Department of Computer Science & Engineering

School of Engineering and Computer Science

Independent University, Bangladesh

Curriculum

for

BSc. in Computer Engineering

Version 3.2

Revision record

Version	Status	Date	Note
1.0	Approved by UGC	Apr 14, 2004	Initial version prepared for program approval
2.0	Approved by Academic council	Mar 13, 2013	Changes in major and optional courses
3.0	Under review	Jul 13, 2017	Update document for peer review along with outcome based education
3.1	Under review	Dec 14, 2017	Incorporation of mapping with PLO and CO
3.2	Under review	Mar 19, 2017	Incorporation of departmental vision, mission along with program Vision, Mission and graduate profile

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING (CSE)

INTRODUCTION:

Bangladesh has seen remarkable growth in the ICT sector in recent times and IUB's Computer Science & Engineering (CSE) Department is an active participant in this growth. The Department of Computer Science & Engineering (CSE) at IUB, under the School of Engineering and Computer Science (SECS), is one of the most dynamic and versatile departments in the university. Our "Application Oriented Learning" philosophy not only teaches students the fundamental principles of computing but also provides them with hands-on training of the various applications of this knowledge. University Grants Commission (UGC) of Bangladesh recognizes this contribution and potential and has provided financial support in excess of Four Crore Taka to develop advanced research facilities. We have arguably the best IT research setup in Bangladesh. 11 Tera Flops GPU server for High-Performance Computing research lab (Center for Cognitive Skill Enhancement), digital fabrication facilities enabled research lab (Fab Lab, IUB), state-of-the-art Robotics and Networking Labs, Electronics and Electrical Circuits laboratories for smart circuit design research, to mention just a few of our facilities.

We offer comprehensive Computer Science and Engineering based curriculums both at the undergraduate and graduate level. Students can mound their education according to their desired research or industry track. The CSE department provides the opportunity to explore specialized topics in Machine Learning, Computer Vision, Data Science, Big Data, Robotics, Software Engineering, Network Administration, Game Development, Cyber Security, and follow the latest and greatest trends in the IT world.

The Department of Computer Science and Engineering offers a 4 (four) year Bachelors of Science program in Computer Science. The degree is designed to provide a deep and broad knowledge of the theory and practical application related to computer systems. The university is distinctive in its emphasis on a broad based liberal arts curriculum based on a North American model. The mission of the university is to deliver a high quality education which will help foster thinking across disciplines, encourage tolerance and understanding of diverse cultural and social traditions, nurture essential values and prepare students for a fast changing world. Department of CSE challenged the students to think critically, encouraged to imagine boldly and guided to implement efficiently.

VISION:

Inspired by the mission of the university, the department of Computer Science and Engineering is striving to create a breed of students who can imagine boldly, think clearly, argue precisely and implement efficiently. Our mission is to perform high impact research leading to sustainable innovation in the area of computer science and engineering thus contributing to the economic growth of the country through a meaningful partnership between the Community, the Industry and the University.

MISSION:

At the very heart of science and technology education lie comprehension, imagination and implementation. The objective of our programs is to contribute in creating a globally recognized and locally sustainable knowledge eco-system through which students will graduate to provide leadership in industry, enterprise, public service and welfare; to encourage and support innovative research; create enthusiasm in learning through hands on training; while creating knowledge throughout the process. We also provide a platform for lifelong learning through graduate programs and continuing education endeavors.

The curriculum objectives for the undergraduate education are to teach communicative skills (oral and written communication) with a strong humanities background through a thorough liberal arts foundation. To have students have a comprehensive understanding of Computer Science and Engineering related subjects (i.e. a major), and a sub-specialization (minor) in a subject of student's own interest and appreciate their inter-connectivity with founding principles. Focus is maintained on outcome based learning. Outcome is quantifiable through students' enhanced skill in comprehension, analytical capability and decision making skill.

The undergraduate programs equip students with the tools needed to become innovators and global leaders in computing and equip them with the background necessary to pursue higher studies. Consequently our programs are designed to have a high impact outcome of contributing to the sustainable development of knowledge-based economy of our nation.

ADMISSION REQUIREMENT

Below we provide the admission requirements of the School of Engineering and Computer Science for the Computer Science and Engineering degree program.

Combined GPA of 8.0 in S.S.C and H.S.C. with minimum 3.5 in each.

- O'Level in minimum 5 subjects with a GPA 2.50 and A'Level in 2 subjects with a minimum GPA 2.00
- International Baccalaureate or High School Diploma
- For other 12 years equivalent degrees must have the equivalence certificate from Ministry of Education.
- Students must have Math and Physics in their H.S.C. with at least B grade.
- All eligible candidates will have to tale a written admission test in English, Math and Physics before final selection into the program.

SEMESTER/TERM

There are three academic semesters namely, Autumn, Spring and Summer. The duration of each semester is about four (4) months.

The admission procedure for Autumn (the beginning of the academic year) starts within the first week of July and ends with the commencement of classes in the second /third week of August. The semester ends by the end of December. The admission procedure for Spring starts within the first week of December and the commencement of classes in the January. The semester ends on April. The Summer class begins on May and ends on August.

MEDIUM OF INSTRUCTION

English is the medium of instruction at the university.

TEACHING STRATEGY

The Department of CSE believes in extra-ordinary quality teaching in a local university with a global connection. The Department is concern about the variance among the same-level teachers taking similar courses at undergraduate level, hence focuses on eliminating these differences and discriminations as much as possible that have negative implications on students' learning. It also tries to equate the learning outputs from the same courses and make a unitary approach toward tertiary-level education by conducting trainings and workshops on assessment, measurement, evaluation and other pedagogical instruments. In general, the faculty members use four broad styles, i.e. formal authority, demonstrator or personal model, facilitator and delegator. In next few lines some commonly practiced teaching strategies have been listed:

- Lecture
- Demonstration
- Reading Assignment
- Individual Project/Assignment
- Group Assignment
- Small Group Discussion
- Panel Discussion
- Video demonstration
- Debate
- Simulation Game
- Brainstorming
- Case Studies
- Role Playing
- Seminar/Workshop
- Cooperative Learning
- Problem-based Learning (PBL)
- Inquiry-based Learning (IBL)

ASSESSMENT STRATEGY:

At CSE, two types of assessments are in practice; formative assessment for continuous improvement of the students' learning, summative assessment for grading of students' performance. Generally, CSE believes in assessment for learning, not assessment of learning. Principally the assessment is the responsibility of the individual faculty members according to the standard of North American academia. However, for courses with multiple sections a faculty coordinator mediates the process of assessment. Each course is assessed over a total of 100 numeric marks which is divided into two categories. Continuous assessment, such as quizzes, presentation, class test, etc. covers 40% to 60% while the rest of the marks are allocated for the mid-term and final exams. In some courses, rigorous assignments may replace other forms of assessments. There are no specific criteria for assessing the performance of the students; however, the following criteria are often used for different courses:

Table 1: General evaluation criteria

Criteria	Weight
Class Tests	20
Assignments	20
Midterm	25
Final	35
Total	100

*Student must attend at least 75% classes to get a valid grade.

GRADING SYSTEM

The grading scale in CSE is in line with the IUB's grading system. However, the numeric score for the corresponding letter grade is not a fixed structure, rather a guideline. Following is the prescribed grading structure at CSE:

Table 2: Grading System

Numerical Scores	Letter Grade	Grade Point	Explanation
100-85	A	4.0	Excellent
84-80	A-	3.7	Excellent
79-75	B+	3.3	Good
74-70	B	3.0	Good
69-65	B-	2.7	Good
64-60	C+	2.3	Passing
59-55	C	2.0	Passing
54-50	C-	1.7	Passing
49-45	D+	1.3	Deficient Passing
44-40	D	1.0	Deficient Passing
Below	F	0.0	Fail

COURSE CONTACT HOURS

For each 3 credits course students attend 2 classes each week total 3 hours a week. Each lab course is 1 credit course and students need to attend 1 class each week total 1.5 hrs a week.

BACHELOR OF SCIENCE IN COMPUTER ENGINEERING

Those studying for the Computer Engineering B.Sc. degree will learn the knowledge and skills necessary for becoming an IT engineer. At the same time, the course will prepare them for further study towards a Master's degree.

The course's core area offers a balanced array of computer engineering modules, basic engineering, and natural sciences subjects, which will be integrated and applied in a practical project and the Bachelor's thesis.

VISION

To implement technical education of Computer Engineering program and improve its educational environment in order to produce engineers who influence the development of welfare of society, locally and internationally.

MISSION

The mission is to train students to effectively apply Computer Engineering program by enhancing industry experience to get acquainted with corporate culture and be able to solve real world problems, hence amplifying their potential for lifelong high quality career and giving them competitive advantages in the ever changing and challenging global work environment of the 21st century. The goal is to produce best quality Computer Engineering graduates by implementing quality training, hands on experience and value education. The target is also to pursue creative research and new technologies in order to serve the needs of industry, government, and society in Computer Engineering field.

PROGRAM EDUCATIONAL OBJECTIVES (PEO):

PEO01 THINK CRITICALLY:

Our education system is more geared towards making the students acquiring knowledge but fails to capture their imagination. We want to change that by introducing the students to the exciting world of logic, rationalization and decision making through games and apps. We will introduce our students to various development, analysis and synthesis tools and will engage them in research early in their studies.

PEO2: DESIGN CONSCIENTIOUSLY

A broad liberal arts curriculum covering computer science as well as related technical subjects will provide students with a deeper understanding of the engineering issues and trade-offs that cross disciplines. Courses in humanities and social sciences will equip them with the knowledge and awareness to become responsible members of society who understand the social, political, economic and environmental impact of their decisions. Graduates will become ethical professionals with the ability to work individually or in multidisciplinary teams to design sustainable solutions to complex real-world problems under real-world constraints.

PEO3: IMPLEMENT EFFICIENTLY

A strong emphasis is placed on developing the students' ability to identify and analyze a problem, and to then define the computing requirements appropriate to its solution with regard to factors such as efficiency, sustainability, scalability, available resources and constraints. We ensure that our students are kept up-to-date with knowledge and practice of the most current tools and techniques, and that they develop an appreciation for continued improvement through self-training or formal graduate study. Graduates will possess the ability to design and implement efficient and future-proof software solutions to problems of varying sizes and complexities using modern software development principles and practices.

PROGRAM LEARNING OUTCOME (PLO):

The learning outcome of the degree program supports all the outcomes suggested in the ABET criteria.

1. Knowledge: An ability to select and apply the knowledge, techniques, skills, and modern tools of the computer science and engineering discipline;

2. Requirement Analysis: An ability to identify, analyze, and solve a problem by defining the computing requirements of the problem through effectively gathering of the actual requirements;

3. Problem Analysis: An ability to select and apply the knowledge of mathematics, science, engineering, and technology to computing problems that require the application of principles and applied procedures or methodologies;

4. Design: An ability to design computer based systems, components, or processes to meet the desire requirement;

5. Problem Solving: An ability to apply mathematical foundations, simulation, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices.

6. Implementation: An ability to apply design and development principles in the construction of software systems of varying complexity

7. Experiment and Analysis: An ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve solutions (products or processes);

8. Community engagement and Engineering: An ability to appreciate human behavior, culture, interaction and organization through studies in the humanities and social sciences. A knowledge of the impact of computing solutions in a local and global context;

9. Teamwork: An ability to function effectively as a member or leader of a technical team to accomplish common goals;

10. Communication: An ability to apply written and oral communication in both technical and non-technical environments; an ability to communicate with a range of audience; and an ability to identify and use appropriate available technical literature;

11. Self-directed: Recognition of the need for and an ability to engage in self-directed continuing professional development; be prepared to enter a top-ranked graduate program in Computer Science and Engineering.

12. Ethics: An understanding of and a commitment to address professional, ethical, legal, security, social issues and responsibilities including a respect for diversity;

13. Process Management: A commitment to quality, timeliness, and continuous improvement.

PEO AND PLO MAPPING:

Table 3: PEO and PLO mapping

	PEO01 Thinking Critically	PEO02 Design Conscientiously	PEO03 Implement Efficiently
PLO01 Knowledge	x	x	x
PLO02 Requirement Analysis	x	x	
PLO03 Problem Analysis	x	x	
PLO04 Design	x	x	
PLO05 Problem Solving	x	x	x
PLO06 Implementation			x
PLO07 Experiment and Analysis		x	x
PLO08 Community engagement and Engineering	x	x	x
PLO09 Teamwork	x	x	x
PLO10 Communication	x	x	x
PLO11 Self-directed	x	x	x
PLO12 Ethics	x	x	x
PLO13 Process Management	x	x	x

GRADUATE PROFILE:

The followings are the graduate profile of the department of Computer Science and Engineering.

1. **Scholars**: Our graduates are expected to have a broad knowledge-base and disciplinary expertise.

2. **Problem Solvers**: With an adequate knowledge of disciplinary expertise and problem domain our graduates will be in a position to formalize any problem and solve that in a methodical way.

3. **Innovators**: We want our graduates to be focused on future-proof solution. They will be critical thinkers, creative designers and efficient makers. They are capable of developing unique and sustainable solutions to the real world problems.

4. **Leaders**: Graduates of our department will take personal responsibility and seek opportunities to work with others to advance thinking and achievement in all spheres of their lives. They are confident, inclusive, inspiring and influential.

5. **Global Citizens**: Our graduates are locally produced but globally in demand. They are aware of global issues and act with integrity, sensitivity and fluency across cultures and perspectives, and are committed to the betterment of the society as a whole.

STRUCTURE OF THE PROGRAM

In order to obtain a B.Sc. in Computer Engineering student must complete a minimum of 134 credits of coursework. This includes 42 credits of Foundation studies. The minimum requirement for the major is 77 credit hours including 6 credit hours for internship/senior project.

Table 4: Summarized Program structure

SL	Course Component	Credits
01	Foundation Courses	42
02	Major Courses (Core)	59
03	Major Courses (Optional)	12
04	Major Courses (Internship/Senior Project)	6
05	Minor Courses (Any track)	15
	Total	**134**

CURRICULUM LAYOUT:

Below we provide the detail break-down of the program structure as curriculum layout.

Table 5: Detail Program structure

Major in Computer Engineering		**134**
Foundation courses		**42**
Communication Skills		**9**
ENG 101	Listening and Speaking Skills	3
ENG 102	English Reading Skills	3
ENG 105	Business English	3
Computer Skills		**4**
CSC 101	Introduction to Programming	3
CSC 101L	Lab for CSC101	1
Numeracy		**6**
MAT 104	Calculus and analytical geometry	3
MAT 212	Probability & Statistics for Science & Engineering	3
Natural Sciences		**8**
PHY 101	University Physics-I	3
PHY 101L	University Physics-I Lab	1
PHY 102	University Physics-II	3
PHY 102L	University Physics-II Lab	1
Social Sciences		**6**
Humanities		**6**
Live-in Field Experience		**3**
Major Courses		**77**
Core Courses		**59**
CEN 104	Electrical Circuit Analysis	3
CEN 104L	Lab work based on CEN104	1
CEN 201	Discrete Mathematics	3
CEN 203	Data Structure	3
CEN 203L	Labwork based on CEN203	1
CEN 204	Computer Hardware & Digital Logic	3
CEN 204L	Lab work based on CEN 204	1
CEN 210	Electronics I	3
CEN 210L	Lab work based on CEN210	1
CEN 212	Microprocessor, Interfacing & Assembly Language	3
CEN 212L	Lab work based on CEN 212	1
CEN 305	Object Oriented Programming	3
CEN 305L	Labwork based on CEN213	1
CEN 306	Algorithms	3
CEN 306L	Lab work based on CEN211	1
CEN 310	Electronics II	3
CEN 310L	Labwork based on CEN310	1
CEN 311	Computer Organization & Architecture	3
CEN 317	Numerical Methods	3
CEN 317L	Labwork based on CEN317	1
CEN 401	Database Management	3
CEN 401L	Labwork based on CEN303	1

CEN 413	Design of Operating System	3
CEN 430	Data Communication & Computer Networks	3
CEN 430L	Labwork based on CEN316	1
MAT 203	Linear Algebra- vectors and matrices	3
MAT 301	Ordinary Differential Equation	3
Optional Courses (Any four)		**12**
CEN 330	Data Communication	3
CEN 403	Network Management	3
CEN 405	System Analysis and Design	3
CEN 404	Embedded Systems	3
CEN 408	Advanced Computer Network	3
CEN 409	Optical Fiber Communication	3
CEN411	Compiler Construction	3
CEN 412	Wireless Networking & Mobile Communication	3
CEN 414	Digital System Design	3
CEN 416	Distributed Database Systems	3
CEN 417	Data Mining and Warehouse	3
CEN 418	Database Systems Implementation	3
CEN 419	Advanced Database Management Systems	3
CEN 420	Image Processing	3
CEN 421	Machine learning	3
CEN 422	Pattern Recognition	3
CEN 423	Theory of Fuzzy Systems	3
CEN 424	Neural Networks	3
CEN 425	Artificial Intelligence	3
CEN 426	Introduction to Robotics	3
CEN 431	Advanced Object Oriented Programming	3
CEN 434	Advance Programming in UNIX	3
CEN 435	Computer Graphics	3
CEN 437	Theory of Computation & Automata	3
CEN 440	Computer Simulation and Modeling	3
CEN 441	Instrumentation & measurements	3
CEN 443	Digital Signal Processing	3
CEN 444	Digital Electronics and Pulse Techniques	3
CEN 445	Software Engineering	3
CEN 447	Computer Peripherals & Interfacing	3
CEN 449	Fault Tolerant System	3
CEN 450	Cryptography and Network Security	3
CEN 452	Software Marketing	3
CEN 453	Software Requirement Engineering	3
CEN 454	Software Engineering Process Management	3
CEN 455	Web Application & Internet	3
CEN 456	Business Process Reengineering	3
CEN 457	Project Management	3
CEN 458	Software Quality and Testing	3
CEN 459	Software Architecture and Component-Based Design	3
CEN 460	Multimedia Systems	3
CEN 461	Advance topics for Application Development	3
CEN 462	Entrepreneurship Development	3
CEN 463	IT Forensic	3
CEN 464	Mobile application development	3
CEN 465	E-commerce and Web Database	3
CEN 470	Introduction to Parallel Programming	3
CEN 475	VLSI Design & Testing	3
CEN 480	Computer Vision	3
CEN 485	Telecommunication Engineering	3
CEN 490	Special Topics in Computer Engineering	3
MAT 401	Graph Theories	3
MAT 403	Introduction to Mathematical Modeling	3
MAT 405	Optimisation Techniques	3
MAT 420	Computational Geometry	3
MAT 430	Introduction to Discrete Dynamical Systems	3
Internship Program or Senior Project		**6**

CEN 4**	Any optional Course	3
CEN 498	Senior project	6
CEN 499	Internship Program	3
Minor/Specialization		**15**

FOUR YEAR PLAN

The following table provides an example of how to progress with Computer Science major program. However, the actual structure should be followed according to the Green Book and Computer Science curriculum.

Table 6: Four year plan for CEN program

Semester 01	**13**	**Semester 02**	**14**	**Semester 03**	**13**	**Year 01**	
ENG101	3	CSC101+L	4	CEN104+L	4	**Total Cr**	**40**
H/S-1	3	ENG102	3	CEN201	3		
MAT104	3	MAT212	3	ENG105	3		
PHY101+L	4	PHY102+L	4	H/S-2	3		
Semester 04	**14**	**Semester 05**	**14**	**Semester 06**	**15**		
CEN203+L	4	CEN210+L	4	CEN212+L	4	**Total Cr**	**43**
CEN204+L	4	CEN305+L	4	CEN306+L	4	**LFE**	**3**
H/S-2	3	CEN311	3	CEN401+L	4		
H/S-4	3	MAT203	3	Minor-1	3		
Semester 07	**13**	**Semester 08**	**12**	**Semester 09**	**14**		
CEN310+L	4	CEN413	3	CEN430+L	4	**Total Cr**	**39**
MAT301	3	Minor-3	3	CEN317+L	4		
Minor-2	3	Minor-4	3	Minor-5	3		
Optional-1	3	Optional-2	3	Optional-3	3		
Semester 10	**9**						
CEN498/499	6					**Total Cr**	**9**
Optional-4	3						
				Total Credits		**134**	

*LFE can be done any time after 2nd year.

MINOR IN COMPUTER ENGINEERING

There are two options of computer engineering minor. Students must complete the prerequisites of the courses. Students must complete minimum 15 (fifteen) credits to complete minor in Computer Engineering.

VARIANT 1:

CEN204+L, CEN311, CEN212+L & CEN430+L.

VARIANT 2:

CEN104+L, CEN210+L, CEN310+L & 1 Optional

COURSE DESCRIPTION (FOUNDATION)

CSC 101 INTRODUCTION TO COMPUTER PROGRAMMING

Introduction to computer program using a high level programming language (using object oriented approach). Topics to be covered are Identifiers; Data types; Variable; Constants; Different operators; Basic Input Output; Control structures i.e., Conditional statements, Loops; Array; Functions; String.

Primary emphasis is given to problem solving approach; Algorithm design and program development. Programming Language C++, Java. Prerequisite: MAT104 with minimum B-)

Text Books:

- C++ How to Program by Deitel & Deitel.
- Beginning C++ the complete language by Ivor Horton.

CSC101L LABWORK FOR CSC101

Course Outcome(CO):

CO1. Reason about interleaved statements operating on a shared data structure

CO2. Reason about compile errors, common runtime errors (e.g. NullPE) and logical errors in given short code segments (1-10 lines)

CO3. Reason about short-circuiting & different code paths for different data

CO4. Reason about computational cost, and return values

CO5. Use an industry-standard fully-featured modern IDE (e.g. Visual Studio, CodeBlocks) as a development tool.

Table 7: CSC101 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓	✓			
PLO 2: Requirement Analysis	✓			✓	
PLO 3: Problem Analysis	✓	✓	✓	✓	
PLO 4: Design			✓	✓	
PLO 5: Problem Solving		✓			
PLO 6: Implementation					✓
PLO 7: Experiment and Analysis		✓	✓		
PLO 8: Community Engagement & Engg.					
PLO 9: Teamwork					✓
PLO 10: Communication					
PLO 11: Self-directed					
PLO 12: Ethics					
PLO 13: Process Management					✓

COURSE DESCRIPTION (CORE)

CEN 104 ELECTRICAL CIRCUIT ANALYSIS

Passive electrical components. Electric circuit concepts and relationship to field theory. Kirchhoff's laws. Node and mesh analysis of resistive networks. Network theorems. Controlled sources. Transient conditions. Sources of periodic signals. Average and r.m.s. values. Circuit models of diodes and transistors. Combinational logic principles and circuits. RLC circuits; sinusoidal circuit response; mutual inductance and transformers; operational amplifiers; computer aided circuit design; state space circuit representations and time responses; homogenous and particular solutions for first and second order linear differential equations; computer aided analysis of signals and systems, including state space representations; continuous time signals, sinusoids and signal norms; convolution, impulse and step responses; phasors; AC circuits (transient and steady state responses); complex power; frequency responses of circuits and systems; three-phase circuits. (Prerequisite: PHY 102, CSC101 with minimum B-)

Text Books:

- Introductory Circuit Analysis, Robert L Boylestad
- Principle of Electrical Engg. V. K. Mehta, Rohit Mehta
- Electric Circuits, Joseph Edministern Mahmood Nahvi

CEN 104L LAB WORK BASED ON CEN 104

Course Outcome (CO):

CO1. 1. Use Kirchhoff's laws, circuit theorems and node voltage methodology to solve simple DC as well as AC circuits

CO2. Solve simple 1st order transient circuits

CO3. Apply simple steady state sinusoidal analysis to circuits

CO4: Demonstrate a basic understanding of phasors and phasor diagrams for AC circuit analysis

CO5. Reflect a basic understanding of transformer operation, through analysis of transformer circuits.

CO6. Analyze ideal operational amplifier application circuits.

CO7: Demonstrate proficiency in building basic electrical circuits and operating fundamental electrical engineering equipment.

Table 8: CEN 104 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7
PLO 1: Knowledge	✓			✓	✓		
PLO 2: Requirement Analysis			✓			✓	
PLO 3: Problem Analysis	✓		✓	✓			
PLO 4: Design				✓		✓	
PLO 5: Problem Solving	✓	✓					
PLO 6: Implementation						✓	✓
PLO 7: Experiment and Analysis			✓			✓	
PLO 8: Community Engagement & Engg.							
PLO 9: Teamwork							✓
PLO 10: Communication							✓
PLO 11: Self-Motivated							
PLO 12: Ethics							
PLO 13: Process Management							✓

CEN 201 DISCRETE MATHEMATICS

Proposition, first order logic, basic logical operations, truth tables, tautologies, contradictions, algebra of propositions, logical implications, logical equivalence, predicates, universal and existential quantifiers. Valid and invalid arguments. Proof of strategies (direct proofs, indirect proofs, proof by contradictions, proof by cases), mathematical induction. Review of set operations, Venn diagrams, basic identities on sets, Cartesian products. Basic definitions of relations, representation of relations, closures, equivalence relations, partial orderings. Basic definitions of functions, injective, surjective and bijective functions, inverse functions, composition of functions, recursively defined functions, countable and uncountable, sets, sequences and sums, recursively defined functions, matrices. Divisibility and modular arithmetic, greatest common divisors, Euclidean algorithm. Basics of counting, pigeonhole principle, permutations and combinations, generalized permutations and combinations, inclusion-exclusion, recurrence relations, solving recurrence relations, generating functions. Semigroups, monoid, groups, subgroups, cyclic groups, permutation groups, homomorphism and isomorphism of groups, rings and fields. Finite state machines, finite automata, languages and grammars. (Prerequisite: CSC 101 with minimum B-)

Text book:

- Discrete Mathematics and its Applications by K. Rosen

Course Outcome (CO):

CO1. Derive big-O running time for simple pseudocode examples, especially recursive examples. Includes finding closed-forms for recursively-defined formulas using unrolling and recursion trees

CO2. Write inductive proofs, including proofs on trees

CO3. Apply predicate logic: determine the truth of statements, perform simple transformations (esp. negation), accurately apply formal definitions (esp. vacuous truth cases, attention to variable types and scope)

CO4. Write literate proofs using straightforward application of standard outlines (direct, contrapositive, contradiction, upper/lower bounds).

CO5. State and apply basic definitions, facts, and notation for commonly used discrete math constructs

CO6. Classify the complexity of very simple examples in terms of countable versus uncountable, polynomial versus exponential, decidable versus undecidable

Table 9: CEN201 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6
PLO 1: Knowledge	✓		✓		✓	✓
PLO 2: Requirement Analysis						
PLO 3: Problem Analysis	✓	✓				
PLO 4: Design	✓					
PLO 5: Problem Solving	✓	✓	✓	✓		
PLO 6: Implementation	✓		✓		✓	
PLO 7: Experiment and Analysis	✓		✓			✓
PLO 8: Community Engagement & Engg.						
PLO 9: Teamwork						
PLO 10: Communication				✓		✓
PLO 11: Self-directed				✓		
PLO 12: Ethics						
PLO 13: Process Management						

CEN 203 DATA STRUCTURE

Elementary data structure: Elements of data representation and storage. Arrays and Linked Lists (singly linked list and doubly linked list). Abstract data types: Stack, Queue, Priority Queue. Comparative analysis of different implementations of ADTs (Array based and linked list based). BST (Binary Search tree), Heap. Efficient Priority Queue (Heap based). Complexity analysis of dictionary operations (Insertion/Deletion/search) on ADTs. Data structure as a facilitator of smart searching and sorting algorithms (Binary search, Heap sort). Graphs (Connectivity graph, Directed and Undirected graph). Balanced search tree: Red Black Tree. (Prerequisite: CSC 101 with minimum B-)

Text Books:

- Data Structures & Algorithms by Aho, Ullman, Hopcroft
- C++ plus Data Structure 5th edition by Nell Dale
- Data Structures and Their Algorithms by H. Lwis, L. Dennenberg

CEN 203L LABWORK BASED ON CEN203

Course Outcome(CO):

CO1: Navigate, organize, compile C++ projects of moderate complexity (many objects and dependencies)

CO2: Decompose a problem into its supporting data structures such as lists, stacks, queues, trees, etc.

CO3: Diagnose appropriate approaches or algorithms to solve problems involving graph search, tree traversal, optimization, data organization, etc., together with appropriate data structures.

CO4: Implement classic and adapted data structures and applications.

CO5: Analyze the efficiency of implementation choices.

Table 10: CEN203 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓				✓
PLO 2: Requirement Analysis	✓	✓	✓		✓
PLO 3: Problem Analysis		✓	✓		
PLO 4: Design	✓	✓	✓		
PLO 5: Problem Solving	✓			✓	
PLO 6: Implementation	✓			✓	
PLO 7: Experiment and Analysis		✓	✓		✓

PLO 8: Community Engagement & Engg.					
PLO 9: Teamwork	✓		✓		
PLO 10: Communication			✓		✓
PLO 11: Self-directed					
PLO 12: Ethics					✓
PLO 13: Process Management	✓				

CEN 204 Introduction to Computer Hardware and Digital Logic

Digital and analog systems. Number systems and codes; logic gates, Boolean algebra, arithmetic circuits, latches, register, counters, MSI logic circuits, flip-flops, A-D and D-A converters, IC logic families, memory devices, PLD, ASIC, FPGA. (Prerequisite: PHY 102, CSC101 with minimum B-)

Text Book:

- Digital Systems by Ronald J. Tocci

CEN 204L Labwork based on CEN 204

Course Outcome(CO):

CO1: Understand and be able to demonstrate fundamental concepts and techniques used in digital electronics.

CO2: Appreciate the structure of various number systems and its application in digital design.

CO3: Understand, analyze and design various combinational and sequential circuits.

CO4: Identify and analyze various hazards and timing problems in a digital design.

CO5: Build and analyze digital circuits.

Table 11: CEN204 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓	✓	✓	✓	
PLO 2: Requirement Analysis	✓	✓	✓	✓	
PLO 3: Problem Analysis	✓	✓	✓	✓	✓
PLO 4: Design	✓		✓		✓
PLO 5: Problem Solving	✓	✓	✓	✓	✓
PLO 6: Implementation			✓	✓	✓
PLO 7: Experiment and Analysis			✓	✓	✓
PLO 8: Community Engagement & Engg.					
PLO 9: Teamwork			✓	✓	✓
PLO 10: Communication		✓	✓	✓	✓
PLO 11: Self-Motivated					✓
PLO 12: Ethics		✓	✓	✓	
PLO 13: Process Management			✓	✓	✓

CEN 210 Electronics 1

Basic Semiconductor and pn-junction theory: Energy Bands, Conductors, Insulators and semiconductors, p-type and n-type semiconductors, Majority and minority carriers, Drift and Diffusion Current. P-N junction as a circuit element: operational principle of p-n junction diode, contact potential, current-voltage characteristics of a diode, simplified dc and ac diode models, dynamic resistance and capacitance. Diode applications: Half wave and full wave rectifiers, rectifiers with filter capacitor, clamping and clipping circuits. Zener diode: characteristics of a zener diode, zener shunt regulator. Introduction to power diodes: schottky diode, tunnel diode, gun diode, varactor diode. Bipolar junction Transistors (BJT): Basic structure, BJT characteristics and regions of operation, BJT Currents, BJT Terminal Voltages, BJT voltage amplification. Bipolar Junction Transistor Biasing: The dc load line and bias point, biasing the BJT for discrete circuits, small signal equivalent circuit models, h parameters. Single-stage BJT amplifier circuits and their configurations: Voltage and current gain, input and output impedances. Introduction to multistage amplifiers; Power amplifiers: Class A, Class B and Class C amplifiers; Introduction to power transistors: Field-Effect Transistors (FET), Junction Field-Effect Transistors (JFET), Metal-Oxide-Semiconductor Field-Effect-Transistor (MOSFET), FET Biasing and Small-Signal Analysis, Metal Semiconductor Field Effect Transistor(MESFET), Insulated

Gate Bipolar Transistors (IGBTs), Static Induction Transistors (SITs) and COOLMOS. Introduction to operational amplifier (Op-Amp); Electronic circuit analysis using PSPICE. (Prerequisite: CEN 104)

Text Books:

- Electronic Dervices and Circuit theory by Robert L Boylestad, Louis Nashelsky
- Principles of Electronics by V. K. Mehta, Rohit Mehta

CEN 210L LABWORK BASED ON CEN 210

Course Outcome(CO):

CO1: Ability to analyze ideal diode and ideal diode circuits.

CO2: Understand real mathematical model of a diode.

CO3: Solve diode circuits.

CO4: Understand basic characteristics of BJT and MOSFET.

CO5: Analyze DC of BJT and FET circuits.

CO6: Analyze AC of BJT and FET circuits.

CO7: Comprehend the concept of amplifier, input resistance, and output resistance.

Table 12: CEN210 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7
PLO 1: Knowledge	✓	✓		✓			✓
PLO 2: Requirement Analysis	✓		✓	✓	✓	✓	
PLO 3: Problem Analysis	✓		✓		✓	✓	
PLO 4: Design			✓		✓	✓	
PLO 5: Problem Solving			✓				
PLO 6: Implementation			✓				
PLO 7: Experiment and Analysis	✓		✓				
PLO 8: Community Engagement & Engg.							
PLO 9: Teamwork			✓				
PLO 10: Communication							
PLO 11: Self-Motivated	✓						
PLO 12: Ethics			✓				
PLO 13: Process Management							

CEN 212 MICROPROCESSOR, INTERFACING AND ASSEMBLY LANGUAGE

Organization of a computer. Introduction to 80X 86 families of microprocessors; Microprocessor Architecture, addressing mechanism, Instruction set, Instruction format. Assembly Language programming: assembling, linking, running and debugging programs. Controlling program development; Interrupt system. Microprocessor interfacing with memory and other devices. 8086 based system design, Programmable peripheral Interface: 8255A, 8251A, DMA controller 8237, Interrupt controller 8259A. Overview of advanced processors: 80386, Pentium and Multicore processors. (Prerequisite: CEN 311)

Text Books:

- Microprocessors and Microcomputer-Based System Design, Mohamed Rafiquzzaman
- The Intel Microprocessors by Barry B. Brey

CEN 212L LABWORK BASED ON CEN 212

Course Outcome(CO):

CO1: Analyze and understand bus/interface structures.

CO2: Characterize the timing/performance behavior of interfaces.

CO3: Utilize Assembly language programs to gain insight into instructions and machine-level operations.

CO4: Program and debug microprocessor devices.

CO5: Control/use peripherals, devices, and buses.

Table 13: CEN212 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓		✓		
PLO 2: Requirement Analysis	✓		✓		
PLO 3: Problem Analysis		✓			
PLO 4: Design	✓				
PLO 5: Problem Solving				✓	
PLO 6: Implementation		✓	✓	✓	✓
PLO 7: Experiment and Analysis		✓	✓	✓	
PLO 8: Community Engagement & Engg.					✓
PLO 9: Teamwork			✓		✓
PLO 10: Communication					
PLO 11: Self-Motivated				✓	
PLO 12: Ethics					✓
PLO 13: Process Management					✓

CEN 305 Object-oriented Programming

Objects and classes; Constructors and destructor; Abstract Data Structures, Function chaining; Friend functions; Function and operator overloading; Composition and Inheritance; Dynamic polymorphism using virtual functions; Exception handling; Template functions and classes; Standard Template Library; Programming Languages C++/ Java/ C#. (Prerequisite: CEN 203)

Text Books:

- Ivor Horton's Beginning Visual C++ 2013, by Ivor Horton, Wrox Publication
- Ivor Horton's Beginning Java, Java 7, by Ivor Horton, Wrox Publication

CEN 305L Labwork based on CEN 305

Course Outcome(CO):

CO1: Understand the benefits of object oriented design and when it is an appropriate methodology to use.

CO2: Design, write and test programs that make appropriate use of advanced object-oriented facilities common to object-oriented languages such as overloading and inheritance.

CO3: Manipulate classes provided in the programming API and incorporate them into solutions.

Table 14: CEN305 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3
PLO 1: Knowledge	✓		✓
PLO 2: Requirement Analysis	✓		
PLO 3: Problem Analysis	✓		
PLO 4: Design		✓	✓
PLO 5: Problem Solving		✓	
PLO 6: Implementation		✓	✓
PLO 7: Experiment and Analysis		✓	
PLO 8: Community Engagement & Engg.	✓		✓
PLO 9: Teamwork		✓	
PLO 10: Communication	✓		
PLO 11: Self-Motivated		✓	
PLO 12: Ethics	✓		
PLO 13: Process Management		✓	✓

CEN 306 Algorithm

Fundamentals of algorithms, Complexity analysis, Asymptotic notations (Theta, Big O, Omega). Different sorting algorithms: Bubble/Insertion(N^2); Recursive sorting algorithms: Merge, Quick, Heap (NlgN); Decision tree analysis: nlgn bound on comparison based sorting. Sorting in linear time: Counting/ Radix sort. Spanning trees. Greedy algorithms: Shortest path (Dijkstra), MST (Minimum spanning tree algorithms: Kruskal, Prim). Hashing. NP problems (TSP). (Prerequisite: CEN201, CEN 203)

Text Books:

- Introduction to Algorithms 2nd Edition : Cormen, Lieserson, Rivest, Stein

- Algorithms 4th Edition: R. Sedgewick, K Wein
- Art of Computer Prgogramming Vol. 1 (Fundamental Algorithms): D. Knuth

CEN 306L LABWORK BASED ON CEN 306

Course Outcome(CO):

CO1: Students will learn methods for designing efficient algorithms, evaluating their performance, and ways of establishing precise limits on the possible effectiveness of classes of algorithms

CO2: They will learn standard algorithms for fundamental problems.

Table 15: CEN306 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2
PLO 1: Knowledge	✓	✓
PLO 2: Requirement Analysis	✓	
PLO 3: Problem Analysis	✓	✓
PLO 4: Design	✓	
PLO 5: Problem Solving	✓	✓
PLO 6: Implementation	✓	✓
PLO 7: Experiment and Analysis	✓	
PLO 8: Community Engagement & Engg.		
PLO 9: Teamwork		
PLO 10: Communication		
PLO 11: Self-Motivated		
PLO 12: Ethics	✓	
PLO 13: Process Management	✓	

CEN 310 ELECTRONICS II

General frequency considerations for single stage or multi stage network: low and high frequency analysis and bode plot, multistage frequency effect and determining the cut-off frequencies. Operational Amplifiers (Op-Amp): Op-amp characteristics, open loop voltage gain, differential input voltage, inverting amplifier, inverting adder, non-inverting amplifier, voltage follower, differentiator, integrator, subtractor, CMRR, zero crossing and voltage level detector, hysteresis and their applications. Signal generators using op-amp: square, triangle, sawtooth and sine wave. DC performance: bias, offset and drift. AC performance: frequency parameter, unity-gain bandwidth, slew rate and noise. Various applications of op-amps: Precision Rectifier, MAV circuit, peak detector, precision clipper, Differential, Instrumentation and bridge amplifier. Active filter: frequency response of low pass, High pass, Band pass and Band stop filters for ideal and practical conditions; Band pass filter: narrow-band and wide-band filter. Feedback Amplifier: classification of amplifier as voltage, current, trans-resistance and trans-conductance amplifier, effect of feedback on amplifier bandwidth, condition of stability and the Nyquest criterion. Sinusoidal oscillator: the Barkhausen criterion, phase shift oscillator, general form of oscillator circuits; Colpitts oscillator, Hartley Oscillator, Crystal oscillator. Power Supplies (Voltage regulator), pnpn devices: SCR, SCS, DIAC, TRIAC, UJT. Timer circuit design, Multivibrators: Astable, monostable and bistable multivibrators. (Prerequisite: CEN 210)

Text Books:

- Electronic Dervices and Circuit theory, by Robert L Boylestad, Louis Nashelsky
- Principle of Electrical Engg. & Electronics (M.E.) by V. K. Mehta, Rohit Mehta
- Operational Amplifiers and Linear Integrated Cicuits. by Robert F. Coughlin, Frederick F. Driscoll

CEN 310L LABWORK BASED ON CEN 310

Course Outcome(CO):

CO1: Design and build basic op-amp circuits, common-emitter amplifiers with required AC characteristics and biasing circuits for common-emitter amplifiers using hand calculations and PSPICE simulations.

CO2: Predict frequency behaviours of amplifiers using hand calculations and PSPICE simulations and sketch appropriate Bode plots.

CO3: Describe the advantages and disadvantages of negative feedback including its influence on gain, bandwidth, input and output resistance.

CO4: Establish feedback topologies of op-amp and BJT amplifiers and evaluate the amplifier's close-loop characteristics using hand calculations and PSPICE simulations.

CO5: Design circuits to partially address circuit issues on specific problems.

CO6: Analyze circuits, extract performance figures-of-merit analytically and analyze them against desired specifications.

CO7: Simulate and extract performance figures-of-merit against desired specifications for circuits and fairly compare circuits.

Table 16: CEN310 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7
PLO 1: Knowledge	✓		✓				
PLO 2: Requirement Analysis	✓					✓	✓
PLO 3: Problem Analysis		✓	✓			✓	
PLO 4: Design	✓			✓	✓		
PLO 5: Problem Solving		✓		✓	✓		✓
PLO 6: Implementation	✓						
PLO 7: Experiment and Analysis	✓	✓		✓		✓	✓
PLO 8: Community Engagement & Engg.						✓	✓
PLO 9: Teamwork							
PLO 10: Communication			✓				
PLO 11: Self-Motivated				✓			
PLO 12: Ethics			✓				
PLO 13: Process Management						✓	✓

CEN 311 COMPUTER ORGANIZATION AND ARCHITECTURE

Computer system: computer structures, components, functions. Memory: cache memory mapping, internal memory, external memory. I/O devices: modules, programmed and interrupt driven I/O, DMA, I/O channels and processors. Interfaces, central processing unit: Computer arithmetic: hardware design algorithms. Instruction cycle, Instruction pipelining, control units design: Hardware and microprogrammed, parallel organizations, RISC, CISC, Multicore Processor organization. (Prerequisite: CEN 204)

Text Books:

- Computer Organization & Architecture: Design for performance by William Stallings
- Computer Architecture and Organization by John P. Hays

Course Outcome(CO):

CO1: Understand design principles and methods used in contemporary processors and memory systems and apply them to new designs.

CO2: Evaluate the performance of a modern computer.

CO3: Determine sources of potential performance bottlenecks in a processor design and determine techniques to address them.

CO4: Reason about sources of low memory system performance for a workload and determine techniques to address them.

CO5: Evaluate tradeoffs between hardware and software techniques to achieve a performance goal.

Table 17: CEN311 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓				✓
PLO 2: Requirement Analysis	✓	✓			
PLO 3: Problem Analysis	✓		✓	✓	✓
PLO 4: Design	✓		✓		
PLO 5: Problem Solving	✓		✓	✓	✓
PLO 6: Implementation	✓				✓
PLO 7: Experiment and Analysis		✓	✓		✓
PLO 8: Community Engagement & Engg.					

PLO 9: Teamwork					
PLO 10: Communication				✓	
PLO 11: Self-Motivated					
PLO 12: Ethics		✓			
PLO 13: Process Management		✓			

CEN 317 NUMERICAL METHODS

Numbers and errors: Floating point number representation inside a computer; floating point computation; accuracy and precision; round-off errors and truncation errors; error propagation. Roots of equations: bracketing method; bisection method; false-position method; Newton–Raphson method. System of linear equations: Gaussian elimination; partial and complete pivoting; LU decomposition method; iterative techniques; tridiagonal and sparse systems. Interpolation: Newton's divided difference technique; Spline interpolation; Fourier approximation. Numerical integration: Rectangular and trapezoidal rule; Simpson's rule with equal and unequal segments; Spline quadrature; adaptive quadrature routines. Ordinary differential equation: Solution of first order differential equations; Euler method, Runge–Kutta method; adaptive Runge–Kutta method; general method for system of initial value problem. (Prerequisite: CSC305, MAT 301)

Text Books:

- Numerical Methods for Engineers and Scientists by Joe D. Hoffman and Steven Frankel
- Numerical Methods Using Matlab by John H. Mathews and Kurtis K. Fink

CEN 317L LABWORK BASED ON CEN 317

Course Outcome(CO):

CO1: Analyze the sources of errors in mathematical operations on the computer.

CO2: Recognize major numerical methods and their merits and pitfalls.

CO3: Calculate the computational cost of a range of numerical methods.

CO4: Select and use software tools, based on their numerical methods, for a range of problems.

CO5: Estimate the accuracy in approximated numerical solutions.

Table 18: CEN317 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓	✓			
PLO 2: Requirement Analysis		✓			
PLO 3: Problem Analysis	✓	✓		✓	
PLO 4: Design					
PLO 5: Problem Solving				✓	✓
PLO 6: Implementation			✓	✓	
PLO 7: Experiment and Analysis			✓		✓
PLO 8: Community Engagement & Engg.					
PLO 9: Teamwork				✓	
PLO 10: Communication					
PLO 11: Self-Motivated				✓	
PLO 12: Ethics					
PLO 13: Process Management				✓	

CEN 401 DATABASE MANAGEMENT SYSTEMS

Introduction to database and DBMS. Database development process, Database architecture; Database languages and Interfaces. E-R Model, Enhanced E-R model; Database Design Relational Data model, Integrity constraint, Transferring ERD to Relations; Introduction to normalization; Relational Algebra; Introduction to Structure Query Language; Programming with SQL and PL/SQL. Database security and administration. Object oriented data modeling; Distributed database. Specific database systems: Oracle. MS SQL Server. (Prerequisite: CEN 305, Senior Standing)

Text Books:

- Modern Database Management by Jeffrey A. Hoffer, Mary B. Prescott, Fred R. Mcfadden
- An Introduction to Database System by C. J. Date
- Fundamentals of Database Systems by Ramez Elmasri, Shamkant B. Navathe

CEN 401L LABWORK BASED ON CEN 401

Course Outcome(CO):

CO1. Proficiency in the design of database applications starting from the conceptual design to the implementation of database schemas and user interfaces.

CO2: Solid foundation on database design concepts, data models (E/R model, relational model), the database query language SQL, and components of a database management system.

CO3: Basic understanding of data access structures, query processing and optimization techniques, and transaction management.

Table 19: CEN401 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3
PLO 1: Knowledge		✓	✓
PLO 2: Requirement Analysis	✓	✓	
PLO 3: Problem Analysis		✓	
PLO 4: Design	✓		✓
PLO 5: Problem Solving			✓
PLO 6: Implementation	✓		✓
PLO 7: Experiment and Analysis			✓
PLO 8: Community Engagement & Engg.			
PLO 9: Teamwork			
PLO 10: Communication			
PLO 11: Self-Motivated			
PLO 12: Ethics	✓		
PLO 13: Process Management	✓		

CEN 413 OPERATING SYSTEMS

Overview: Background, Computer-system structures, Operating system structures. Process Management: Processes and threads, Process synchronization, Deadlocks, CPU scheduling. Storage Management: Memory management, memory allocation, addressing, Swapping, paging, segmentation, Virtual memory organization, demand paging. File system, structure and access methods: File-system interface, File-system implementation, File protection. I/O Systems: I/O Systems, Mass-storage structure, Computer systems performance, network and security. Distributed Systems: Structure, file systems and coordination. (Prerequisite: CEN 305, CEN 311)

Text Books:

- Operating Systems Concepts, by Abraham Siberchatz, Peter Baer Galvin,Greg Gagne
- Operating Systems: Design and Implementation, Andrew S. Tanenbaum, Albert S. Woodhull
- Operating Systems: Internals And Design Principles, William Stallings

Course Outcome(CO):

CO1: Explain and implement kernel programming principles.

CO2: Explain basic OS components and the inter-dependencies among operating system components such as process management, memory management, file system management, I/O management, as well as get understanding of implementation of some of these basic components through machine problems.

CO3: Explain, analyze and argue system tradeoffs based on OS design decisions.

CO4: Explain and analyze the performance impact of basic operating system concepts and principles on parallel/distributed OS, mobile OS, multimedia OS and cloud OS.

CO5: Explain, analyze, and argue about OS security issues and their impact on various OS components.

Table 20: CEN413 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5
PLO 1: Knowledge	✓	✓		✓	
PLO 2: Requirement Analysis		✓			
PLO 3: Problem Analysis		✓	✓	✓	✓
PLO 4: Design		✓	✓		

PLO 5: Problem Solving			✓	✓	
PLO 6: Implementation	✓				
PLO 7: Experiment and Analysis		✓			
PLO 8: Community Engagement & Engg.					✓
PLO 9: Teamwork			✓		
PLO 10: Communication	✓		✓		
PLO 11: Self-Motivated					
PLO 12: Ethics				✓	✓
PLO 13: Process Management				✓	✓

CEN 430 DATA COMMUNICATION & COMPUTER NETWORKS

Basic concepts, categories of networks, network topologies, OSI model and TCP/IP protocol suite, TCP/IP applications, FTP, SMTP, HTTP and WWW, transport layer protocols, Internetworking devices, repeaters, bridges and routers, routing algorithms, IP addressing, sub netting, domain name systems, Network programming: Client-Server programming, socket programming, data link control protocols, LAN types and technology, MAC protocols, high speed LANs and Gigabit Ethernet, Wireless LANs, MAN, Circuit switching and Packet switching, ISDN, Frame Relay and ATM, SONET/SDH. Spectrum and bandwidth, Digital Transmission, encoding, modulations and demodulations, multiplexing: FDM, TDM and WDM, interfaces and modems, transmission media, fiber optic and wireless media, error detection techniques. (Prerequisite: CEN 305).

Text Books:

- Computer Networking, A top-down approach featuring the Internet, by James F. Kurose, Keith W. Ross
- Data Communication and Networking, by Behrouz A. Forouzan
- Data and Computer Communication by W. Stallings,

CEN 430L LABWORK BASED ON CEN 430

Course Outcome(CO):

CO1: Identify the problems that arise in networked communication

CO2: Explain the advantages and disadvantages of existing solutions to these problems in the context of different networking regimes

CO3: Understand the implications of a given solution for performance in various networking regimes

CO4: Evaluate novel approaches to these problems

CO5: Identify and describe the purpose of each component of the TCP/IP protocol suite

CO6: Develop solid client-server applications using TCP/IP

CO7: Understand the impact of trends in network hardware on network software issues

Table 21: CEN430 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7
PLO 1: Knowledge	✓	✓			✓		✓
PLO 2: Requirement Analysis		✓					
PLO 3: Problem Analysis	✓	✓		✓			✓
PLO 4: Design			✓	✓			
PLO 5: Problem Solving			✓	✓			
PLO 6: Implementation			✓			✓	
PLO 7: Experiment and Analysis				✓			
PLO 8: Community Engagement & Engg.							✓
PLO 9: Teamwork						✓	
PLO 10: Communication		✓					
PLO 11: Self-Motivated				✓			
PLO 12: Ethics	✓						
PLO 13: Process Management						✓	

MAT 203 LINEAR ALGEBRA VECTORS AND MATRICES

vectors and matrices; unit vectors; algebra of vectors; dot and cross products; elementary concepts of a matrix; matrix algebra; row operations; solutions of a system of linear equation. Systems of linear equations and matrices, vector spaces and subspaces, linear dependence and independence, dimensions and bases, linear transformations and matrices, eigenvalues and eigenvectors, changes of coordinates, orthogonality, diagonalization. (Prerequisite: MAT 104 with minimum B-)

Text Books:

- Elementary Linear Algebra by Howard Anton
- Linear Algebra and Its Applications, 4th Edition by David C. Lay

Course Outcome(CO):

CO1: Solve systems of linear equations using multiple methods, including Gaussian elimination and matrix inversion.

CO2: Carry out matrix operations, including inverses and determinants.

CO3: Demonstrate understanding of the concepts of vector space and subspace.

CO4: Demonstrate understanding of linear independence, span, and basis.

CO5: Determine eigenvalues and eigenvectors and solve eigenvalue problems.

CO6: Apply principles of matrix algebra to linear transformations.

CO7: Demonstrate understanding of inner products and associated norms.

Table 22: MAT203 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7
PLO 1: Knowledge	✓	✓	✓	✓		✓	✓
PLO 2: Requirement Analysis							
PLO 3: Problem Analysis					✓		
PLO 4: Design						✓	
PLO 5: Problem Solving	✓				✓	✓	
PLO 6: Implementation	✓				✓	✓	
PLO 7: Experiment and Analysis							
PLO 8: Community Engagement & Engg.							
PLO 9: Teamwork							
PLO 10: Communication							
PLO 11: Self-Motivated							
PLO 12: Ethics							
PLO 13: Process Management							

MAT 301 ORDINARY DIFFERENTIAL EQUATIONS

First order ordinary differential equations (existence and uniqueness of solutions, solution techniques, direction fields and stability, modeling applications). Second and higher order linear equations (existence and uniqueness, fundamental set of solutions of homogeneous equations, Wronskian, reduction of order, equations with constant coefficients, method of undetermined coefficients, method of variation of parameters, solutions in series, Laplace transform method, modeling applications). Systems of linear differential equations (existence and uniqueness of solutions, eigenvalue method for homogeneous systems, method of variation of parameters for systems, Laplace transform method for systems, modeling applications).Introduction to nonlinear systems. (Prerequisite: MAT 203)

Text Books:

- Differential Equations With Applications and Historical Notes by George F. Simmons
- A First Course in Differential Equations by Dennis G. Zill

Course Outcome(CO):

CO1: Identify, analyze and subsequently solve physical situations whose behavior can be described by ordinary differential equations.

CO2: Determine solutions to first order separable differential equations.

CO3: Determine solutions to first order linear differential equations.

CO4: Determine solutions to first order exact differential equations.

CO5: Determine solutions to second order linear homogeneous differential equations with constant coefficients.

CO6: Determine solutions to second order linear non-homogeneous differential equations with constant coefficients.

Table 23: MAT 301 Program Learning Outcome and Course Outcome Mapping

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6
PLO 1: Knowledge	✓	✓	✓	✓	✓	✓
PLO 2: Requirement Analysis	✓	✓	✓	✓	✓	✓
PLO 3: Problem Analysis	✓	✓	✓	✓	✓	✓
PLO 4: Design	✓					
PLO 5: Problem Solving	✓	✓	✓	✓	✓	✓
PLO 6: Implementation	✓	✓	✓	✓	✓	✓
PLO 7: Experiment and Analysis	✓					
PLO 8: Community Engagement & Engg.						
PLO 9: Teamwork						
PLO 10: Communication						
PLO 11: Self-Motivated						
PLO 12: Ethics						
PLO 13: Process Management						

COURSE DESCRIPTION (OPTIONAL)

CEN 330 DATA COMMUNICATION

Data: representation, signal encoding, signal analysis; Data Transmission Channel: channel capacity, transmission line characteristics, Baseband and Broadband transmission; Transmission media: guided and unguided; Transmission networks; Transmission modulation techniques, modems and interfaces; Multiplexing techniques; Error handling; Switching techniques; Introduction to advanced data communication technologies and Internet.

Text Books:

- Data and Computer Communications by William Stallings
- Data Communication and Networking by Behrouz A. Forouzan

CEN 403 NETWORK MANAGEMENT

This course will introduce students to methods, techniques and tools for the management of telecommunication systems and computer networks with specific examples from Internet and the public switched telecommunication networks. It will introduce the fundamental models that are used In the Internet (SNMP), and the telecommunication networks (TMN). In addition it will look In detail at the QOS management of IP base communications networks, by examining the emerging IETF protocols associated with Inteserv and Diffserv architectures. (Prerequisite CSC430, Senior Standing)

Text Books:

- Network Management by William Stallings
- SNMP, SNMPv2, and RMON: practical network management by William Stallings
- Network Management, Principals and Practice by Mani Subramanian

CEN 404 EMBEDDED SYSTEMS

Provides a detailed overview of the important topics in the field. Typical examples of embedded systems; real time and safety critical issues; constraint driven design; systems integration; hardware-software partitioning and time-to-market considerations will be addressed. The subject will examine programmable devices, micro-controllers, application specific standard processors: importance of interrupts; re-configurable logic; system-on-a-chip; finite state machines; dataflow architectures; and distributed embedded systems. Software for embedded systems, including: programming languages and software architectures; interrupt servicing; multi-tasking; task communications and scheduling; verification: hardware-software co-simulation; and real-time operating systems will be introduced. (Prerequisite: CEN 212)

Text Books:

- Embedded Systems Architecture, Programming and Design by Raj Kamal
- The 8051 Microcontrollers & Embedded Systems by Mazidi McKinlay

CEN 408 ADVANCED COMPUTER NETWORK

This subject provides insight into how to design, analyze and evaluate performance of the telecommunication networks. The subject identifies the benefits of high speed networks such as effectiveness, cost and customer control. It also describes the functions and characteristics of several services and technologies, including Personal Communication Services, Frame Relay, Asynchronous Transfer Mode (ATM), SONET/SDH and Switched Multimegabit Data Services; Protocol modeling and verification techniques; ATM LANs, multimedia communication; Analysis of protocols for data link, network and transport layers; Network design; Operating system views of communication. (Prerequisite: CEN 430)

Text Books:

- Data and Computer Communications by William Stallings
- Computer Networks by Andrew S. Tanenbaum
- Data Communication and Networking by Behrouz A. Forouzan

CEN 409 OPTICAL FIBER COMMUNICATION

Wave propagation in single mode and multimode optical fibers. Step-index and graded index fibers. Gaussian approximation of fields in single mode fiber, spot size, equivalent step index of single mode fiber. Material, waveguide and internodes dispersions. Polarization and birefringent fibers. Ray theory, optimal profile, mode coupling in multimode fiber. Optical fiber measurement and characterization. Launching efficiencies in multimode and single mode fibers. (Prerequisite: CEN 430, Senior Standing)

Text Book:

- Fiber-Optic Communications Technology by Djafar K. Mynbaev and Lowell L. Scheiner

CEN 412 WIRELESS NETWORKING AND MOBILE COMPUTING

Several topics related to wireless networking and mobile computing will be covered in this course. The topics include: cellular networks, multiple access protocols, channel assignment and resource allocation, mobility and location management, handoffs, routing, authentication, call admission control and QoS provisioning, network layer issues, wireless data networking (WAP, GSM, GPRS, CDMA, WCDMA), mobile ad hoc networks. (Prerequisite CEN 430)

Text Books:

- Principles of wireless networks, by Kaveh Pahlavan
- Wireless Personal Communications, Theodore S. Rappaport, Brian D. Woerner, Jeffrey H. Reed and William H. Tranter

CEN 414 DIGITAL SYSTEM DESIGN

Design of memory subsystems using SRAM and DRAM; PLA design; Microoperations: Inter-register transfer, arithmetic operations, logic operations, shift operations; Design of various components of a computer: ALU, control unit (hardwired, microprogrammed); Computer bus standards; Design of a computer; Digital Systems in control, communication and instrumentation.
(Prerequisite: CEN 204, Senior Standing)

Text Books:

- Logic and Computer Design Fundamentals (4th Edition) by M. Morris Mano and Charles Kime
- Digital logic and Computer Design by M. Morris Mano
- Digital system design and microprocessors by Jhon P. Hays

CEN 416 DISTRIBUTED DATABASE SYSTEMS

A detailed study of advanced topics related to relational database theory, query processing and optimisation, recovery techniques, concurrency control. Crash recovery. Distributed database systems: security and integrity. Other database paradigms such as deductive and object oriented issues. Heterogeneous databases. (Prerequisite: CEN 306, CEN 401)

Text Books:

- Principles of Distributed Database Systems by M. Tamer Özsu and Patrick Valduriez

- Distributed Database Management Systems: A Practical Approach by Saeed K. Rahimi and Frank S. Haug
- Distributed Systems: Principles and Paradigms (2nd Edition) by Andrew S. Tanenbaum and Maarten Van Steen

CEN 417 DATA MINING AND WAREHOUSE

Basic concept of data mining, issues and techniques. Data warehouse and OLTP technologies for data mining, Classification of data mining techniques and models, data pre-processing, data mining primitives, query languages and system architecture, characterization and comparison. Mining association rules in large database. Cluster analysis, multidimensional analysis and descriptive mining of complex data object. Data mining in distributed heterogeneous database systems. Data mining applications and future research issues. (Prerequisite: CEN 306, CEN 401)

Text Books:

- Data Mining: Concepts and Techniques, Third Edition by Jiawei Han, Micheline Kamber and Jian Pei
- Data Mining: Practical Machine Learning Tools and Techniques, Third Edition by Ian H. Witten, Eibe Frank and Mark A. Hall
- Introduction to Data Mining by Pang-Ning Tan, Michael Steinbach and Vipin Kumar

CEN 418 DATABASE SYSTEMS IMPLEMENTATION

Detailed examination of techniques used in the implementation of relational, object-oriented and distributed database systems. Topics are drawn from: query optimisation, transaction management, advanced file access methods, database performance tuning. (Prerequisite CEN 306, CEN 305, CEN 401)

Text Books:

- Database Systems: Design, Implementation, and Management by Carlos Coronel, Steven Morris and Peter Rob
- Database Management Systems, 3rd Edition by Raghu Ramakrishnan and Johannes Gehrke
- Fundamentals of Database Systems by Ramez Elmasri, Shamkant B. Navathe

CEN 419 ADVANCED DATABASE MANAGEMENT SYSTEMS

This course covers new database technology with emphasis on object orientation. The focus is mainly on the data modeling aspect. Other aspects e.g., transactions, Concurrency control, Recovery system, Database system architectures, Parallel databases, Distributed databases. (Prerequisite: CEN 401)

Text Books:

- Modern Database Management by Jeffrey A. Hoffer, Mary B. Prescott, Fred R. Mcfadden
- An Introduction to Database System by C. J. Date
- Fundamentals of Database Systems by Ramez Elmasri, Shamkant B. Navathe

CEN 420 IMAGE PROCESSING

Introduction; Point operations; Histograms; Spatial operations; Affine transformations; Image rectification; Interpolation and other transformations; Contrast enhancement; Convolution operation, Magnification and Zooming; Fourier transform; Edge detection; Boundary extraction and representation; Mathematical morphology , Wavelets, compression. (Prerequisite: CEN 305, MAT 212, MAT203)

Text Books:

- Digital Image Processing (3rd Edition) Rafael C. Gonzalez, Richard E. Woods
- Fundamentals of Digital Image Processing by A. K. Jain., Prentice-Hall.

CEN 421 MACHINE LEARNING

Introduction to Machine Learning; Classification of learning: Unsupervised and supervised learning, Connectionist learning, Reinforcement learning, Machine discovery; Supervised learning: Information theoretic decision tree learner, Best current hypothesis search, Candidate elimination (version space) algorithm, Learning in the first order Horn clause representation, Inductive logic programming, Application; Unsupervised learning: Hierarchical clustering, Category utility, Incremental and non-

incremental algorithms for hierarchical clustering, Applications; Connectionist learning: Introduction to Neural Network, Feed forward and recurrent network, Perception, Multilayer feed forward network, Back propagation algorithm for training a feed forward network, Applications; Genetic Algorithms: Genetic operators, Fitness function, Genetic algorithm in supervised learning framework, Applications. (Prerequisite: CEN 305, MAT 212, MAT 203)

Text Books:

- Introduction to Machine Learning by Ethem Alpaydin
- Pattern Recognition and Machine Learning, by Chris Bishop.
- Machine Learning: a Probabilistic Perspective, by Kevin Murphy.

CEN 422 PATTERN RECOGNITION

Basic concepts, Design concepts, Examples; Decision functions: Linear decision functions, Generalized decision functions; Pattern classification by distance functions: Minimum distance pattern classification, Cluster seeking; Pattern classification by likelihood functions: Bayes classifier; Structural pattern representation: Grammars for pattern representation, Picture description language and grammars, Stochastic grammars; Structural pattern recognition: String to string distance; Matching other structures: Relational structures, Graph matching, Matching by relaxation, Random graph. (Prerequisite: CEN 305, MAT 212, MAT 203)

Text Books:

- Pattern Recognition and Machine Learning by Christopher M. Bishop
- Pattern Classification, by Richard O. Duda, Peter E. Hart, David G. Stork

CEN 423 THEORY OF FUZZY SYSTEMS

Introduction to Neuro-Fuzzy and Soft Computing, Soft Computing and AI, Neural Networks, Fuzzy Set Theory, MF Formulation and Parameterization, Fuzzy Union, Intersection, and Complement, Fuzzy Rules and Fuzzy Reasoning, Fuzzy Inference Systems, Regression and Optimization, Supervised Learning Neural Networks, Neuro-Fuzzy Modeling, ANFIS, Neuro-Fuzzy Control, ANFIS Applications. (Prerequisite: CEN 305, MAT 203, MAT 212)

Text Books:

- Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, by J.S.R. Jang, C.T. Sun, and E. Mizutani, Prentice Hall
- Fuzzy Logic with Engineering Applications by Timothy J. Ross, published by John Wiley & Sons
- An Introduction to Fuzzy Logic for Practical Applications by T. Niimura

CEN 424 NEURAL NETWORKS

Elementary Neurophysiology - Biological Neurons to Artificial Neurons. Adaline and the Medaline. Perceptron. Backpropagation Network. Bidirectional Associative Memories. Hopfield Networks. Counterpropagation Networks. Kohonen's Self Organizing Maps. Adaptive Resonance Theory. ART1 - ART2 - ART3. Boltzman Machines, Spatiotemporal Pattern Classifier, Neural Network models: Neocognitron, Application of Neural Networks to various disciplines. (Prerequisite: CEN 305, MAT 212, MAT 203)

Text Books:

- Neural Network Design by Martin T. Hagan
- Neural Networks by Simon Haykin, Prentice Hall
- Neural Networks for Pattern Recognition by C. Bishop, Oxford University Press.

CEN 425 ARTIFICIAL INTELLIGENCE

Principal ideas and development of artificial intelligence; intelligent agents; problem solving methods; search method; knowledge and reasoning; Logic; uncertainty; probabilistic reasoning; puzzle solvers; expert system and data processing; simulative and cognitive process; natural language analysis and synthesis; representation design and design knowledge. (Prerequisite CEN 306)

Text Books

- Artificial Intelligence: A Modern Approach, 3rd Edition, by Stuart Russell and Peter Norvig
- The elements of statistical learning by Hastie, Tibshirani, and Friedman.

CEN 426 INTRODUCTION TO ROBOTICS

In addition to traditions rooted in mechanics and dynamics, geometrical reasoning, and artificial intelligence, the study of robot systems is growing to include many issues traditionally part of the

computing sciences; distributed and adaptive control, architecture, software engineering, real-time systems, information processing and learning. In robotics, processing and its relationship to mechanical function are dependent on the target platform and the world in which it is situated. Designing an embedded computational system for sensory and motor processes requires that designers appreciate and understand all of these disciplines. This course is concerned with the design and analysis of adaptive, closed-loop physical systems. The focus will be sensory and motor systems that interpret and manipulate their environments. Toward this end, we will study mechanisms (kinematics and dynamics), actuators, sensors (with a focus on active vision), signal processing, associative memory, feedback control theory, supervised and unsupervised learning, and task planning. Interesting examples of integrated sensory, motor, and computational systems can be found in nature, so occasionally we will relate the subject matter to biological systems. Students will experiment with system identification and control, image processing, path planning, and learning on simulated platforms to reinforce the material presented in class. (Prerequisite: CEN 305, MAT 212, MAT 203)

Text Books:

- Introduction to AI Robotics, by Robin Murphy, MIT Press.
- The Robotics Primer by Maja J. Mataric, MIT Press.
- Introduction to Robotics: Mechanics and Control by John J. Craig

CEN 431 ADVANCED OBJECT ORIENTED PROGRAMMING

Object oriented programming and introduction to GUI application development; Application Programming Interfaces (API); .NET Framework and Java packages; Multithreaded Programming; GUI Programming tools. Applications of OOP in database, networking and website development; Object oriented analysis and design; OOP in dynamic Languages like XML; Programming Languages C++/ Java/ C#. (Prerequisite: CEN 305)

Text Books:

- Core Java, Volume II--Advanced Features (9th Edition) (Core Series) by Cay S. Horstmann and Gary Cornell
- Professional Visual Studio 2013 by Bruce Johnson

CEN 434 ADVANCE PROGRAMMING IN UNIX

Exploration of the Unix operating system, including its tools and utilities for program development, such as makefile, piping and redirection, shell scripts, regular expressions, and symbolic debuggers. In addition, this course explores advanced features of the C programming language, including various file processing, command-line and variable arguments, exception handling, and generic interfacing. Multiprocessing and Multithreading programming in Unix/Linux C. Thread synchronization. Network programming and TCP/IP socket programming. The course includes a compulsory 3 hour laboratory work each week. (Prerequisite: CEN 306, CEN 413)

Text Books:

- Advanced Programming in the UNIX Environment (3rd Edition) (Addison-Wesley Professional Computing Series) by W. Richard Stevens and Stephen A. Rago
- Unix Shell Programming (3rd Edition) by Stephen G. Kochan and Patrick Wood

CEN 435 COMPUTER GRAPHICS

Output primitives and attributes; Line, circle and ellipse drawing algorithms; Two dimensional geometric transformation; Two dimensional viewing; Line, polygon, curve and text clipping algorithms; Parallel and perspective projections; Three dimensional object representation; Visualization of data sets; 3D transformations; Visible surface identification; Color models (RGB, YIQ, CMY, HSV); General computer animation, raster, keyframe; Graphics programming using OPENGL; Drawing 3D objects and sCENes; Shading models (flat, smooth); Adding texture to faces; Adding shadows of objects; Fractals and self similarity; Random fractals; Ray tracing; Adding surface texture; Reflection and transparency. (Prerequisite: CEN 305, MAT 203)

Text Books:

- Interactive Computer Graphics: A Top - Down Approach with OpenGL, By Ed Ange.
- Fundamentals of Computer Graphics, 3rd Edition Peter Shirley and Steve Marschner, A.K. Peters, 2009.
- OpenGL Programming Guide (the red book)

CEN 437 THEORY OF COMPUTATION & AUTOMATA

Basic notions: string, prefix, suffix, substring, concatenation; Cardinality; Distinction between uncountable and countable infinite. Different proof techniques: Proof by construction, proof by contradiction, pigeon hole principle. Deterministic and non-deterministic Finite state automata; Regular language, regular expression. Equivalence of NFA and DFA. Pumping Lemma, non regular languages. Context free grammar (CFG) and Push down automata (PDA). Chomsky Normal form. Parsing. Turing machine. Universal Turing machine and Halting problem. Goedel numbering. Computability. P/NP. (Prerequisite: CEN 201)

Text Books:

- Elements of the Theory of Computation 2nd Edition. by H. Lewis, C. Papadimitriou
- Introduction to the Theory of Computation by M. Sipser
- Introduction to Automata Theory, languages & Computation 3rd Edition by J. Hopcroft, R. Motwani, J. Ullman

CEN 440 COMPUTER SIMULATION AND MODELING

Statistical background for simulation; system reliability; mathematical description of general dynamic systems; discrete event; discrete time and continuous time; queuing models; effects of queue disciplines; factors affecting queue systems; implementation and management of models; performance evaluation of models; simulation languages; SLAM. (Prerequisites CEN 305, MAT 212, MAT 203)

Text Books:

- Computer Simulation and Modelling by Francis Neelamkavil
- Simulation Modeling and Analysis (Third Edition), Law and Kelton, McGraw Hill
- Discrete-Event System Simulation (5th edition), Jerry Banks, John Carson, Barry L. Nelson, David Nicol, Prentice Hall

CEN 441 INSTRUMENTATION AND MEASUREMENTS

Single phase transformers; Principles of operation of DC, Induction and Stepper motors; Thyristor and microprocessor based speed control of motors. Introduction to amplifiers; Basic differential amplifiers; logarithmic amplifiers; Temperature compensation of Logarithmic amplifiers; Antilog amplifier; Chopper stabilized amplifier. Frequency and voltage measurements using digital techniques: Digital frequency meter, digital voltmeter. Recorders and display devices: Oscilloscope, Spectrum analyzers and logic analyzers. Data acquisition system and interfacing to microprocessor based systems. Transducers: terminology, types, principles and application of piezoelectric, photovoltaic, thermoelectric, variable reactance and opto-electronic transducers. Noise reduction in instrumentation. (Prerequisite: Senior Standing)

Text Book:

- Modern Electronic Instrumentation and Measurement Techniques by Albert D. Helfrick and William David Cooper

CEN 443 DIGITAL SIGNAL PROCESSING

The mathematics of signals and linear systems. Fourier and Laplace transforms, discrete Fourier and Z transforms. Analogue filters: approximation theory, Butterworth, Bessel, Chebyshev and elliptic filters. Filter impulse and frequency responses, stability, and sensitivity. Sampling continuous signals: the sampling theorem, reconstruction, and aliasing. The discrete Fourier transform (DFT) and the fast Fourier transform (FFT). Fundamentals of the design and realisation of finite impulse response (FIR) and infinite impulse response (IIR) digital filters. Digital processing of analog signals, including applications of digital signal processing (DSP) and programmable DSP chips. The representation and modelling of non-deterministic (random) signals, correlation functions, and power density spectra. (Prerequisite: Senior Standing)

Text Book:

- Digital Signal Processing: Principles, Algorithms and Applications (3rd Edition) by John G. Proakis and Dimitris K Manolakis

CEN 444 DIGITAL ELECTRONICS AND PULSE TECHNIQUES

Diode logic gates, transistor switches, transistor gates, MOS gates, Logic families: TTL, ECL, IIL and CMOS logic with operation details. Propagation delay, product and noise immunity. Open collector and High impedance gates. Electronic circuits for flip flops, counters and register, memory systems. PLA's (A/D, D/A converters with applications, S/H circuits) LED, LCD and optically coupled oscillators.

Non-linear applications of OPAMPs. Analog switches. Linear wave shaping: diode wave shaping techniques, clipping and clamping circuits, comparator circuits, switching circuits. Pulse transformers, pulse transmission. Pulse generation:monostable, bistable and stable multivibrations, Timing circuits. Simple voltage sweeps, linear circuit sweeps. Schmitrigger, blocking oscillators and time base circuit. (Prerequisite: Senior Standing)

Text Book:

- Pulse, Digital, and Switching Waveforms: Devices and Circuits for Their Generation and Processing by Herbert Taub Jacob Millman

CEN 445 SOFTWARE ENGINEERING

Introduction to the principles of software engineering. Software as product and process. Project management and planning; tracking and scheduling; risk analysis and quality assurance techniques.; configuration management. Project and process metrics, size and function oriented metrics. Software testing techniques: black box and white box techniques. Testing strategy: unit, integration and system testing.. Concepts of object-oriented, event-driven and network programming, client-server architecture, web engineering. The course focuses on taking a group development project from beginning to end. (Prerequisite CEN 401)

Text Books:

- Software Engineering: A Practitioner's Approach by Roger Pressman and Bruce Maxim
- Software Engineering (9th Edition) by Ian Sommerville

CEN 447 COMPUTER PERIPHERALS AND INTERFACING

The role of computer peripherals. The connection of peripherals to computers. Display. Keyboard. Visual display units. Printers. Analogous signal input output. Graphic systems. Output devices. OMR, OCR and MCR. Backing stores. Data communication. Interfacing components and their characteristics. Important peripheral chips e.g., Intels 8255, 8251, 8253/8254, 8155, 8237/8239 etc and their uses and applications in different systems. Microprocessor I/O. Disk. Drums. Optical displays and sensors. High power interface devices. Interfacing for Transducers, stepper motors and peripheral devices. Design and operation of interface between computer and the outside world. (Prerequisite: Senior Standing)

Text Book:

- Microprocessors & Interfacing: Programming & Hardware. by D.V. Hall

CEN 449 FAULT TOLERANT SYSTEM

Introduction to redundancy theory, limit theorems, decision theory in redundant systems. Hardware fault tolerance: Computer redundancy, detection of faults, replication and compression techniques, self repairing techniques, conCENtrated and distributed voters, models of fault tolerant computer. Software fault-tolerance: Fault tolerance versus fault intolerance, fault tolerance objectives; errors and their management strategies, implementation of error management strategies. Software fault tolerance techniques, software defence, protective redundancy. Architectural support of fault-tolerant software protection mechanisms, recovery mechanisms. (Prerequisite: Senior Standing)

Text Books:

- Fault-Tolerant Systems by Israel Koren and C. Mani Krishna
- Design and Analysis of Fault Tolerant Digital Systems by Barry W. Johnson

CEN 450 CRYPTOGRAPHY AND NETWORK SECURITY

Introduction; nature and types of security attacks, key based cryptography, symmetric and asymmetric key. Cryptanalysis. Fiestel cipher structure; conventional encryption algorithms, DES and triple DES. Key distribution problem. Asymmetric cryptography: public key cryptography, message authentication, hash function, RSA and Diffie-Hellman algorithms. Model for network security. Digital signature, digital certificate. Quantum cryptography. (Prerequisite: CEN 306, CEN 430)

Text Books:

- Cryptography & Network Security: Principles & Practice 5th Edition by W. Stallings
- Cryptography & Network Security by B. Forouzan
- Introduction to Modern Cryptography: Principles & Protocols by J. Katz, Y.Lindell

CEN 452 SOFTWARE MARKETING

Introduction to marketing and marketing communication, service marketing, marketing challenges of technology products and services; methodology to identify target buyer's perceptions and behaviors; marketing software product: market research, product positioning, determining value proposition of

the product, pricing, distribution, promotions, intellectual property management, advertising and product management; marketing customized software development services: target market determination, educating clients, response to request for proposal, basics of software effort and cost estimation, client relationship management, business value determination of software solutions, base line data collection, determining return on software investment (ROI), impact assessment due to software use, and organization change management; marketing software engineering services to offshore clients: determining offshore market opportunities, understanding constraints in penetrating those markets, developing strategies, establishing linkages with complementary partners and packaging and promoting software engineering service capability to targeted markets; Software quality assurance: basic of software quality assurance (SQA), business value of SQA, and clients role in SQA. Introduction to ISO and SEI's capability maturity model for software SQA. Case studies. Contractual and legal issues. (Prerequisite CEN 445)

Text Books:

- Software That Sells: A Practical Guide to Developing and Marketing Your Software Project by Edward Hasted
- Just Enough Requirements Management: Where Software Development Meets Marketing by Alan Mark Davis

CEN 453 SOFTWARE REQUIREMENT ENGINEERING

Role of requirements in system development and maintenance, goals of the requirements phase, essential difficulties of specifying requirements, effective methods, tools and techniques, techniques for formally modeling and specifying software requirements, process of identifying stakeholders, capturing, analyzing, reviewing and verifying their requirements for new or extended software products, optimization of software requirements and business benefits, the role of prototyping in validating requirements; process of requirements management, configuration management, change management, impact estimation due to requirements change. (Prerequisite CEN 445)

Text Books:

- Software Requirements Engineering, 2nd Edition by Richard H. Thayer and Merlin Dorfman
- Software Requirements 3rd edition by Karl E Wiegers and Joy Beatty
- Requirements Engineering for Software and Systems, Second Edition (Applied Software Engineering Series) by Phillip A. Laplante

CEN 454 SOFTWARE ENGINEERING PROCESS MANAGEMENT

Challenge of producing and maintaining complex software-intensive system; predictability and improved cost; team work in software development; quality assurance; process CENtric software engineering practices; software engineering process framework developed by Software Engineering Institute (SEI); capability of each process area; framework to meet challenges; characteristics of software products and processes, its quantification, analysis, prediction, control, and guidelines to achieve both business and technical goals. (Prerequisite CEN 445)

Text Books:

- Practical Software Metrics for Project Management and Process Improvement by Robert B. Grady
- Software Engineering Essentials, Volume I: The Development Process (Volume 1) by Dr. Richard Hall Thayer, Dr. Merlin Dorfman, Mr. Leonard L. Tripp and Dr. Friedrich L. Bower

CEN 456 BUSINESS PROCESS REENGINEERING

Introduction to process centric understanding of business processes; analysis and modeling techniques of business practices as processes, analysis of processes of different categories of organizations operating both in private and public sectors; e-Governance, e-Commerce, process of generating software solutions for improving performance of business processes, process performance parameter determination and determination of optimum software features for performance improvement; ROI estimation and measurement framework determination for verification; over view of different enterprise resource planning (ERP) applications and their uses in BPR; implementation and organizational change management; process performance parameter collection and validation of ROI estimation. (Prerequisite CEN 445)

Text Books:

- Business Process Reengineering: Breakpoint Strategies for Market Dominance by Henry J. Johansson, Patrick McHugh, A. John Pendlebury and William A. Wheeler
- The Ultimate Guide to Business Process Management: Everything you need to know and how to apply it to your organization by Theodore Panagacos

CEN 457 PROJECT MANAGEMENT

Overview of Project Management, Project tracking and scheduling, Risk management & analysis. Cost estimation models. Project metrics. Function Point Estimation. Software quality assurance. Program verification and validation techniques Software testing techniques, black-box and white-box techniques. Testing of various areas: unit, domain, path, equivalent class based portion, component, aggregation, testing, requirement based testing, acceptance testing. Software reuse and maintenance; Industrial practices in software engineering. ISO certification standards for software quality assurance; Software capability maturity model and its impact. The course focuses on taking a group development project from beginning to end. (Prerequisite CEN 445)

Text Books:

- Mastering Software Project Management: Best Practices, Tools and Techniques by Murali K. Chemuturi and Thomas M. Cagley Jr.
- Applied Software Project Management by Andrew Stellman and Jennifer Greene

CEN 458 SOFTWARE QUALITY AND TESTING

Software quality assurance (SQA), review of SQA practices, quality management, the role of SQA, the SQA program planning, launching and management, independent verification and validation; software inspections, basic principles, reviews, reporting and tracking, managing inspections and reviews; principles of software testing, testing types, test planning, development, execution and reporting; real-time testing and test organization; basic concepts of reliability, modeling software reliability from test results, techniques for analyzing, predicting, designing, and engineering the required and expected reliability of software systems. (Prerequisite CEN 445)

Text books:

- Software Testing and Quality Assurance: Theory and Practice by Sagar Naik and Piyu Tripathy
- Software Testing: Fundamental Principles and Essential Knowledge by James D. McCaffrey
- Quality Code: Software Testing Principles, Practices, and Patterns by Stephen Vance

CEN 459 SOFTWARE ARCHITECTURE AND COMPONENT-BASED DESIGN

High-level architectural designs of software systems and products, strengths and weaknesses of each design style, component-based design, cohesion, interconnection and complexity, middleware, performance analysis and simulation, and COTS components; commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures Object-oriented design, design patterns, and UML; application of domain analysis, impact of platform dependence and independence, relation of software architecture to requirements, domain analysis and the architectural design process, and products in a real-world context. (Prerequisite CEN 445)

Text Books:

- Software Architecture: Foundations, Theory, and Practice by R. N. Taylor, N. Medvidovic and E. M. Dashofy
- Software Modeling and Design: UML, Use Cases, Patterns, and Software Architectures by Hassan Gomaa

CEN 460 MULTIMEDIA SYSTEMS

Multimedia system architecture, Text, images and graphics, audio, video and animation. Data compression, JPEG and MPEG, DVI, AVI, multimedia files standards; overview of multimedia storage and retrieval technologies. Video and Image display systems, multimedia communication and database systems, multimedia user interfaces, and applications of multimedia systems. (Prerequisite: CEN 306, CEN 305)

Text Books:

- Fundamentals of Multimedia, Ze-Nian Li, and Mark S. Drew, Pearson Prentice Hall
- F. Halsall: "Multimedia Communications: Applications, Networks, Protocols, and Standards", 1/e 2000 Addison-Wesley

CEN 461 ADVANCE TOPICS FOR APPLICATION DEVELOPMENT

Selected advanced topic related to different applications from the field of computer science and its applications. It may vary from time to time. (Prerequisite: Senior Standing)

CEN 462 ENTREPRENEURSHIP DEVELOPMENT

This course studies the planning stages involved in starting a new business including market, financial, and legal feasibility requirements. The students required to develop a full business plan and elevator pitch. The purpose of the course is to provide a practical opportunity for students to realistically assess the potential of some new venture idea and develop a detailed program or plan for a small business. The course covers a range of topics that are required to succeed in an entrepreneurial career. From an overview of entrepreneurship and the entrepreneurial process, the course spreads out to consider how to evaluate a possible idea for a business, buy an existing firm, acquire a franchise, develop a marketing plan, and create a comprehensive business plan for your new venture concept. (Prerequisite: Senior Standing)

Text Books:

- The Entrepreneur Mind: 100 Essential Beliefs, Characteristics, and Habits of Elite Entrepreneurs by Kevin D. Johnson
- Amazon's Jerry W. Moorman Page
- Start Your Own Business, Fifth Edition: The Only Start-Up Book You'll Ever Need by The Staff of Entrepreneur Media

CEN 463 IT FORENSIC

Purpose of Forensics: Investigative Mindset, Focus on the Fundamentals; Evidence Fundamentals: Admissibility & Authenticity, Threats against Authenticity, Reporting and Presenting Evidence, Evidence Acquisition Basics, Preservation of Evidence; Types of Acquisition; Forensic Field Kits: Forensic Automated Tools, Registry Forensics In-Depth; Browser forensics. (Prerequisite: Senior Standing)

Text Books:

- Cyber Forensics: A Field Manual for Collecting, Examining, and Preserving Evidence of Computer Crimes by Albert Marcella Jr. and Doug Menendez
- Computer Forensics and Cyber Crime: An Introduction (3rd Edition) by Marjie T. Britz

CEN 465 E-COMMERCE AND WEB DATABASE

Electronic Commerce environment, modes, types; Intranet, intranet, extranet, VPN, and VAN; Security and authentication; Cryptography, key management, certificate authority, PKI, digital signature and digital certificate; Payment gateway; Electronic cash and electronic payment schemas: EDI, EFT, SWIFT. Secure transaction through credit cards and PayPal; Shopping cart; Cloud-hosting; Web database design, development and management; Integrating database with web applications, Web database security and access controls; Legal framework of e-Commerce. (Prerequisite: CEN455)

Text Books:

- Effortless E-Commerce with PHP and MySQL (2nd Edition) by Larry Ullman
- Web Information Retrieval (Data-Centric Systems and Applications) by Stefano Ceri, Alessandro Bozzon, Marco Brambilla and Emanuele Della Valle

CEN 470 INTRODUCTION TO PARALLEL PROGRAMMING

Parallel architectures; linear, mesh, binary, and hypercube connections; routing mechanisms; communication models; scalability and efficiency; Principles of parallel algorithm design: Design approaches, design issues, performance measurement & analysis, complexities, anomalies in parallel algorithms; parallel searching, parallel sorting, parallel graph and parallel computational algorithms; parallel programming paradigms: message passing, shared memory and multi-core parallel programming. (Prerequisite: CEN 306, CEN 305, MAT 203)

Text Books:

- An Introduction to Parallel Programming by Peter Pacheco
- Programming Massively Parallel Processors, Second Edition: A Hands-on Approach by David B. Kirk and Wen-mei W. Hwu
- The Art of Multiprocessor Programming, Revised Reprint by Maurice Herlihy and Nir Shavit
- Parallel Programming with Microsoft® .NET: Design Patterns for Decomposition and Coordination on Multicore Architectures by Colin Campbell, Ralph Johnson, Ade Miller and Stephen Toub
- Parallel and Concurrent Programming in Haskell: Techniques for Multicore and Multithreaded Programming by Simon Marlow

CEN 475 VLSI DESIGN & TESTING

VLSI Technology: MOS transistor and inverter characteristics, complex CMOS gates and functional circuits. Design and operation of large fan-out and fan-in circuits; Clocking methodologies; Techniques for data path and data control design. VLSI layout partitioning, placement routine, and writing in VLSI Reliability aspects and testing of VLSI. (Prerequisite: Senior Standing)

Text Book:

- Basic VlSI Design: Systems and Circuits by Douglas A. Pucknell, Kamran Eshraghian

CEN 480 COMPUTER VISION

This course aims to introduce the application areas of computer vision. How challenges related to understanding human visual system and how the understanding of the natural visual system can be implemented into computers is discussed in this course. Stereo or 3D counterpart creation from 2D images, motion detection in 2D image or video sequences, video processing for action annotation - are the main areas of discussion. After successful completion the course the students will able to know how to use low-level vision techniques learned in image processing be combined or applied to acquire higher level-visual perception. (Prerequisite: CEN 305, MAT 212, MAT 203)

Text Books:

- Computer Vision: Algorithms and Applications by Richard Szeliski
- Computer Vision: A Modern Approach by David Forsyth and Jean Ponce
- Digital Image Processing with Matlab by Ganzalez, Woods and Eddins (2004)

CEN 485 TELECOMMUNICATION ENGINEERING

To present a general introduction to telecommunications aspects such as signal acquisition, transmission and processing in communication systems. This subject provides general telecommunication knowledge. Including: Characteristics of typical communication channels; Typical signals (speech, audio, video, data) and their characteristics; Basic analogue and digital techniques; Key techniques in handling transmission system issues (modulation, coding, multiplexing, etc); System performance and evaluation (channel noise, inters symbol interference, bit error rate, etc.); Major communication systems including telephony, radio, TV, satellite, mobile phone, optical fiber, radar and networks. (Prerequisite: CEN 430)

Text Book:

- Wireless Personal Communications, Theodore S. Rappaport, Brian D. Woerner, Jeffrey H. Reed and William H. Tranter

CEN 490 SPECIAL TOPICS IN COMPUTER SCIENCE & ENGINEERING

Selected advanced topic from the field of computer science and engineering and its applications. It may vary from time to time.

CEN 498 SENIOR PROJECT

CEN 499 INTERNSHIP

MAT 104 CALCULUS AND ANALYTICAL GEOMETRY (FOUNDATION)

Functions and their visualization, limits, and continuity; Differential calculus, differentiation of product and quotient; Successive differentiation. Additional techniques of integration. Interpretations of the derivative, applications of the derivative to geometry, mechanics, marginality and optimization. Newton's method. Introduction to modeling; Integral calculus, integration by parts; Definite integral, interpretations and properties of the definite integral, applications of the definite integral to geometry, mechanics, economics and modeling. Approximating definite integral, approximation errors and Simpson's rule, improper integrals. Taylor polynomials and series, convergence of series, finding and using Taylor's series, indeterminate forms, Fourier series. First order differential equations: Slope fields, Euler's method, separation of variables, linear equations, applications and modeling.

Text Books:

- Calculus and Analytic Geometry by George B. Thomas and Ross L. Finney

MAT 212 PROBABILITY & STATISTICS FOR SCIENCE AND ENGINEERING (FOUNDATION)

Discrete and continuous random variables; probability concepts; discrete and continuous distributions; Binomial, Poisson, Normal, Exponential distributions; moments and moment generating functions,

joint probability distributions; sampling distributions; confidence intervals; Least Square regression; hypothesis testing; analysis of variance; Markov process, Monte-Carlo simulation.

Text Books:

- Statistics for Engineers and Scientists by William Navidi
- Engineering Statistics by Douglas C. Montgomery, George C. Runger and Norma F. Hubele

MAT 401 GRAPH THEORIES

Graphs and subgraphs, trees, connectivity, Eule tours and Hamjlton cycles, matchings, graph colorings, plana graphs and Euler's formula, directed graphs, network flows, counting arguments, graph algorithms. (Prerequisite: CSC306, MAT 203)

Text Books:

- Introduction to Graph Theory (2nd Edition) by Douglas B. West
- Introduction to Graph Theory by Richard J. Trudeau
- Graph Theory and Its Applications, Second Edition by Jonathan L. Gross and Jay Yellen

MAT 403 INTRODUCTION TO MATHEMATICAL MODELING

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems in many disciplines including mathematical sciences, operations research, engineering and the management and life sciences. Students will be encouraged to recognize and formulate problems in mathematical terms, solve the resulting mathematical problems and interpret the solution in real terms. (Prerequisite: MAT 301)

Text Book:

- An Introduction to Mathematical Modeling (Dover Books on Computer Science) by Edward A. Bender

MAT 405 OPTIMIZATION TECHNIQUES

Discrete , deterministic models of interest to social sciences. Linear programming, duality, simplex method, sensitivity analysis, convex sets. Selections from assignment, transportation, network flow, nonlinear programming problems. (Prerequisite: MAT 301)

Text Book:

- Optimization Techniques by C. Mohan and Kusum Deep

MAT 420 COMPUTATIONAL GEOMETRY

Polygon triangulation; Polygon partitioning; Convex hull in two and three dimensions; Voronoi diagrams; Combinatorics; Sweep algorithms; Polygon intersection; Robot motion planning. (Prerequisite: CSC306, Senior standing)

Text Books:

- Computational Geometry: Algorithms and Applications by Mark de Berg, Otfried Cheong, Marc van Kreveld and Mark Overmars
- Discrete and Computational Geometry by Satyan L. Devadoss and Joseph O'Rourke

MAT 430 INTRODUCTION TO DISCRETE DYNAMICAL SYSTEMS

Iterations, orbits, graphical analysis, fixed and periodic points, bifurcations, the quadratic family, transition to chaos, iteration of two-dimensional maps, complex dynamics, Julia set, introduction to fractals. (Prerequisite: MAT 301, Senior Standing).

Text Books:

- Discrete Dynamical Systems: Theory and Applications by James T. Sandefur
- Discrete Dynamical Systems by Oded Galor