Master of Technology

(2 Years)

DEPARTMENT OF ELECTRONICS ENGINEERING

Indian Institute of Technology (Indian School of Mines), Dhanbad, India.

"Optoelectronics and Optical Communication Engineering"

Course Curriculum -2019

Sl. No.	Course No.	Course Name	L	T	P	C
Semester 1						
1.	DC xxx	Advanced Optical Communication	3	0	0	9
2.	DC xxx	Photonic Integrated Circuits	3	0	0	9
3.	DC xxx	Mathematical and Simulation Technique	3	0	0	9
4.	DC xxx	Optoelectronic and Photonic Devices	3	0	0	9
5.	DC xxx	Advanced Communication Theory	3	0	0	9
6.	DC xxx	Optical Communication Lab	0	0	3	3
7.	DC xxx	Communication Systems Lab	0	0	3	2
		TOTAL	**15**	**0**	**6**	**51**

Sl. No.	Course No.	Course Name	L	T	P	C
Semester 2						
1.	DE xxx	D Elective 1	3	0	0	9
2.	DE xxx	D Elective 2	3	0	0	9
3.	DE xxx	D Elective 3	3	0	0	9
4.	OE xxx	Open Elective 1	3	0	0	9
5.	OE xxx	Open Elective 2	3	0	0	9
6.	DC xxx	Optoelectronic and Photonic Devices Lab	0	0	3	3
7.	DC xxx	Modelling and Design Lab	0	0	3	3
		TOTAL	**15**	**0**	**3**	**51**

Sl. No.	Course No.	Course Name	L	T	P	C
Semester 3						
1.	DC xxx	Thesis Unit 1	0	0	0	9
2.	DC xxx	Thesis Unit 2	0	0	0	9
3.	DC xxx	Thesis Unit 3	0	0	0	9
4.	DC xxx	Thesis Unit 4	0	0	0	9
		TOTAL	**0**	**0**	**0**	**36**

Sl. No.	Course No.	Course Name	L	T	P	C
Semester 4						
1.	DE xxx/OE xxx	D Elective 4/Open Elective 3	3	0	0	9
2.	DE xxx/OE xxx	D Elective 5/Open Elective 4	3	0	0	9
3.	DC xxx	Thesis Unit 5	0	0	0	9
4.	DC xxx	Thesis Unit 6	0	0	0	9
		TOTAL	**6**	**0**	**0**	**36**

List of Electives

Sl. No.	Course No.	Course Name	L	T	P	C
D Elective for Semester-II						
1.	DE xxx	Nonlinear Fiber Optics	0	0	0	9
2.	DE xxx	Microwave Photonics	0	0	0	9
3.	DE xxx	Nanophotonics	0	0	0	9
4.	DE xxx	Silicon Photonics	0	0	0	9
5.	DE xxx	Ultra-fast Technology	0	0	0	9
6.	DE xxx	Numerical Techniques in Electromagnetics	0	0	0	9
7.	DE xxx	Wireless Optical Communication	0	0	0	9
8.	DE xxx	Optical and Quantum Computation	0	0	0	9
9.	DE xxx	Wireless Communication Systems				
10.	DE xxx	Advanced Operating Systems	0	0	0	9
11.	DE xxx	Optical Signal Processing	0	0	0	9
Open Electives for Semester-II						
1.	DE xxx	Optical Networks	0	0	0	9
2.	DE xxx	Optical Fiber and Optoelectronic Sensors	0	0	0	9

List of Electives

Sl. No.	Course No.	Course Name	L	T	P	C
Semester-IV						
		D Elective				
1.	DE xxx	Internet of Things	0	0	0	9
2.	DE xxx	Photonics Modelling and Design	0	0	0	9
		O Elective				
1.	DE xxx	Design and Analysis of Algorithms	0	0	0	9

Theory (CORE): 05
Lab: 02

SEMESTER 1 | Subject: Advanced Optical Communication | CORE | L-T-P : 3-0-0

Course Philosophy: Recent years have seen an exponential increase in demand for large bandwidth and high data rate applications. This is driven by rapid advances in advance optical communications. A thorough grounding in advance optical communications is necessary to communication engineers to address future needs of high data rate communications. The topics covered include modal analysis of optical fibers, impairments in optical fiber channel, lasers and photodiodes, optical amplifiers, digital optic fiber communications, WDM systems.

Learning Outcomes: At the end of the course, the student must be able to

- Understand basic principles of light propagation and modal analyses of optical fiber.
- Understand the basic operating principles of light sources, detectors.
- Fiber Nonlinearities.
- Understand coherent detection, Noises, Comparison of direct and coherent detection.
- Design optical link, power penalty etc

Topics to be covered	***No. of Lecture***
Module 1: Ray theory and Mode theory of optical fibers, linearly polarized modes. Fiber- SMF, MMF, Attenuation and Dispersion in fibers; Special fibers.	12
Module 2: Brief overview of optical transmitter and optical receiver. Receiver Noise processes, BER measurement, Noise measurement for optical communication system, Optical Losses.	09
Module 3: Optical Amplifiers, Optical Filters.	04
Module 4: Fiber Nonlinearities: Kerr effects, SPM, XPM, FWM.	04
Module 5: Coherent detection: fundamental concept, comparison of direct and coherent detection, Noises formulations, On-off keying, PSK, DPSK, FSK generation and detection.	06
Module 6: Optical transmission Link design, Power budget and rise time budget. WDM Systems.	04
Total number of classes	39

Text book:

1. Optical Fiber Communication-principles and practice, J. M. Senior (Prentice hall of India),Eight Impression 2014

Reference books:

1. Optical Fiber Communications, Gerd Keiser (TMH publication), 4th edition 2011
2. Optoelectronics and Photonics, O S Kasap (Pearson publication), 2013

SEMESTER 1 | Subject: Photonic Integrated Circuits | CORE | L-T-P : 3-0-0)

Course Philosophy: Photonics is a rapidly growing industry as well as an active area of advanced research. The course on photonic integrated circuits (PICs) deals with the key principles underlying the analysis and design of integrated photonic devices and circuits, where light propagating in optical waveguides takes the central role. Various aspects that will be dealt are optical waveguide theory; passive, dynamic and functional devices; materials and fabrication technology; systems and applications – optical communication devices and current research and development on chip applications. This course is also highly research Impact for High-Speed Optical Interconnect, 5G, IoT.

Learning Outcomes: At the end of the course, the student must be able to

● Design and analysis all types of optical waveguides for photonic integrated circuits.
● Understand concept of photonic waveguide components and applications.
● Learn fabrication and characterization technology.

Topics to be covered	***No. of Lecture***
Module 1: Introduction and requirement of PICs; Optical Waveguides: Planar slab waveguides, symmetric and asymmetric waveguides; rectangular waveguides, Marcatili's method, Effective index method; graded index waveguides; loss in planar slab waveguide; Coupled mode theory and applications.	12
Module 2: Numerical techniques and simulation tools for analyzing PICs; Analysis of Plasmonic waveguide, Photonic crystal waveguides	06
Module 3: Photonic waveguide components and applications - couplers, multimode interference-based couplers, tapers, bends, y- branch, gratings, switches, polarizers, filters, resonators, multiplexer/demultiplexer, optical Integrated optical systems and applications, optical interconnects.	10
Module 4: Technology: materials-glass, lithium niobate, silicon, compound semiconductors, polymers; fabrication techniques - lithography, ion-exchange, deposition, diffusion process, and device characterization, packaging and environmental issues.	08
Module 5: More recent developments in PICs	03
Total number of classes:	39

Text book:

1. C R Pollock and M Lipson: Integrated photonics, Kluwer Academic Pub, 2003

Reference books:

1. Govind P Agrawal: Lightwave technology: component and devices, John Wiley , 2004
2. Katsunari Okamoto: Fundamentals of Optical Waveguides Academic Press 2006

SEMESTER 1 | Subject: Mathematical and Simulation Techniques | CORE | L-T-P : 3-0-0	
Course Philosophy: The 5 modules of the course exposes the students to some of the popular tools required for optimization, mathematical analysis, modeling and design through simulations. Monte Carlo simulations find applications in IC design, communication engineering and quantum mechanics. Estimation theory as well signal transforms are being considered as elements of "machine learning", it is highly relevant for researchers in pre-processing of data, feature extraction, and inferring parameters from data gathered from measurements or simulations, and is extremely important within communication and signal processing. Queuing theory Mathematical models for complex systems are rarely solvable analytically, and algorithms for numerical methods based on computational mathematics needs to be understood by researchers in many problem domains. Queuing theory provides a rich and useful set of mathematical models for the analysis and design of service process for which there is contention for shared resources and provides the student with a framework to compute performance metrics in networking and other similar problems. Several commercial software use the various modules forming a part of the course.	
Topics to be covered	***No. of Lecture***
Module 1: Introduction to the course, Filtering techniques for signal estimation, Monte Carlo simulation method, Fast computation of Transforms, Tutorials.	10
Module 2: Root finding techniques, Review of Solution of ordinary and partial differential equations, Numerical methods for solution of differential equations, Numerical integration methods, Tutorials.	10
Module 3: Introduction to Finite element method, Boundary point method, Finite difference method, Discretization of differential equations, Tutorials.	10
Module 4: Introduction to Variational technique, Finite Difference Time Domain method, Mode matching method, Tutorials.	10
Module 5: Optimization Techniques, Queuing models.	10
**** Out of 5 modules, any 4 modules may be floated**	
Total number of classes	40
Books (for individual modules):W. H. Press, S. A. Teukolsky, W. T. Vellerlingand B. P.,Flannery.,"NumericalRecipes",CambridgeUniversity Press. ●Monson H Hayes, "Statistical Digital Signal Processing and Modeling",JohnWiley & Sons ●B.SGrewal, "Higher Engineering Mathematics", 42nd Edition, Khanna Publishers 2012. ●Erwin Kreyszig, "Advanced Engineering Mathematics", 10th Edition, John Wiley 2010. ●David Kincaid and Ward Cheney, "Numerical Analysis: Mathematics of Scientific Computing", 3rd Edition, American Mathematical Society 2010. ●AtefZ. Elsherbeniand VeyselDemir, "The finite-difference time-domain method for electromagnetics with matlabsimulations", ScitechPublishing Inc. 2ndEdition.	

SEMESTER 1 | Subject: Optoelectronic & Photonic Devices | CORE | L-T-P : 3-0-0

Course Philosophy: Optoelectronic and Photonic Devices are becoming increasingly essential devices for next generation industrial and defense applications for high speed optical communications.

Learning Outcomes: At the end of the course, the student must be able to

Learn about the construction and working principle of high speed optoelectronics and photonics devices such as high speed laser diode MZI, MZM, EAM, and SOA for design of high speed communication system, microwave photonic system.

Topics to be covered	***No. of Lecture***
Module 1: Introduction: Distinction between electronic, optoelectronic and photonic devices; Electrical and optical bandwidth. Optoelectronic Devices: Semiconductor Sources- LEDs, LDs (Double heterojunction, DFB, Quantum wire & dot).	11
Module 2: Semiconductor Detectors – Structure and noise analysis of PIN and APD detectors, Solar cells.	6
Module 3: Modulators – Electro-optic and magneto-optic. Semiconductor amplifiers.	6
Module 4: Photonic Devices: Fiber Amplifiers and Fiber Lasers**.** Optical Filters, Fiber Bragg grating (FBG) and its application as dispersion compensator and Add-Drop Multiplexer.	12
Module 5: MZI and its applications. Optical Switches.	4
Total number of classes:	39

Text book:

1. Fundamentals of Photonics, B. E. A. Saleh and M. C. Teich (Wiley-India, 2007)

Reference books:

2. Optoelectronics and Photonics, O S Kasap (Pearson publication) Semiconductor Optical Amplifiers, 2013

SEMESTER 1 | Advanced Communication Theory | CORE | L-T-P : 3-0-0	
Course Philosophy: The students will gain advanced knowledge on the physical layer mechanism of the various communication technologies **Learning Outcomes:** The students will gain advanced knowledge on the physical layer mechanism of the various communication technologies	
Topics to be covered	***No. of Lecture***
Module 1: Geometric representation of signals, Gram-Schmidt Orthogonalization, Maximum likelihood procedure for detection of a signal in a AWGN channel, Probability of symbol error, union bound on the probability of error. representation of narrowband noise, properties of its in-phase and quadrature components.	07
Module 2: Advanced Digital Modulation techniques – QPSK, QAM, OQPSK, CPFSK, MSK, , GMSK, Power and bandwidth efficiency of different schemes. Noncoherent Orthogonal Modulation techniques.	10
Module 3: Carrier phase and symbol timing synchronization techniques. Spread Spectrum Modulation – DSSS and FHSS systems, CDMA of DSSS, applications of spread spectrum systems. Multicarrier communication – OFDM, DMT and their real-life application.	12
Module 4: Receivers for nonideal channel – signal distortion over a communication channel (linear distortion / distortion due to channel nonlinearities/multipath effects/fading), equalization techniques. Diversity techniques for reliable communication over a fading channel.	10
Total number of classes	39
Text book: 1. Proakis, John G., and Masoud Salehi. Digital communications. Vol. 4. New York: McGraw-hill, 2014. **Reference books:** 1. Haykin, Simon S. Digital communications. New York: Wiley, 2010. 2. Lathi, Bhagwandas P. Modern digital and analog communication systems. Oxford University Press, Inc., 2018. 5th ed.	

SEMESTER 1 | LAB: Optical Communication Lab | L-T-P : 0-0-3

Course Philosophy: The goal of this lab is to provide knowledge about optical communication system through lots of experiments using optical trainer Kits and/or discrete component and simulation tools.

Learning Outcomes: By the end of the course, the student must be able to:

- understand the various fiber optic and digital communication techniques
- Do simulation in Matlab and Photonics CAD

Hardware + Software

(Practical : 13 Lab Days | Exam : 01 Lab Days)

Hardware-based Experiments (to be carried out using optical trainer Kits and/or discrete component)

1. Introduction and familiarization of different types of fiber and optical components.
2. Setting up a fiber optic analog link and digital link
3. Study of propagation loss, bending loss and measurement of Numerical Aperture
4. Study the current-intensity relation of LED and LASER diode.
    1. Threshold current (b) Spectral bandwidth
5. Measurement of Quantum efficiency of Photodiode.
6. Study of PWM and PPM and their demodulation
7. Measurement of BER and eye pattern in optical fiber.
8. Study of non-linear effect in optical fiber.
9. Study of optical amplifiers

Simulation –based Experiments (to be carried out in MATLAB/Photonic CAD Tool)

1. Mode analysis in optical fiber.
2. Analysis of Dispersion in optical fiber.
3. Design and analysis of WDM link.
4. Study of BER and Q-factor in optical communication.
5. Design and analysis of optical transceiver.

SEMESTER 1 | Communication Systems Lab| L-T-P : 0-0-3

Course Philosophy: The goal of this lab is to provide knowledge about the real time communication through lots of experiments using PYTHON, SCILAB/MATLAB.

Learning Outcomes: By the end of the course, the student must be able to:

- Do simulation in PYTHON, SCILAB/MATLAB
- Do Software Defined Radio (SDR) based real time communication.

(Practical : 12 Lab Days | Exam : 01 Lab Days)	***No. of Lab Days***
Unit 1: Frequency division multiplexing system. Time division multiplexing system.	02
Unit 2: PN sequence communication through baseband channels (LP, BP, HP) and eye pattern measurements. Digital modulations systems (ASK, FSK, PSK).	04
Unit 3: Carrier and clock recovery systems. Optimal Detection of the signal for AWGN channel and error calculation Optimal detection of the signal in presence of both ISI and AWGN. Introduction to Software Defined Radio (SDR).	06

SEMESTER – II **Lab: 02**

Theory (D Electives):03
Theory (Open Electives):02

SEMESTER 2 | LAB: Optoelectronic & Photonic Devices Lab | L-T-P : 0-0-3

Course Philosophy: The goal of this lab is to provide knowledge about optoelectronics & photonics Devices through experimental setup.

Learning Outcomes: At the end of the course, the student must be able to learn about the construction and working principle of high speed optoelectronics and photonics devices such as high speed laser diode MZI, MZM, EAM, and SOA for design of high speed communication system.

(Practical : 10 Lab Days | Exam : 01 Lab Days)

1. Study the characteristics of DFB Laser.
2. Design and analysis of optical filter for optical communication.
3. Design of optical sensor based on FBG.
4. Study of the characteristics of Ring resonator based optical components.
5. To measure the insertion losses and extinction ratio in Optical splitter.
6. To measure the insertion losses and extinction ratio in Optical Mux/Demux
7. Perform characteristics of an EDFA.
8. Perform characteristics of an SOA.
9. Analysis the characteristics of Mach-Zehnder Modulator.

SEMESTER 2 | LAB: Modelling and Design Lab L-T-P : 0-0-3

Course Philosophy: Use of lumerical CAD and Optiwave Photonics software to analyze the photonics devices and systems. Design of novel device structure for desired application

Learning Outcomes: At the end of the course, the student must be able to learn about design and modeling of all types of optical waveguides, devices and systems

(Practical : 10 Lab Days | Exam : 01 Lab Days)

1. Design and model analysis of silicon strip and rib waveguide.
2. Design, simulation and analysis of passive Directional Coupler.
3. Design, simulation and analysis insertion losses and extinction ratio in Optical splitter.
4. Design, simulation and analysis of MZI switch.
5. Study of different modulation techniques in optical communication
6. Analysis the characteristics of Mach-Zehnder Modulator.
7. Design optical link using different optical components and measures of link performance (losses and BER).
8. Design and simulation of Semiconductor optical amplifier
9. Design of Radio over fibre link.
10. Design of wavelength convertible optical network with multiple nodes

SEMESTER 2 | Subject: Nonlinear Fiber Optics | D ELECTIVE | L-T-P : 3-0-0 **Course Philosophy:** This course deals with techniques of nonlinear optics with emphasis on fundamentals for research and engineering in optics, photonics, and spectroscopy. **Learning Outcomes:** A successful student should be able to: 1. apply the concepts fiber characteristics, fiber nonlinearities. 2. learn SPM, XPM,FWM	
Topics to be covered	***No. of Lecture***
Module 1: Introduction, fiber characteristics, fiber nonlinearities. Pulse propagation in fibers, Maxwell's equations, fiber modes, nonlinear-Schrödinger equation (NLSE), variational and numerical methods to solve NLSE.	10
Module 2: Group velocity dispersion, dispersion-induced pulse broadening, third-order dispersion, dispersion managemen .	06
Module 3: Self-phase modulation, SPM-induced spectral broadening, and effect of group-velocity dispersion.	06
Module 4: Optical solitons, modulation instability, fiber solitons, perturbation of solitons, higher-order effects Cross phase modulation, XPM-induced nonlinear coupling, XPM-induced modulation instability, spectral and temporal effects, applications of XPM, FWM and its effects.	17
Total number of classes	39
Text book: Govind Agrawal, Nonlinear Optics 5th edition	

SEMESTER 2 | Subject: Microwave Photonics | D ELECTIVE | L-T-P : 3-0-0	
Course Philosophy: Microwave Photonics is an interdisciplinary area which brings microwave and optical technologies to overcome the limitation of microwave technology and exploited the advantage of optical technology. **Learning Outcomes:** This subject will explore the close interactions of lightwave and microwave and understand the physical principles of the hybrid field. Students will learn and investigate the microwave photonics principles through a number of cutting-edge system applications ranging from high-speed fibre-wireless links to microwave photonic signal processing. The focus will be on link and subsystem design and performance analysis that are usually not covered in other subjects. Through these studies, students will understand the different functionalities that can only be created by combining the two different disciplines.	
Topics to be covered	***No. of Lecture***
Module 1: Introduction to Microwave Photonics: An introductory overview, Advantages of Microwave photonics over conventional Microwave techniques. Photonic devices and its application at high frequency, Limitation of direct modulation at high frequency, Microwave photonic detectors	12
Module 2: Microwave photonic components: High speed Modulator. Electro-optic modulators: Biasing and transfer characteristic of Mach-Zehnder Modulator (MZM), Electro-absorption modulators, Fiber Bragg Grating filter, Semiconductor optical amplifier.	12
Module 3: Microwave photonic systems: Introduction to Radio over fiber, Photonic microwave signal generation and processing, Optoelectronic microwave oscillator, Microwave photonic mixer, Microwave photonic filter, Terahertz signal generation and detection.	10
Module 4: Microwave photonics in instrumentation and measurement: Photonic approach of microwave frequency measurement.	05
Total number of classes	39

Text book:

Microwave Photonics: Devices and Applications by Stavros Iezekiel John Wiley & Sons, Ltd 2009.

Reference books:

1. Optoelectronics and Photonics, O S Kasap (Pearson publication) Semiconductor Optical Amplifiers, 2013
2. Semiconductor optical amplifiers, second edition by N.K Dutta , Q. Wang January 2013

SEMESTER 2 | Subject: Nanophotonics| D ELECTIVE | L-T-P : 3-0-0)

Course Philosophy: This course provides material supporting research students, theoretical, embarking on projects in nanoscale materials in 2,1 and 0 dimensional systems and nanoscale coupled light-matter systems. It demonstrates the application of concepts of quantum mechanics and electromagnetism in a modern research field, and outlines extensions necessitated by research work such as quantum electrodynamics.

To overview the fundamental concepts of optical effects in nanoscale systems and coupled light-matter systems, particularly as they apply to semiconductor nanostructures and microcavities**.**

Learning Outcomes: On successful completion of this module, students will be able to:

1. Understand Basics of quantum mechanics.
2. Understand Electrons in solids (periodic structure).
3. Nano-plasmonics

Topics to be covered	***No. of Lecture***
Module 1: Basics of quantum mechanics: quantum particles and EM wave, wavelengths and dispersion laws, density of states, uncertainty relation, wave function and Schrödinger equation, quantum particle in complex potentials. Wave mechanics and wave optics: propagation over wells and barriers, propagation through potential barriers, Evanescent waves and tunneling.	11
Module 2: Electrons in solids (periodic structure): Bloch waves, electron band structure, Brillouin zones, quasi particles (holes, excitons, polaritons), defect states, quantum confinement effects, quantum wells, wires and dots. Semiconductor nanocrystals, electron-hole states, absorption spectra, luminescence, applications e.g., QD laser, nonlinear optics, electro-optical properties.	13
Module 3: Nano-plasmonics: optical properties and response of metal nanoparticles, size-dependent absorption and scattering, metal dielectric nanostructures, electromagnetic fields near metal nanoparticles, optical response of metal-dielectric core-shell nano-composites.	08
Module 4: Light in periodic structure: concept of photonic crystals, Bloch waves and bandstructure in 1-D periodic structures, 3-D multilayer slabs, band gap and band structures in 2-D and 3-D lattices, multiple scattering theory of periodic structures, nonlinear optics and photonic crystal.	08
Total number of classes	39

Text book:

1. Introduction to Nanophotonics by Sergey V. Gaponenko, Cambridge University Press

Reference books:

1. Fundamentals of Quantum Mechanics For Solid State Electronics and Optics by C. L. Tang, Cambridge University Press
2. Principles of Nano- Optics by Lukas Novotny, Bert Hecht, Cambridge University Press
3. Principles of Nanophotonics by Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui, Makoto Naruse, CRC Press Taylor and Francis Group

SEMESTER 2 | Subject: Silicon Photonics | D ELECTIVE | L-T-P : 3-0-0	
Course Philosophy: Silicon Microphotonics is a platform for the large scale integration of CMOS electronics with photonic components. This course will evaluate the most promising silicon optical components and the path to electronic-photonic integration.The course objective is an overview of the silicon microphotonic platform drivers and barriers in design or fabrication **Learning Outcomes:** This course will enable you to identify trends in optical interconnection and the power of electronic-photonic convergence explain how the electronic, thermal and mechanical constraints of planar integration promote silicon as the optimal platform for microphotonics design application-specific photonic devices that take advantage of unique materials processing and device design solutions compute the performance of micron-scale optically passive/active devices judge the feasibility and impact of the latest silicon photonic devices.	
Topics to be covered	***No. of Lecture***
Module 1: Introduction: Requirement - technological metrics, Silicon-on-Insulator (SOI) Photonics	05
Module 2: Integration of photonic devices: Major Issues, photonic device integration, photonic-electronic integration, power and power density issues on-chip.	10
Module 3: Silicon Optical I/O: The challenge of optical coupling to silicon photonic chip, Grating coupler, Edge coupler, Polarization and mode converter.	05
Module 4: Advanced waveguides and devices – Silicon-on Insulator waveguide, Silicon plasmonic waveguide, and silicon wire waveguide. MZI, MMI coupler, Ring Resonator – Applications, Ultrafast Modulators Thermo-optic and Electro-optic switch, optical filters.	10
Module 5: Fabrication, Testing and packaging of Silicon photonic devices: Silicon Photonics Research and Manufacturing using SOI wafer. Silicon Photonics Application: Telecom and Datacom Applications, Optical sensors, Optical networks.	09
Total number of classes	39
Text book: **1.** Silicon Photonics: Fueling the Next Information Revolution by Daryl Inniss, Roy Rubenstein **Reference books:** 1. C R Pollock and M Lipson: Integrated photonics, Kluwer Academic Pub, 2003 2. Govind P Agrawal: Lightwave technology: component and devices, John Wiley , 2004	

SEMESTER 2 | Subject: Ultrafast Technology | D ELECTIVE | L-T-P : 3-0-0

Course Philosophy: This course will address regarding ultrafast technology and their applications. Develop basic understanding of the concepts behind ultrafast and nonlinear optics, in addition to becoming informed about contemporary trends and developments in this rapidly evolving field of research. Topics to be covered include: Generation, propagation and applications of ultrashort pulses; Ultrafast Quantum Control in Atoms and Molecules, Applications in research and industry.

Learning Outcomes: After having passed the course the student is expected to:

•Understand concept of generating and measuring Ultrashort Optical Pulses.
•Ultrafast Quantum Control in Atoms and Molecules.
•Ultrafast Nonlinear Fibre Optics and Supercontinuum Generation.
•Short Laser Pulses.
•Micromachining.

Topics to be covered	***No. of Lecture***
Module 1: Generating and measuring Ultrashort Optical Pulses.- Ultra-Broadband Optical Parametric Amplifiers.- Advances in Solid-State Ultrafast Laser Oscillators.	08
Module 2: Ultrafast Quantum Control in Atoms and Molecules.- Femtosecond Optical Frequency Combs.- Ultrafast Material Science Probed using Coherent X-Ray Pulses from High-Harmonic Generation	05
Module 3: Ultrafast Nonlinear Fibre Optics and Supercontinuum Generation.- Nonlinear Wavelength Conversion and Pulse Propagation in Optical Fibres.- Applications of Ultra-Intense.	08
Module 4: Short Laser Pulses.- Utilizing Ultrafast Lasers for Multiphoton Biomedical Imaging.-Femtosecond Laser.	09
Module 5: Micromachining.- Technology and Applications of THz waves, Ultrafast Nonlinear Microscopy,- Attosecond Generation.	09
Total number of classes	39

Books:

1. Robert Thomson, Ultrafast Nonlinear Optics, Springer, Heidelberg, 2013
2. Research papers

SEMESTER 2 | Subject: Numerical Techniques in Electromagnetics | D ELECTIVE | L-T-P : 3-0-0	
Course Philosophy: To familiarize the students with the basic as well as advanced numerical and analytical techniques in electromagnetics for different boundary value problem with respect to real time situation. The course prepares PG students where the advance topics like spectral domain, finite difference time domain, mode matching, method of separation variable, etc. will be covered, particularly those including an in-depth description. . **Learning Outcomes:** By the end of the course, the students should be able to solve challenging boundary value problems involving planer and 3D antennas, filter and other waveguide problems.	
Topics to be covered	***No. of Lecture***
Module 1: Maxwell's Equation, Circuit field relations, Boundary conditions, Power & Energy and Time harmonic electromagnetic fields, Classification of EM Problems and Some Important Theorem etc	07
Module 2: Wave equation and solution, Auxiliary vector potential, Construction of solution, Solution of inhomogeneous vector potential wave equations, Mode Matching Techniques for waveguide structure and solution construction, method of separation variable methods.	12
Module 3: Spectral Domain Methods, Mesh generation in Rectangular and Arbitrary Domain, Transmission Line Matrix method, Method of Line: Solution to Laplace Equation, Wave Equation and Time Domain Solution..	06
Module 4: Variational Method: Construction of Functional from PDEs, Rayleigh Ritz Method, Weighted Residual Method, Eigen Value Problems and Practical Applications. Application to Study Open Ended Waveguide Problem. Moment Method, Finite Element Method: Solution to Poisson, Laplace and Wave Equation.	04
Module 5: Finite Difference Method: Finite Difference Schemes, Differencing of Parabolic, Hyperbolic and Elliptic PDEs, Accuracy and Stability in PD, Application in Guided Structure, Wave Scattering (FDTD), Absorbing Boundary Conditions, Finite Differencing for Non-Rectangular System.	08
Total number of classes	39

Text book:

1. C. A. Balanis, 'Advanced Engineering Electromagnetics', Jhon Wiley & Sons, USA.
2. R. F. Harrington., 'Time Harmonic Electromagnetics Field', Jhon Wiley & Sons and IEEE, USA.
3. Matthew N.O. Sadiku, 'Numerical Techniques in Electromagnetics, 3e, 2009, A&M University, Texas, USA
4. Journal Papers of IEEE Trans. on Antenna and Propagation & IEEE Transaction on Microwave Theory and Techniques.

SEMESTER 2 | Subject: Wireless Optical Communication | D ELECTIVE | L-T-P : 3-0-0	
Course Philosophy: The objective of the course is to provide a comprehensive understanding of optical communication systems and networks. The course covers both guided wave propagation along single/multimode optical fibres and unguided propagation resulting in optical wireless communications. **Learning Outcomes:** At the end of the course, the student must be able to understand the latest technologies used in advanced wireless optical communication systems.	
Topics to be covered	***No. of Lecture***
Module 1: An Overview of Optical Wireless Communications Optical Propagation in Unguided Media, Effects of Adverse Weather on Free Space Optics	10
Module 2: Experimental Validation of FSO Channel Models.	03
Module 3: Channel Characterization and Modeling for LEO-Ground Links Channel Modeling for Visible Light Communications, Information Theoretical Limits of Free-Space Optical Links.	10
Module 4: Performance Analysis of FSO Communications Under Correlated Fading Conditions MIMO Free-Space Optical Communication, OFDM-Based Visible Light Communications.	12
Module 5: Satellite Downlink Coherent Laser Communications; FSO for High Capacity Optical Metro and Access Networks.	04
Total number of classes	39

Text book:

Murat Uysal, Carlo Capsoni, Zabih Ghassemlooy, Anthony Boucouvalas,Eszter Udvary Editors Optical Wireless Communications: An Emerging Technology;2016

Reference books:

1. Andreas Molisch F, "Wireless Communications", John Wiley and Sons Ltd., 2011.
2. David Tse and PramodViswanath, "Fundamentals of Wireless Communication", Cambridge University Press, 2005.
3. Theodore S. Rappaport, "Wireless Communications: Principles and Practice", 2nd Edition,

SEMESTER 2 | Subject: Optical and Quantum Computation | D ELECTIVE | L-T-P : 3-0-0

Course Philosophy: This course will provide a modern understanding of light as a quantum phenomenon, and explore how quantum applications such as quantum communications and quantum sensing are developed using quantum light.

Learning Outcomes: After having passed the course the student is expected to: have an overview of the field of quantum optics, be able to formulate and treat mathematical descriptions of basic quantum optical phenomena.

Topics to be covered	***No. of Lecture***
Module 1: Quantum theory of light: quantization of the electromagnetic field, evolution of the field operators, quantum states of light, Quantum information processing.	04
Module 2: Photon sources and detectors: Mathematical model of photodetectors, physical implementations of photodetectors, single-photon sources, entangled photon sources, quantum non-demolition photon detectors.	05
Module 3: Quantum communication with single photons: photons as information carriers, quantum teleportation and entanglement swapping, decoherence-free subspaces for communication, quantum cryptography. Quantum computation with single photons.	06
Module 4: Quantum communication with continuous variables: phase space in quantum optics, continuous-variable entanglement, teleportation and entanglement swapping, entanglement distillation, quantum cryptography.	05
Module 5: Quantum computation with continuous variables. Quantum treatment of linear optics, Quantum light by non-linear optical processes, signatures of quantum behaviour, light-matter interaction, Quantum memories.	06
Module 6: An ensemble of identical two-level atoms, electromagnetically induced transparency, quantum memories and quantum repeaters, the atomic ensemble of a single qubit, photon-photon interactions via atomic ensembles.	08
Module 7: Solid-state quantum information carriers: Definition and optical manipulation of solid-state qubits, interactions in solid-state qubit systems, entangling two qubit operations, scalability of solid-state devices.	05
Total number of classes	39

Text book:

1. P. Lambropoulos and D. Petrosyan, Fundamentals of Quantum Optics and Quantum Information, Springer 2007

Reference books:

1. L. Mandel and E. Wolf, Coherence and Quantum Optics, Cambridge Univ. Press 1995
2. M. O. Scully and S. Zubairy, Quantum Optics, Cambridge university Press, 1997

SEMESTER 2 | Subject: Wireless Communication Systems | D ELECTIVE | L-T-P : 3-0-0

Course Philosophy: This course will provide the fundamental mechanism behind the wireless communication techniques (3G, 4G, 5G).

Learning Outcomes: At the end of the course, the student must be able to acquire knowledge on various wireless communication technologies which is very much helpful for academia research and Industries working in wireless communication technologies.

Topics to be covered	***No. of Lecture***
Module 1: Introduction and evolution of wireless and mobile radio communication systems. The Cellular Concept-System Design Fundamentals, Frequency reuse, Handoff, Co-channel and Adjacent Interference. System Capacity, Improving Cell Capacity and Coverage, trunking, cell splitting, sectoring, micro-cell zone concept.	10
Module 2: Mobile Radio Propagation, Large-scale Path Loss; free space propagation model, log-distance path loss model, shadowing, and coverage area. Small-scale fading and multipath; Doppler shift, multipath channel; delay spread and coherence bandwidth; Doppler spread and coherence time; flat fading and frequency-selective fading; fast fading and slow fading.	10
Module 3: MIMO, OFDM, CDMA, Multi-user MIMO	19
Total number of classes	39

Text book:

1. Rappaport, Theodore S. "Wireless communications: Principles and practice." (2002).
2. Goldsmith, Andrea. Wireless communications. Cambridge university press, 2005

Reference books:

Tse, David, and Pramod Viswanath. Fundamentals of wireless communication. Cambridge university press, 2005.

SEMESTER 2 | Subject: Advanced Operating Systems | D ELECTIVE | L-T-P : 3-0-0

Course Philosophy:

- Operating Systems is the key platform that manages the hardware and software. To explore programming language and operating system facilities essential to implement real-time, reactive, and embedded systems
- To discuss limitations of widely-used operating systems, introduce new design approaches to address challenges of security, robustness, and concurrency
- To give an understanding of practical engineering issues in real-time and concurrent systems; and suggest appropriate implementation techniques

Learning Outcomes:

- Clearly differentiate the issues that arise in designing real-time systems; analyse a variety of real-time scheduling techniques, prove correctness of the resulting schedule; implement basic scheduling algorithms;
- Understand how to apply real-time scheduling theory to the design and implementation of a real-world system using the POSIX real-time extensions, and be able to demonstrate how to manage resource access in such a system; understand the impact of heterogeneous multicore systems on operating systems; compare and evaluate different programming models for concurrent systems, their implementation, and their impact on operating systems;
- Construct and/or analyse simple concurrent programs using transactional memory and/or message passing, to understand the trade-offs and implementation decisions..

Topics to be covered	***No. of Lecture***
Module 1: Operating Systems – Overview - Distributed systems; Issues in communication; Remote Procedure Call; Remote Method Invocation;	10
Module 2: Message- and Stream-Oriented communication; Processes and threads; Code migration and distributed scheduling; Naming; Clock Synchronization; Distributed mutual exclusion and distributed deadlocks; Distributed transaction; Consistency models; Replication;	10
Module 3: Distributed mutual exclusion and distributed deadlocks; Distributed transaction; Consistency models; Replication;. Fault tolerance; Distributed commit and failure recovery;	10
Module 4: Distributed file systems (NFS, AFS & coda); Security in distributed systems; Security: authentication; Distributed middleware – case study.	09
Total number of classes	39

Text book:

1. Jean DollimoreTim KindbergGeorge Coulouris," **Distributed Systems : Concepts and Design", Pearson Education, 2009**

Reference books:

1. Andrew S. TanenbaumMaaten Van Steen, "Distributed Systems: Principles and Paradigms", Pearson Education, 2015

SEMESTER 2 | Subject: Optical Signal Processing | D ELECTIVE | L-T-P : 3-0-0

Course Philosophy: Optical signal processing is very useful for all-optical devices capable of processing high-speed optical signals in a lightwave technology.

Learning Outcomes: At the end of the course, students must be able to

- Understand basics of signal processing and optics
- Understand the detection process in Fourier domain
- Understand the basic Acousto-optic power spectrum analyzer.

Topics to be covered	***No. of Lecture***
Module 1: Basics of signal processing and optics, Characterization of a General signal, examples of signals, Spatial signal. Basic laws of geometrical optics, Refractions by mirrors, the lens formulas, General Imaging conditions, the optical invariant, Optical Aberrations.	12
Module 2: Physical Optics, The Fresnel Transforms, the Fourier transform, Examples of Fourier transforms, the inverse Fourier transform, Extended Fourier transform analysis, Maximum information capacity and optimum packing density, System coherence. Spectrum Analysis and Spatial Filtering, Light sources, spatial light modulators.	12
Module 3: The detection process in Fourier domain, System performance parameters, Dynamic range. Some fundamentals of signal processing, Spatial Filters, Binary Spatial Filters, Magnitude Spatial Filters, Phase Spatial Filters, Real valued Spatial Filters, Interferometric techniques for constructing Spatial Filters.	10
Module 4: Optical signal processor and filter generator, Applications for optical signal processing. Acousto-optic cell spatial light modulators, Applications of acousto-optic devices. Basic Acousto-optic power spectrum analyzer. Heterodyne systems: Interference between two waves, the optical Radio.	05
Total number of classes	39

Text book:

1. Anthony Vanderlugt ,"Optical signal processing" ,Wiley-Interscience
2. Hiroshi Ishikawa ,"Ultrafast All-Optical Signal Processing Devices",Wiley

Reference books:

1. D. Casasent, "Optical data processing-Applications", Springer-Verlag, Berlin,
2. H.J. Caulfield, "Handbook of holography", Academic Press New York 1979 3. P.M. Dufffieux, "The Fourier Transform and its applications to Optics", John Wiley and sons

SEMESTER 2 | Subject: Optical Networks | Open ELECTIVE | L-T-P : 3-0-0

Course Philosophy:

- An optical network is a type of data communication network built with optical fiber technology. It utilizes optical fiber cables as the primary communication medium for converting data and passing data as light pulses between sender and receiver nodes. The course will give the student in-depth understanding of the functionality of optical networks and how they may be implemented. How an optical network can work together with an IP-based network infrastructure for ensuring both high reliability and performance in access, metro and transport networks, is paid special attention.
- The topics covered includes building blocks for optical networks and systems, an introduction to optical components, principles and functionality in optical network elements as well as basic physical principles and properties and constraints in optical fiber transmission. Principles and the function of optical circuit switched networks, both network elements like reconfigurable add/drops and optical cross-connects as well as the principle of a wavelength routed optical network are covered. Finally, up-to-date research in optical packet switched node and network architectures is studied.

Learning Outcomes: A. Knowledge:

1) To get a basic understanding of physical properties of optical networks. 2) To get a profound understanding of protocols applied in optical networks 3) To get a profound understanding of optical switching methods and networking techniques, circuit, packet, hybrid, burst and flow. 4) To get a basic understanding of optical components and optical node design. 5) To be able to communicate, reason and creatively think about optical networks. 6) To be able to design optical networks, taking both physical transmission properties and optical networking constraints into account. 7) To be able to evaluate performance of optical packet switched nodes using discrete event simulation methods.

Topics to be covered	***No. of Lecture***
Module 1: Evolution of optical networking - Overview of Fibre optic LANs: Suitable topologies and MAC protocols, FDDI, DQDB, Gigabit Ethernet;	06
Module 2: Review of SONET/SDH and concepts of networking using IP-over-ATM-over-SONET/SDH architecture;	06
Module 3: WDM networks: Elements of WDM networks, Optical line terminals, Optical line amplifiers, Optical add/drop multiplexers (OADMs), Reconfigurable OADMs, Optical cross-connects.	07
Module 4: WDM backbone networks: Concepts of wavelength routing and lightpaths, Lightpath topology design, Routing and wavelength assignment, LP-based optimum design and heuristic algorithms, Wavelength conversion.	07
Module 5: Traffic grooming in wavelength-routed backbones; IP-over-WDM and GMPLS, Protection in SONET/SDH, Protection in WDM backbone networks - dedicated and shared schemes.	07
Module 6: Overview of Optical access networks: Hybrid fiber coax (HFC), Enhanced HFC, Fibre to the home (FTTH), Overview of Passive optical networks; Optical CDMA and Elastic Optical Network.	06
Total number of classes	39

Text book:

1. Rajiv Ramaswami, Kumar N. Sivarajan and Galen H. Sasaki, “Optical Networks: A Practical Perspective” (Third Edition) The Morgan Kaufmann Series in Networking, David Clark, Series Editor, 2010

Reference books:

1. Biswanath Mukherjee, Optical WDM Networks, Springer, 2006
2. P.E Green, Jr. ``Fiber Optic Networks," Prentice Hall; 1 edition (July 9, 1992).
3. G. P.Agarwal, ``Fiber-Optic Communication Systems," Wiley Pubisher (2015)
4. C. Siva Ram Murthy and Mohan Gurusamy, “WDM Optical Networks - Concepts Design and Algorithms”, Prentice-Hall PTR, 2002. **5.**López, Víctor, Velasco, Luis (Eds.) “Elastic Optical Networks: Architectures, Technologies, and Control”, Springer, 2016.

SEMESTER 2 | Subject: Optical Fiber and Optoelectronic Sensors| Open ELECTIVE | L-T-P : 3-0-0

Course Philosophy: The field of photonic sensing has shown extraordinary capabilities of highly sensitive and accurate sensors. Optical based sensors provide high sensitivity and detection accuracy along with the additional benefits of remote sensing, miniaturization, low cost and online monitoring. The objective of this course is to introduce the students the field of photonic sensors and its application.

Learning Outcomes: After completion of course, students will be able:

- To describe the concept used in the designing of sensors.
- To explain the working principle of various optoelectronic sensors.
- To explain the applications of various types of optical sensors.

Topics to be covered	***No. of Lecture***
Module 1: Introduction: Use of optical fiber as sensor. Sensing using optoelectronics. Motivation and learning outcome of the course. Advantages of fiber optic sensors, few examples. Intensity, phase and polarization based fiber optic sensors for measurement of temperature, pressure, strain, acceleration, displacement and velocity. Evanescent field absorption based sensors, different probing techniques and derivation of sensitivity in each cases. Characteristics and components of optical fiber sensors. Fibre types and materials for optical fibre sensing (silica based, polymer based, etc.). Intensity based Reagent mediated sensors for humidity, pH level etc. and their experimental set-ups.	12
Module 2: Interferrometry based and FBG based sensing technology: LPG, SPG, microfibres/nanowires, Mach-Zhender, Sagnac, Michelson Interferrometers - Design, fabrication and characterization of sensors.	08
Module 3: Hydrogen leakage sensing in cryo engines. Fiber Optic Gyroscope for navigation application.	04
Module 4: Physics of plasmons, surface plasmons at semi-infinite metal-dielectric interface, excitation of surface plasmons, surface plasmon resonance (SPR) condition, Theory of SPR based optical fiber sensors, N-layer model, excitation by meridional rays: on axis excitation, performance parameters: sensitivity, detection of accuracy and figure of merit.	08
Module 5: Electro-optic sensors and its applications. Micro-opto-electro-mechanical Systems (MOEMS): MOEM overview, MOEM scanners, MOEM technology and applications to telecom, CMOS compatible MOEMS, optics specific issues for MOEMS, micro-optics, automation and sensing, shape.	04
Module 6: Principles and application of optical fibre sensors in medicine and life sciences, civil engineering, e.g. structural monitoring and aircraft navigation.	03
Total number of classes	39

Text book:

5. Fiber Optic Sensors – Principle and Applications by B. D. Gupta, New India Publishing Agency 2006.

Reference books:

Fiber Optic Sensors, An Introduction for Engineers and Scientists edited by Eric Udd, William B. Spillman, Jr., John, Wiley and Sons Inc. Publication 2011

SEMESTER – IV **Theory (D Electives/Open Elective):02**

SEMESTER 4 | Subject: Internet of things | D ELECTIVE | L-T-P : 3-0-0 **Course Philosophy:** The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The course introduces advanced concepts and methodologies of IoT to design, build and deploy IoT solutions. It also discusses various technologies and protocols used for communication including new generation IoT-friendly applications and physical layer protocols. **Learning Outcomes:** A. Knowledge: - Understanding building blocks of Internet of Things and characteristics - Thorough understanding of widely accepted IoT frameworks and standards - Understanding the application areas of IOT - Building and deploying IoT solutions - Realizing the revolution of Internet in Mobile Devices, Cloud & Sensor Networks	
Topics to be covered	***No. of Lecture***
Module 1: Introduction to IoT: Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications.	07
Module 2: Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino.	08
Module 3: Introduction to Python programming, Introduction to Raspberry Pi, Implementation of IoT with Raspberry Pi, Implementation of IoT with Raspberry Pi.	07
Module 4: Introduction to SDN; SDN for IoT, Data Handling and Analytics, Cloud Computing.	07
Module 5: Sensor-Cloud; Fog Computing, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring.	08
Total number of classes	39
Text book: **1.** 1.Pethuru Raj and Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2017 **Reference books:** 1. Arshdeep Bahga and Vijay Madisetti "Internet of Things: A Hands-on Approach", Universities Press, 2014 2. Olivier Hersent, "The Internet of Things: Key Applications and Protocols", Wiley Press, 2015 3. Adrian McEwen, "Designing the Internet of Things", Wiley Publishers, 2013 4. Daniel Kellmereit, "The Silent Intelligence: The Internet of Things". 2013	

SEMESTER 4 | Subject: Photonics Modelling and Design | D ELECTIVE | L-T-P : 3-0-0	
Course Philosophy: This course delivers a concise introduction to the modelling and design of photonic devices. This subject analyze the light propagation in dielectric media. It discusses the heat diffusion and carrier transport which applies in the presented theory to develop fibre and semiconductor laser models and also addresses the propagation of short optical pulses in optical fibres. So, Photonics Modelling and Design is written for students and professionals interested in modelling photonic devices either for gaining a deeper understanding of the operation or to optimize the design. **Learning Outcomes:** At the end of the course, the student must be able to ● Understand the basic operating principle of photonic devices and systems. ● Design and Modelling of all types of optical waveguides, devices and systems.	
Topics to be covered	***No. of Lecture***
Module 1: Introduction: Light Propagation in Homogenous Media: Fourier Method, Optical Beam Reflection and Refraction	04
Module 2: Introduction to Optical Waveguide Theory: Examples of Planar Optical Waveguides, Slab Optical Waveguide, Effective Index Method, Propagation Constant Calculation Techniques for Planar Optical Waveguides, Comparison of Polarised, Scalar, and Effective Index Approximations, Optical Fibres, Wave guiding in Optical Fibres.	08
Module 3: Numerical technique: Beam Propagation Method, Introduction, BPM Algorithms, Split Operator BPM, Eigen mode Expansion BPM, Numerical Implementation of BPM, Boundary Condition, Selected Examples of BPM Application, Optical Taper, Oblique and Bent Waveguides, Y Junction, Time Domain Analysis, Time Domain BPM, Travelling Wave Approach; Finite-Difference Time-Domain method; Finite difference modelling of straight waveguide.	16
Module 4: Fibre Amplifier and lasers Modelling: Co-propagating and Counter propagating Pump Fibre Amplifier Models, Amplified Spontaneous Emission, Fibre Laser Modelling, Time Domain Models, Extraction of Modelling Parameters.	06
Module 5: Modelling of Nonlinear Propagation in Waveguides: Introduction, Formalism, Nonlinear Polarization, The Nonlinear Schrödinger Equation, Numerical Implementation.	05
Total number of classes	39
Text book: **1.** Slawomir Sujecki: Photonics Modelling and Design, CRC Press, 2015 **Reference books:** 1. Vittorio M.N. Passaro: Modelling of Photonics Device, Nova Science, 2009	

SEMESTER 4 | Subject: Design and Analysis of Algorithms | Open ELECTIVE | L-T-P : 3-0-0

Course Philosophy: Algorithms are essential to the study of computer science and are increasingly important in the natural sciences, social sciences and industry. Learn how to effectively construct and apply techniques for analyzing algorithms including sorting, searching, and selection. Gain an understanding of algorithm design technique and work on algorithms for fundamental graph problems including depth-first search, worst and average case analysis, connected components, and shortest paths.

Learning Outcomes:

- To develop the algorithm in every domain
- Understanding the issues of complexities
- To structure the algorithm for better efficiency

Topics to be covered	***No. of Lecture***
Module 1: Fundamentals – Growth of functions	07
Module 2: Sorting and searching - Advanced data structures	08
Module 3: Graph algorithms - Numerical algorithms	08
Module 4: Distributed algorithms - Computational geometry	08
Module 5: String matching - NP –completeness	07
Total number of classes	39

Text book:

1. Jean DollimoreTim KindbergGeorge Coulouris," **Distributed Systems : Concepts and Design", Pearson Education, 2009**

Reference books:

1. Andrew S. TanenbaumMaaten Van Steen, "Distributed Systems: Principles and Paradigms", Pearson Education, 2015