; comparative advantage; production possibilities frontier.
- **Allocation of Resources:** Demand; supply; demand and supply shifters; equilibrium; elasticity; price ceiling and floors; the labor market
- **Costs and Production:** Profits and losses; how much should a firm produce; production function.
- **Government and the Macroeconomy:** Public goods and private goods; economics of environment; GDP; unemployment; inflation; the role of central banking; other measures of development; green and welfare economies.
- **International trade and globalization:** Trade between countries; growth of globalization; the role of free trade; multinational companies; foreign exchange and balance of payments stability.
- **Group Project:** Case Study Presentation

Teaching/Learning Methods:

Lectures, Student Based Activities

Assessment Strategy

<table>
<tr><td>Continuous Assessments
50%</td><td colspan="3">Final Assessment
50%</td></tr>
<tr><td>Small Group Activities 20%
Group Project 20%
Quizzes 10%</td><td>Theory
50%</td><td>Practical
-</td><td>Other
-</td></tr>
</table>

Recommended Reading:

- Cowen, T. & Tabarrok, A. (2015). *Modern Principles of Economics*, 3rd Edition, Worth Publishers, New York.
- Mankiv, N.G. (2021). *Principles of Economics*. Pearson Education, 9th Edition, Cengage, UK.
- Mateer, D., Koppock, L. and O'Roark, B. (2016). *Essentials of Economics*. Norton & Co.
- Parkin, M. (2010). *Macroeconomics*, Pearson Education, UK.

Semester	6		
Course Code:	MA5610		
Course Name:	Corporate Finance and Accounting for Engineers		
Credit Value	3 (Notional hours: 150)		
Pre-requisites	None		
Core /Optional	Optional		
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Independent Learning (hrs)
	15	30	105

Aim(s):

- To introduce corporate finance and accounting concepts for engineering managers to function effectively in the industry.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **appreciate** the role of an engineer in the financial goals of a firm.
ILO2: **apply** the costing and budgeting technique for engineering projects and products.
ILO3: **appraise** investment decisions for engineering projects, products and services.
ILO4: **analyze** financing decisions for engineering projects and products.
ILO5: **appreciate** the role of financial statement analysis in the value creation of the firm.

Course content:

Introduction to Branches of Corporate Finance and Accounting:
Financial goals of a firm: survive in business, avoid financial distress and bankruptcy, beat the competition, maximize sales or market share, minimize costs, maximize profits, and maintain steady earnings growth; the engineer's role in the financial goals of a firm; fundamental financial concepts: time value of money; risk and return.

Costing and Budgeting Techniques for Decision-Making:
Types and nature of costs; project costing: analogous estimation, bottom-up estimation, parametric estimation, three-point estimation, cost of quality, reverse analysis and vendor bid analysis, project management estimating software and expert judgment; services and product costing: activity-based costing vs traditional costing.

Investment Decisions:
Process of capital budgeting; capital budgeting techniques – ARR, payback, NPV, IRR; effect of risk; inflation and tax on investment decisions; lifecycle costing; cost-volume-profit (break-even) analysis and decision making.

Financing Decision:
Financing requirements of a business; sources of finance and different classifications; life cycle financing; capital structure and cost of capital; operating budgets and cash budgets; working capital management: profitability vs liquidity.

Financial Statements and Analysis:

<table>
<tr><td colspan="4">Basic accounting concepts; accounting statements - balance Sheet; income statement; cash-flow statement; statement of retained earnings; key financial ratios; ratio analysis.</td></tr>
<tr><td colspan="4">Teaching/Learning Methods:
Lectures
Student Based Activities</td></tr>
<tr><td colspan="4">Assessment Strategy</td></tr>
<tr><td>Continuous Assessments
50%</td><td colspan="3">Final Assessment
50%</td></tr>
<tr><td>Small Group Activities 30%
Quizzes 20%</td><td>Theory
50%</td><td>Practical
-</td><td>Other
-</td></tr>
<tr><td colspan="4">Recommended Reading:
● Lawrence J. G. (2006). Managerial Finance (11^{th} Edition). Pearson Education. SBN: 13: 978-0-13-354640-8.
● Stephen R., Westerfield, R., Jordan, B. (2021). Fundamentals of Corporate Finance. 13^{th} Edition. McGraw-Hill Education. ISBN: 1265553602,9781265553609.
● Weetman, P. (2016). Financial and management accounting: an introduction (7^{th} Edition). Pearson Education, England, New York. ISBN 978-0-273-71845-1.</td></tr>
</table>

<table>
<tr><td>Semester</td><td colspan="4">6</td></tr>
<tr><td>Course Code:</td><td colspan="4">MA5620</td></tr>
<tr><td>Course Name:</td><td colspan="4">Business Law and Intellectual Property</td></tr>
<tr><td>Credit Value</td><td colspan="4">3 (Notional hours: 150)</td></tr>
<tr><td>Pre-requisites</td><td colspan="4">None</td></tr>
<tr><td>Core /Optional</td><td colspan="4">Optional</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture (hrs)</td><td>Small-Group Discussions (hrs)</td><td>Assignments (hrs)</td><td>Independent Learning (hrs)</td></tr>
<tr><td>28</td><td>14</td><td>6</td><td>102</td></tr>
</table>

Aim(s):

- To explain how the law evolved and how it applies in the commercial context, introduce the concept of intellectual property and explain the pathway to obtaining a patent.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **differentiate** between Civil and Criminal Law.
ILO2: **examine** the conditions under which contracts can be formed and discharged.
ILO3: **discuss** law relating to the sale of goods, agency and different forms of business organizations.
ILO4: **analyze** the principles of the law of employment, intellectual property and environment pertaining to business scenarios.

Course content:

Introduction:
Sources of law; legal system in Sri Lanka; the difference between civil and criminal law; tort of negligence and 'duty of care'.

Law of Contracts:
Essential elements of a contract; conditions and warranties; terms and misrepresentation; essential elements of a contract; conditions and warranties; terms and misrepresentation; discharge of contracts; alternative dispute resolution

Sale of Goods:
Definition of 'goods'; sale of goods ordinance.

Law of Agency:
Legal concept of 'agency'; creation of agency; authority of an agent; duties of agent/principal towards principal/agent.

The law Relating to Partnerships:
Formalities in establishing a partnership; business names legislation; JVs and partnerships; rights and duties between partners.

Company Law:
Nature of a company – 'separate legal entity'; lifting the corporate veil; types of companies; company registration; company liquidation.

Intellectual Property:
Types of IP; patents; prior to research; application for a patent; patent drafting; legal issues of IP.

Law Relating to Employment:
Sri Lankan legislation on labor; occupational health and safety - factories ordinance; workmen's compensation.

Environmental Law:
Environmental law in Sri Lanka; environmental approval of projects.

Teaching/Learning Methods:

Lectures
Student Based Activities

Assessment Strategy

Continuous Assessments 50%	**Final Assessment** 50%		
Small Group Activities 30% Quizzes 20%	**Theory** 50%	**Practical** -	**Other** -

Recommended Reading:

- Mann, A.G. and Roberts B.S. (2019). *Essentials of Business and the Legal Environment Law and Managerial Finance*. Cengage.
- Weerasooriya, W. (2010). *Commercial Law* (1st Edition), Project Management Institute, Sri Lanka.

Semester	7			
Course Code:	MA5700			
Course Name:	Environmental Economics			
Credit Value	3 (Notional hours: 150)			
Pre-requisites	None			
Core /Optional	Optional			
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Assignments (hrs)	Independent Learning (hrs)
	12	24	18	96

Aim(s):

- To provide an overview of integrating environmental management and economic theory within a sustainable development framework.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **appreciate** the environmental considerations in economic decision-making.
ILO2: **analyze** the total economic value of engineering projects and products.
ILO3: **analyze** investment and financing decisions of engineering projects and products.
ILO4: **appreciate** the climate change mitigation efforts through engineering projects and products.
ILO5: **create** a total economic value model for an engineering project.

Course content:

Integration of Environmental Management and Economic theory:
National income and environmental accounting; Utility and consumer demand; Production, supply, and costs; Externalities and market failure; Policies. Applications in manufacturing, production, transportation, and energy.

Environmental valuation:
Total economic value: Direct-use, indirect-use, and non-use values; Valuation methods: market-based, contingent valuation, travel cost, hedonic pricing, restoration and replacement cost, benefits transfer, off-trade. Applications in projects, products, ecosystem services, and conservation

Investment Decisions:
Identifying alternatives; environmental costs and benefits; Lifecycle assessment and costing; tax and tariff; accounting for long-term ecological damage. Applications in infrastructure projects, green technology decision making.

Climate change mitigation:
Carbon abatement cost curves, emission taxes, cap and trade schemes, subsidies, carbon offsets and neutrality, feed-in tariff, carbon market and auditing. Applications in engineering projects and product development.

Group Project:
Investigate the total economic value of an engineering product or project.

Teaching/Learning Methods:
Lectures
Student Based Activities

Assessment Strategy

Continuous Assessments 50%	Final Assessment 50%		
Small Group Activities 30% Group Project 20%	**Theory** 50%	**Practical** -	**Other** -

Recommended Reading:

- Daniel, P., Keen, M., McPherson, C. (2010). *The Taxation of Petroleum and Minerals: Principles, Problems and Practice.* Series: Routledge explorations in environmental economics. Routledge. ISBN: 0415569214,9780415569217,9780203851081,0203851080,0415781388,9780415781381
- Mäler, K.G., Vincent, J.R. (2003). *Handbook of Environmental Economics* 1. North-Holland. ISBN: 978-0-444-50063-2
- Smith, J.B., Mendelsohn, R. O. (2007). *New Horizons in Environmental Economics*. Edward Elgar Publishing. ISBN: 9781845427474,1845427475

<table>
<tr><td>Semester</td><td colspan="4">7</td></tr>
<tr><td>Course Code:</td><td colspan="4">MA5710</td></tr>
<tr><td>Course Name:</td><td colspan="4">Project Management</td></tr>
<tr><td>Credit Value</td><td colspan="4">3 (Notional hours: 150)</td></tr>
<tr><td>Pre-requisites</td><td colspan="4">None</td></tr>
<tr><td>Core /Optional</td><td colspan="4">Optional</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture (hrs)</td><td>Small-Group Discussions (hrs)</td><td>Practical (hrs)</td><td>Independent Learning (hrs)</td></tr>
<tr><td>25</td><td>11</td><td>18</td><td>96</td></tr>
</table>

Aim(s):

- To provide theoretical and technical knowledge, skills and techniques required to manage projects throughout the project life cycle.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **explain** the project life cycle, phases, management processes and project performance domains.

ILO2: **apply** project planning techniques for creating a project plan.

ILO3: **interpret** and **apply** contractual procedures, rights and obligations of the parties to the contract.

ILO4: **explain** the importance of managing change, risks & communication for project success.

ILO5: **create** a project schedule using project management software for monitoring and controlling.

Course content:

Project Management Concepts:
Project definition, life cycle, environment; evolution in project management, project management knowledge areas, processes, and performance domains.

Initiation Phase:
Business case, identify stakeholders, project charter.

Planning Phase: Scope, work breakdown structure, project activities: durations, resources and cost, schedule development and use of project planning software.

Execution, monitoring and controlling phase:
Contract administration, project communication, managing time, cost, quality, change and risks.

Closing phase: Close-out records, final payment, post-project evaluation, lessons learned.

<table>
<tr><td colspan="4">Teaching/Learning Methods:
Lectures
Student Based Activities</td></tr>
<tr><td colspan="4">Assessment Strategy</td></tr>
<tr><td rowspan="2">Continuous Assessments
50%</td><td colspan="3">Final Assessment
50%</td></tr>
<tr><td>Theory</td><td>Practical</td><td>Other</td></tr>
<tr><td>Small Group Activities 30%
Group Project 20%</td><td>50%</td><td>-</td><td>-</td></tr>
<tr><td colspan="4">Recommended Reading:
● Gido, J., and Clements, J. P. (2015). Successful Project Management, 6th edition, Cengage Learning, USA.
● Project Management Institute Inc., (2017). A guide to the Project Management Body of Knowledge, 6th edition, Project Management Institute Inc., USA.
● Project Management Institute Inc., (2021). A guide to the Project Management Body of Knowledge, 7th edition, Project Management Institute Inc., USA.
● Stephen, P. R., David A, D., & Mary, C., (2013). Fundamentals of Management, 8th Edition, Pearson, USA.</td></tr>
</table>

Semester	7		
Course Code:	MA5720		
Course Name:	Organizational and Industrial Psychology		
Credit Value	3 (Notional hours: 150)		
Pre-requisites	None		
Core /Optional	Optional		
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Independent Learning (hrs)
	15	30	105

Aim(s):

- To provide the necessary organizational behavior tools to perform effectively in different organizational situations.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **discuss** motivational theories with worker attitudes.
ILO2: **relate** leadership models to the climate and culture of organizations.
ILO3: **appreciate** the need for stress and conflict handling in organizational development.
ILO4: **appreciate** the recruitment process of an organization.
ILO5: **analyze** performance using Key Performance Indicators.

Course content:

Organizational Psychology:

Motivation and work attitudes: motivational theories,
Leadership: positive and negative leaders; transformational and transactional leaders, leadership models.
Culture and climate: Individual differences; organizational structure and culture; multinational organizations; women in the industry; Organizational development: developmental process; change forces and types of change; resistance to change; costs and benefits; stress and conflict management; counseling

Industrial Psychology:

Human Resources Planning: Job Analysis, specifications and descriptions
Selection and placement: recruitment and selection process
Training: induction, on-the-job, institutional, outward bound; Performance appraisal: appraisal methods; performance evaluation and Key Performing Indicators (KPIs)

Teaching/Learning Methods:

Lectures
Student Based Activities

Assessment Strategy

Continuous Assessments 50%	**Final Assessment** 50%		
Small Group Activities 30% Case Studies 20%	**Theory** 50%	**Practical** -	**Other** -

Recommended Reading:

- King, D. and Lawley, S. (2013). *Organisational Behaviour*. Oxford University Press.
- Robbins, S. P., Judge, T. A. and Sanghi, S. (2010). *Organisational Behaviour*. Pearson.
- Sinha, J. B. P. (2008). *Culture and Organisational Behaviour*. Sage.

<table>
<tr><td>Semester</td><td colspan="4">8</td></tr>
<tr><td>Course Code:</td><td colspan="4">MA5800</td></tr>
<tr><td>Course Name:</td><td colspan="4">Sustainable Technology and Economic Development</td></tr>
<tr><td>Credit Value</td><td colspan="4">3 (Notional hours: 150)</td></tr>
<tr><td>Pre-requisites</td><td colspan="4">None</td></tr>
<tr><td>Core /Optional</td><td colspan="4">Optional</td></tr>
<tr><td rowspan="2">Hourly Breakdown</td><td>Lecture (hrs)</td><td>Small-Group Discussions (hrs)</td><td>Assignments (hrs)</td><td>Independent Learning (hrs)</td></tr>
<tr><td>10</td><td>30</td><td>10</td><td>100</td></tr>
</table>

Aim(s):

- To provide background information on managing technology for sustainable development.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **explain** the impact of technology on the economy, society and environment.
ILO2: **discuss** the role of transferred technology on existing technology.
ILO3: **explain** the process of technology innovation and evolution.
ILO4: **reflect** goals of green and appropriate technology in mega projects and at workplaces.
ILO5: **apply** technology management concepts in developing Sri Lankan Technology.

Course content:

Role/Impact of Technology:
Positive and negative impacts of technology on society, economy, and environment; sustainable development

Technology Acquisition and Transfer:
Technology as a source of competitive advantage; insourcing and outsourcing; managing core competencies; the role of the transferred technology.

Technology and Innovation:
Invention and innovation; innovation systems; selection of projects; managing technological assets.

Evolution of Technology:
Effective utilization of resources; project externalities; waste and environmental pollution exploitation.

Green/ Appropriate Technology:
Green economics; goals of green and appropriate technology.

Group Project: Improvement of Sri Lankan technology for sustainable development

Teaching/Learning Methods:

Lectures
Student Based Activities

<table>
<tr><td colspan="4">Assessment Strategy</td></tr>
<tr><td>Continuous Assessments
50%</td><td colspan="3">Final Assessment
50%</td></tr>
<tr><td>Small Group Activities 30%
Group Project 20%</td><td>Theory
50%</td><td>Practical
-</td><td>Other
-</td></tr>
<tr><td colspan="4">Recommended Reading:
● Audretsch, D.B., Lehmann, E.E., Link, A.N., Starnecker, A. (2012). Technology Transfer in a Global Economy. Springer.
● Thomas A. Easton. (1997). Taking sides: Clashing Views on controversial issues in science, technology and society. Brow .A. & Benchmark.</td></tr>
</table>

Semester	8			
Course Code:	MA5810			
Course Name:	Procurement Management			
Credit Value	3 (Notional hours: 150)			
Pre-requisites	None			
Core /Optional	Optional			
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Assignments (hrs)	Independent Learning (hrs)
	26	13	12	99

Aim(s):

- To impart the concepts and frameworks of procurement management and to develop analytical and decision-making skills related to procurements.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **explain** the procurement process and how it relates to the supply chain of an organization.
ILO2: **apply** procurement principles to the acquisition of goods and services.
ILO3: **discuss** the incorporation of sustainable procurement strategies into existing procurement guidelines.
ILO4: **develop** a procurement strategy for a project.

Course content:

Introduction to Procurement:
Need of procurement; development and planning, procurement cycle; proactive procurement; positioning and transformations; strategic procurement.

Method of Procurement:
International competitive bidding; national competitive bidding; limited/restricted bidding; shopping; direct contracting; repeat orders; force account; emergency procurement; community participation in procurement; two-stage bidding; two envelope system; pre-qualification of Bidders.

Types of Procurement:
Unit price works (BOQ), lump sum, cost reimbursable, time and material, design and build, and BOOT and BOT contracts.

Procurement Guidelines:
National/International procurement guidelines; Bid documents, technical specification; evaluation criteria; pre-bid conference; bid opening; bid examination; bid evaluation and award of contract.

Sustainable Procurement:
Policies and principles of sustainable procurement; sustainability in the procurement process; circularity and metrics for sustainability; implementing sustainable procurement; and technology for sustainability.

Procurement Strategy: Prepare and present a procurement plan for a project.

Teaching/Learning Methods:

Lectures

Student Based Activities

Assessment Strategy

Continuous Assessments 50%	**Final Assessment** 50%		
Small Group Activities 30% Group Project and Presentation 20%	**Theory** 50%	**Practical** **-**	**Other** **-**

Recommended Reading:

- Baily, P., Farmer, D., Crocker, B., Jessop, D. and Jone. D., (2022). *Procurement Principles and Management,* 12th Edition, Pearson Education Limited, UK.
- National Procurement Agency, (2006). *Procurement Guidelines*: Goods and Services, Sri Lanka.
- National Procurement Commission, (2018). *Procurement Manual: Goods, Works, Services and Information Systems*, Sri Lanka.
- Project Management Institute Inc., (2021). *A guide to the Project Management Body of Knowledge*, 7th edition, USA.

Semester	8			
Course Code:	MA5820			
Course Name:	Engineer as an Entrepreneur			
Credit Value	3 (Notional hours: 150)			
Pre-requisites	None			
Core /Optional	Optional			
Hourly Breakdown	Lecture (hrs)	Small-Group Discussions (hrs)	Assignments (hrs)	Independent Learning (hrs)
	24	12	18	96

Aim(s):

- To inspire and provide tools to start engineering ventures by recognising opportunities and overcoming challenges.

Intended Learning Outcomes:

On completion of the course, students should be able to:

ILO1: **explain** the value of generating ideas and converting them into business opportunities.
ILO2: **analyze** the financial and technological feasibility of a new venture.
ILO3: **explain** the role of leadership and marketing in new ventures.
ILO4: **explain** the applicable laws for business ventures and intellectual property.
ILO5: **develop** a business plan for a new venture.

Course content:

Introduction to Entrepreneurship:
Role of an entrepreneur in creating jobs and wealth; risks and rewards of starting a business.

Idea Generation and Feasibility Analysis:
The idea to market process; market and competitive analysis; idea generation and creativity; technology to lower barriers; sustainability and green businesses.

Financial Analysis:
Raising capital; venture capital; loans etc.; financial analysis and projections; cash management; duties and taxation

Technology Strategy:
Developing or adopting technology; acquiring technology; diffusion of technology.

Leadership and Management:
Providing leadership, developing an organisational structure and culture; developing human resources, and delegating authority.

Marketing, Operations Sales and Distribution:
Manufacturing or sourcing strategy; advertising and publicity; sales and distribution; online sales; retail sales; intermediaries.

Legal Framework for a Business:
Sole proprietorships; partnerships and limited liability companies; registering a company; memorandum and articles of association; labour and industrial law.

Management of Intellectual Property:
Forms of intellectual property; patents and its impact on the diffusion of technology.

Writing a Business Plan:
Reasons for writing a business plan; outline of the plan; presenting the business plan to investors.

Group Project:
Develop a business plan for a new venture.

Teaching/Learning Methods:

Lectures
Student Based Activities

Assessment Strategy

Continuous Assessments 50%		**Final Assessment** 50%		
Small Group Activities Group Project	30% 20%	**Theory** 50%	**Practical** -	**Other** -

Recommended Reading:

- Allen, K. (2015). *Launching New Ventures: An Entrepreneurial Approach*. Cengage Learning.
- Barringer, B. R. (2015). *Preparing Effective Business Plans* (2nd edition). Pearson Press.
- Barringer, B. R. and Ireland, R. D. (2012). *Entrepreneurship* (4th Edition). Pearson.
- Evans, V. (2015). *Writing a Business Plan* (2nd Edition). Pearson.