UNIVERSITYOF KERALA

DEPARTMENT OF OPTOELECTRONICS

MSc DEGREE PROGRAMME IN ELECTRONICS (Optoelectronics)

SYLLABUS

MSc. Degree program (from 2022-23 academic year)

1. **Aim of the program**

MSc. Electronics with specialization in Optoelectronics forms the formal training of Electronics and hence the program aims at providing an in-depth knowledge of Electronics and Optoelectronics to the student. After the successful completion of the program, a student should be capable of pursuing research in theoretical/ experimental or related areas.The program also aims at enhancing the employability of the student. Rigorous training requires phased teaching. With this intention credit and semester system is followed in this program.An M.Sc. student should be capable of doing research at least in the preliminary way.To accomplish this,research-oriented project is made part of this curriculum.

2. **Eligibility for admissions**

Bachelor's degree in Physics/Electronics/Photonics with an aggregate minimum of 50%marksin optional subjects or 2.0 CGPA (s) out of 4.0 or 5.0 CCPA(s) out of 10.0 subject to the usualconcessions allowed for backward classes and other communities as specified from time to time.

3. **Admission**

The admission to the MSc degree course shall be as per the rules and regulations of the University.Students admitted under this programme are governed by the Regulations in force.

4. **Medium of instruction and assessment**

English

5. **Faculty under which the degree is awarded**

Applied Science and Technology

6. **Specialization offered if any**

(1) Optoelectronics

7. **Note on compliance with the UGC minimum standards for the conduct and award of postgraduate degrees**.

MSc Electronics is a two-year program in which credit and semester system is followed. An M.Sc. student should be capable of doing research at least in the preliminary way. To accomplish this,research-oriented project is made part of this curriculum.There are 18 weeks in a semester and in each week there are16 lecture hours and 8 laboratory hours and 1 tutorial hour. In each semester there are 288 lecture hours, 144 practical hours and 18 tutorial hours. Thus, the total calendar hours in each semester are 450 which is in compliance with the minimum 390 hours stipulated by the UGC.

CHAPTER-I

1. GENERAL SCHEME OF THE SYLLABI

1.1 Theory Courses:

There are twelve theory courses in all four semesters in the M.Sc. Program. Distribution of theory courses is as follows. There are nine core courses common to all students. Semester I will have four core courses and Semester II will have three core courses and Semester III will have two core courses. In the fourth semester there will be one main project and one seminar. One elective course is in semester II and two elective courses are in semester III. There are two Elective Group offered in this syllabus. An Elective Group has three theory coursesand one laboratory course.

1.2 Practical:

All four semesters will have courses on laboratory practicals. A minimum of 10 experiments should be done and recorded in each semester. The practical examinations will be conducted at the respective examination centers by two examiners (one internaland one external appointed by the University) at the end of each semester.

1.3 Project:

The project of the PG program should be relevant to the Elective Group and innovative in nature. The type of project can be decided by the student and the guide (a faculty of the department or other department/college/university/institution). The project work should be taken up seriously by the student and the guide. The project should be aimed to motivate the inquisitive and research aptitude of the students. The students may be encouraged to present the results of the project in seminars/symposia. The project is evaluated by the external examiners. The project guide or a faculty member deputed by the head of the department may be present at the time of project evaluation. This is to facilitate the proper assessment of the project.

1.4 Viva - Voce:

A viva - voce examination will be conducted by the two examiners (one internaland one external appointed by the University)at the time of evaluation of the project. The components of viva consist of project related (60%), topics covering all semesters and awareness of current and advanced topics (40%).

1.5 Course Structure of M.Sc. Electronics Program:

The detailed structure of the Core courses common to all students of the program is given in Table 1.1

Table 1.1: Course Structure of M.Sc. Electronics

Sem. No.	CourseCode	Name of the Course	Credits	Total Credit per Semester
I		**Core Courses (CC)**		
	OPE-CC-511	Mathematical Methods in Electronics	4	**22**
	OPE-CC-512	Analog and Digital Circuits	4	
	OPE-CC-513	Solid State Electronics and Optoelectronics	4	
	OPE-CC-514	Electromagnetic Theory and Antennas	4	
	OPE-CC-515	Analog & Digital Circuits Lab	3	
	OPE-CC-516	General Lab	3	
II		**Core Courses (CC)**		
	OPE-CC-521	Communication Systems	4	**22**
	OPE-CC-522	Programming in Python	4	
	OPE-CC-523	Linear Control Systems	4	
	OPE-CC-524	Python Programming lab	3	
	OPE-CC-525	Communication, Signal Analysis and Circuit Design Lab	3	
		Discipline-Specific Electives (DE)		
		Elective I*	4	
III		**Core Courses (CC)**		
	OPE-CC-531	Digital Signal Processing	4	**22**
	OPE-CC-532	VLSI Design	4	
	OPE-CC-533	Digital Signal Processing Lab	3	
	OPE-CC-534	Elective Lab	3	
		Discipline-Specific Electives (DE)		
		Elective II*	4	
		Elective III*	4	
IV		**Core Courses (CC)**		
	OPE-CC-541	Project	12	**16**
	OPE-CC-542	Seminar	2	
	OPE-CC-543	Viva-Voce	2	
		Generic Courses (GC)		
Any Semester (I-IV)		Open Elective I	2	**4**
		Open Elective II	2	
		MOOC/NPTEL Course	2	
	Total Credits			**86**

*The students will have to select Elective subject from list of Discipline-Specific Electives provided as given below:

List of Electives

Course Code	Discipline-Specific Electives (DE)	Credits
OPE-DE-501(O)	Fiber Optics Technology	4
OPE-DE-502(O)	Modern Optics	4
OPE-DE-503(O)	Integrated Optics	4
OPE-DE-504(O)	Lasers	4
OPE-DE-505(O)	Optoelectronic Devices and Optical Communication	4
OPE-DE-506(O)	Fiber Optics Sensors and Applications	4
OPE-DE-507(O)	Optical Fiber Communication Systems	4
OPE-DE-508(O)	Nano sensors and Devices	4
OPE-DE-509(O)	Laser Spectroscopy	4
OPE-DE-5010(O)	Laser Material Processing	4
OPE-DE-5011(O)	Laser Remote Sensing	4
OPE-DE-5012(O)	Holography and Speckle Interferometry	4
OPE-DE-5013(O)	Optical Signal Processing	4
OPE-DE-5014(O)	Optical Networks	4
OPE-DE-5015(O)	Advanced Spectroscopy	4
OPE-DE-5016(O)	Optical Instrumentation	4
OPE-DE-5017(O)	Nanophotonics	4
OPE-DE-5018(O)	Nanobiophotonics	4
OPE-DE-5019(O)	Solar Photovoltaics	4
OPE-DE-5020(O)	Nonlinear Optics	4
OPE-DE-5021(O)	Energy Science	4

1.6 Distribution of Credit:

The total credit for the program is fixed at 86. The distribution of credit points in each semester and allocation of the number of credits for theory courses, practicals, project and viva is shown in Table 1.1.

CHAPTER - II

ASSESSMENT AND EVALUATION

2.1 Examinations

The evaluation of each course shall contain two parts such as Internal or Continuous Assessment (CA) and External or End-Semester Assessment (ESA).

2.2 Internal or Continuous Assessment (CA)

Internal evaluation is to be done by continuous assessments. The internal assessment should be fair and transparent. The evaluation of the components should be published and acknowledged by students. All documents of internal assessments are to be kept in the institution for 2 years and shall be made available for verification by the university. The responsibility of evaluating the internal assessment is vested on the teacher(s) who teach the course. The test papers should be in the same model as the end semester examination question paper. The duration and the number of questions in the paper may be adjusted judiciously for the sake of convenience. There shall be no separate minimum grade point for internal evaluation of Theory, Practical, Project, and Comprehensive viva-voce. No minimum is required for Internal evaluation for a pass, but a minimum is required for a pass in an external evaluation.

2.2.1Attendance, Assignment and Seminar

Attendance is not a component for the internal evaluation.But students with attendance less than 75% in a course are not eligible to attend external examination of that course. The performance of students in the seminar and assignment should also be documented.

2. 2.2 Project Evaluation

The internal evaluation of the project is done by the supervising guide of the department or the member of the faculty decided by the head of the department. The project work may be started at the beginning of the Semester IV.The supervising guide should keenly and sincerely observe the performance of the student during the course of project work. The supervising guide is expected to inculcate in student(s), the research aptitude and aspiration to learn and aim high in the realm of research and development. A maximum of three students may be allowed to perform one project work if the volume of the work demands it.Project evaluation begins with (i) the selection of problem, (ii) literature survey, (iii) work plan, (iv)experimental/theoretical setup/data collection, (v) characterization techniques/computation/analysis (vi) use of modern software for data analysis/experiments (Origin, LABView, MATLAB, etc) and (vi) preparation of dissertation.The project internal grades are to be submitted at the end of Semester IV.

2.2.3 General Instructions

i. The assignments/ seminars / test papers are to be conducted at regular intervals. These should be marked and promptly returned to the students.

ii. One teacher appointed by the Head of the Department will act as a coordinator for consolidating grade sheet for internal evaluation in the department in the format supplied by the University. The consolidated grade sheets are to be published in the department notice board, one week before the closing of the classes for end semester examinations. The grade sheet should be signed by the coordinator and counter signed by the Head of the Department.

iii. The consolidated grades in specific format supplied by the university areto be kept in the college for future references. The consolidated grades ineach course should be uploaded to the University Portal at the end of eachsemester as directed by the University.

iv. A candidate who fails to register for the examination in a particular semester is not eligible to continue in the subsequent semester.

2.3 External or End Semester Assessment (ESA)

The external examination of all semesters shall be conducted by the University on the close of each semester. There will be no supplementary examinations.

2.3.1 Question Paper Pattern for Theory Courses

All the theory question papers are of three-hour duration. All question papers will have two/three parts.

2.3.2 Practical, Project and Viva-Voce Examinations

Practical Evaluation: The practical examinations are conducted immediately after the semester theory examinations. All practical examinations will be of five hours duration. One examiner from the panel of examiners of the University will be deputed by the board chairman to each of the examination centers for the fair and transparent conduct of examinations. Practical examination is conducted in batches having a maximum of eight students. The board has the right to decide on the components of practical and the respective weights.

Project Evaluation: The project is evaluated by the two external examiners deputed from the board of practical examination. The dissertation of the project is examined along with the oral presentation of the project by the candidate. The examiners should ascertain that the project and report are genuine. Innovative projects or the results/findings of the project presented in national seminars may be given maximum advantage. The supervising guide or the faculty appointed by the Head of the Department may be allowed to be present at the time of project evaluation. This is only to facilitate proper evaluation of the project.

Viva-Voce Examination: Viva-voce examination is conducted by the two examiners (one internaland one external appointed by the University)of the board of practical examinations. The viva-voce examination is given a credit two.

2.3.3Generic (Open Elective) Courses:

The students should successfully complete two generic (open elective) courses offered by other departments during the programme. NPTEL/MOOC courses of more than three months duration also will be considered equivalent to the generic courses. The generic course credit will be added in Semester IV.

2.3.4 Reappearance/Improvement:

For reappearance/ improvement as per university rules, students can appear along with the next regular batch of students of their particular semester. A maximum of two chances will be given for each failed paper. Only those papers in which candidate have failed need be repeated.

CHAPTER III

M.Sc. ELECTRONICS SYLLABUS

3.1 INTRODUCTION

This chapter deals with the syllabi of all Core courses, Elective courses of the MSc. Electronics program. The semester wise distribution of the courses is given. The Programme Outcomes and Programme Specific Outcomes and Course Outcomes are described.

Programme Outcomes (POs)

PO1	Enhance knowledge by understanding, experimenting and co-relating information (existing and new) in the field of electronics.
PO2	Demonstrate ability to model, simulate and estimate the phenomenon and systems in the chosen areas of electronics.
PO3	Improve skills in solving scientific problems and designing devices.
PO4	Effectively communicate technical content through written reports/design documents, and presentations.
PO5	Students will become able to demonstrate a degree of mastery over the area as per the specialization of the program.

Programme Specific Outcomes (PSOs)

PSO1	Understand the principles and theoretical concepts in the fabrication of electronic devices and optoelectronic materials.
PSO2	Develop skills in designing electronic devices and optoelectronic systems which are in tune with current technology and adaptable for future changes.
PSO3	Create an environment such that students develop a passion for hardware and software design using electronic, optoelectronic components.
PSO4	Act as the part of the electronic design industry to become leaders in indigenous product development.
PSO5	Get mathematical background for theoretical analysis of modelling.

Course Outcomes

Semester: I	Course Code: OPE-CC-511
Course Title: MATHEMATICAL METHODS IN ELECTRONICS	**Credits: 4**

Prerequisite : Knowledge in complex analysis and probability.

Objective : To provide knowledge in Differential Equation, Fourier Series, Integral transforms, Complex variables and Probability distributions.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Analyze theoretically the differential equations and Special functions
CO2	Apply differential equations and Special functions
CO3	Remember the principles of Fourier series, infinite series, and transformations.
CO4	Understand Fourier transform, integral transform.
CO5	Understand the functions of a complex variable
CO6	Apply probability distribution functions

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Analyze theoretically the differential equations and Special functions	PSO5	An	M
CO2	Apply differential equations and Special functions	PSO5	Ap	P
CO3	Remember the principles of Fourier series, infinite series, and transformations.	PO3/PSO5	R	F and C
CO4	Understand Fourier transform, integral transform.	PO3/PSO5	U	C
CO5	Understand the functions of a complex variable	PO2/PSO5	U	C

CO6	Apply probability distribution functions	PO2/PSO5	Ap	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

ModuleI

PartialDifferentialEquations: Linear second order partial differential equations– solutions of partial differential equations-separation ofvariables- solutionof waveequations.

Legendre, Hermite and Laguerre's differential equations – Series solutions– Rodrigues formulae - Generatingfunctions –Orthogonality and associatepolynomials.

Bessel functions: Seriessolution- - secondkind–GeneratingfunctionforJn(x)–Bessel'sintegral representation – Recurrence formula for Jn(x) – Orthogonality of Jn(x)– SphericalBessel function

Green's function: Green' function in one dimension – motion of a particle in a resistive medium- motion of a damped harmonic oscillator – Green's function in three dimensions – solution of Poisson's equation.

Module II

Fourier analysis: Representation of periodic signals: Continuous Time Fourier Series, convergence of Fourier series, Gibbs phenomenon, Representation of aperiodic signals: Continuous Time Fourier Transform, The Fourier Transform for periodic signals, Properties of Fourier representations, Frequency Response of systems characterized by linear constant coefficient differential equations.

Laplacetransform: Laplace Transform and its existence, Laplace Transform of standard functions, properties of Laplace Transform, Laplace Transform of periodic functions, Laplace Transform of some special functions, inverse Laplace Transform, circuit analysis using Laplace Transform (R, RC, LC, RLC circuits).Inverse Laplace Transform

Z-transform: Definition, Z-transform of elementary signals, Region of convergence, Properties of ROC and Z transform, Inverse Z-transform, Analysis and characterization of LSI systems, causality and stability, Transfer function and difference equations.

Module III

Complex variables: Functions of a complex variable-derivatives-Cauchy-Reimann equations- Cauchy's integral formula- derivatives of analytic functions- Taylor series- Laurent series- singular points of an analytical function- poles –removable singularity- essential singularity- point at infinity- residues- calculation of residues- the residue theorem – evaluation of residues- evaluation of definite integrals.

Probability: Laws of probability – discrete probability distributions – theory of combinations and permutations – Stirling approximation for the factorial – continuous distributions – moments and standard deviations– Binomial distribution – Poisson distribution – normal distribution – distribution of a sum of normal variates.

References:

1. Alan V. Oppenheim Alan S. Willsky and S. Hamid Nawab, "Signals and Systems", 2nd Edition, Pearson Education India, 2015.
2. Simon Haykin and Barry V. Veen, "Signals & Systems", John Wiley, 2nd Edition, 2007.
3. B. P. Lathi, "Linear Systems and Signals", Oxford University Press, 2004.
4. Taylor F. H., "Principles of Signals & Systems", McGraw Hill, 1994.
5. Mathematical Methods for Physicists 4^{th}Edn by Arfken& Weber, Academic Press.
6. Applied Mathematics for Engineers and Physicists- L.A. Pipes and L. R. Harvill, McGraw-Hill.

Semester: I	Course Code: OPE-CC-512
Course Title: ANALOG AND DIGITAL CIRCUITS	**Credits: 4**

Prerequisite : Knowledge in basic electronics.

Objective : To understand the operations of various electronic circuits, and develop the circuits for the hardware design.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the concept of feedback and oscillators
CO2	Understand the fundamental principles of linear electronic systems
CO3	Analyze electronic circuits using active devices
CO4	Design the electronic circuits using linear devices
CO5	Understand and analyse different modelling circuits

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the concept of feedback and oscillators	PO1/PSO1	U,	C
CO2	Understand the fundamental principles of linear electronic systems	PO1/PSO1	U	F and C
CO3	Analyze electronic circuits using active devices	PSO2	An, Ap and Cr	P and M
CO4	Design the electronic circuits using linear devices	PO3/PSO5	Cr, Ap	M
CO5	Understand and analyse different modelling circuits	PO5/PSO5	U, An and Ap	C

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15

Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Operational amplifiers: Characteristics, op-amp architecture, Offset and Bias Voltages and Current, Slew Rate, Finite Frequency Response, Gain-bandwidth product, Linear op- amp circuits, Non-Linear Op-amp Circuits: Open Loop Comparator, Polarity Indicator, Schmitt Trigger; astable and monostable circuits, Active filters: LPF & HPF using Sallen-Key configuration, Simulation of circuits using LTSPICE.

Linear circuits: UJT relaxation oscillator, time base generators -bootstrap, miller; blocking oscillators, transient switching and characteristics., voltage regulators, VCO and emitter coupled VCO, Basic PLL topology and principle, transient response of PLL, Linear model of PLL, Major building blocks of PLL – analog and digital phase detector, VCO, filter, Applications of PLL Monolithic PLL - IC LM565 and CD4046 CMOS PLL.

Module II

Combinational Circuits: Multiplexers, decoders, encoders, buffers, code converters, adder, subtractor, Programmable Devices - Read Only Memory, Programmable Logic Array, Programmable Array Logic, Complex Programmable Logic Devices.

Sequential Circuits: Latches, Flip-Flops, Analysis of clocked sequential circuits, Mealy and Moore Models, state reduction and assignment, design procedures, excitation tables, state-transition table, state diagram, Finite State Machine design, Registers and Counters, Counter Design using flip flops.

Module III

Hardware Description Languages, Verilog, Rules and Syntax, Modules, Ports, Variables, Datatypes, Operators, Assignments, Procedural Assignments, Always block, Delays, Dataflow modeling, Behavioral modeling, Structural modeling, Tasks and functions. Modeling combinational and sequential circuits using verilog – arithmetic and logic circuits, registers, counters, sequential machines, tristate buffers, Mealy and Moore finite state machines, Simulation and verification - Verilog test bench, Memory, File read and write.

References:

1. Sergio Franco, “Design with Operational Amplifiers and Analog Integrated Circuits”, McGraw Hill Book Company 1998.
2. Millman J. and C. Halkias, “Integrated Electronics”, 2/e, TMH, 2010.
3. Gaykward, “Operational Amplifiers”, Pearson Education, 1999.
4. Coughlin R. F. and Driscoll F. F., “Operational Amplifiers and Linear Integrated Circuits”, Pearson Education 2002.
5. P. S. Bimbhra, “Power Electronics”, Khanna publishers, 2012.
6. Sen P. C., “Power Electronics”, Tata Mc Graw Hill,2003.
7. Rashid, “Power Electronics”,Prentice Hall India,1993.
8. G. K. Dubey et.al, “Thyristorised Power Controllers”, Wiley & Sons, 2001.
9. Dewan and Straughen, “Power Semiconductor Circuits”, Wiley & Sons, 1984.
10. Singh M. D. &Khanchandani K. B., Power Electronics, Tata Mc Graw Hill, 1998.
11. Charles H. Roth Jr. “Fundamentals of Logic Design”, 5th edition, Cengage Learning 2009.

12. Charles H. Roth Jr. Lizy Kurian John, BeyeongKil Lee, “Digital Systems Design Using Verilog”, CL Engineering, 1st edition, 2015.
13. Samir Palnitkar, “Verilog HDL”, Pearson Education, 2nd edition, 2004.
14. Morris Mano, “Digital Logic Design”, Fourth Edition, Pearson Publication,2008.
15. NripendraN.Biswas“LogicDesignTheory”PrenticeHallofIndia,2001.
16. ParagK.Lala“DigitalsystemDesignusingPLD”BSPublications,2003.
17. John F. Wakerly, “Digital Design - Principles and Practices”, Pearson, 4th edition, 2008.
18. Victor P. Nelson, H. Troy Nagle, J. David Irvin, Bill D. Carol, “Digital logic Analysisanddesign”,1stedition,Prentice HallPublications.

Semester: I	Course Code: OPE-CC-513
Course Title: SOLID STATE ELECTRONICS AND OPTOELECTRONICS	**Credits: 4**

Prerequisite : Basic knowledge aboutelectronics.

Objective : To enhance the knowledge in optoelectronic materials and semiconductor electronics.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the concept of quantum theory and wave equations.
CO2	Understand the fundamental concepts and properties of energy band.
CO3	Understand the distribution of carrier concentration and charge density
CO4	Analyse the carrier transportation mechanism in semiconductors
CO5	Understand the electronic properties of optoelectronic devices.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the concept of quantum theory and wave equations.	PO1	U,	C
CO2	Understand the fundamental concepts and properties of energy band.	PO1/PSO1	U and E	F, P and C
CO3	Understand the distribution of carrier concentration and charge density	PO2/PSO2	U, An and Ap	P and M
CO4	Analyse the carrier transportation mechanism in semiconductors	PO3	An, Cr and Ap	P and M
CO5	Understand the electronic properties of optoelectronic devices.	PO5/PSO4	U, An and Ap	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I:
Quantum Mechanics-Wave nature of particles-uncertaintyPrinciple-Wave motion-SuperpositionPrinciple-De-Broglie Hypothesis-Time dependent and independent Schrodinger wave Equation-Planck'sconcept of energy & Quantization particle in one dimensional infinite potential well-Finite and infinitesquare well-Particle in Box-Square potential –Barrier and quantum mechanical Tunneling.

Module II
Energy Bands in Solids: Energy Band Diagram, Direct and Indirect band gap semiconductors, Effective mass. Semiconductors- Intrinsic and Extrinsic. Carrier Concentration-Fermi-Dirac distribution function, Electron and Hole concentration at equilibrium, Temperature dependence of intrinsic carrier concentration & majority carrier concentration in extrinsic semiconductor, Equilibrium electron hole concentration. Carrier transport in semiconductors - mobility and conductivity. Variation of mobility with temperature & doping. Constancy of Fermi level at equilibrium. Hall Effect. Quasi Fermi level, Diffusion of charge carriers. Einstein relation. Continuity equation. PN junction under thermal equilibrium, Equilibrium energy band diagram - Distribution of carrier concentration, potential, electric field and charge density.

Module III
Optoelectronic materials, Semiconductors, compound semiconductors, III-V and II-VI compounds, ZnO, ITO, GaN, direct and indirect band gap, electronic properties of semiconductors, Fermi level, density of states, life time and mobility of carriers, invariance of Fermi level at equilibrium, diffusion, continuity equation, excess carriers, Quasi-Fermi levels.
LED, Blue LED, Laser diodes. Quantum well lasers, VCSEL, DFB and DBR lasers. Photodetectors, photoconductors and photodiodes, PIN diodes, heterojunction diodes and APDs, photomultiplier tube, Solar cell materials and their properties.

References:

1. AmnonYariv, Optical Electronics, Holt Rine hart & Winston, Philadelphia, 1991
2. Ben G. Streetmann& Sanjay Banerjee, Solid State Electronic Devices, 5thEdn, 2000.
3. Bhattacharya P., Semiconductor Optoelectronic Devices, PHI, New Delhi.1995
4. Martin A. Green, Solar Cells: Operating principles, Technology and System Applications, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.
5. Poortmans J and Arkhipov V Thin Film Solar Cell: Fabrication, Characterizations and

Applications, John Wiley & Sons, England 2006.
6. W.R Fahrner: Nanotechnology&Nanoelectronics, (Springer 2005)
7. M S Tyagi: Introduction to semiconductor materials and devices (Wiley India)
8. D A Neeman: Semiconductor Physics& Devices (Tata Mc-Graw-Hill).

Semester: I	Course Code: OPE-CC-514
Course Title: ELECTROMAGNETIC THEORY AND ANTENNAS	Credits: 4

Prerequisite : Basic knowledge aboutelectricity and magnetism.

Objective : To enhance the knowledge in propagation of EM waves and design of antennas.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the various theorems related to Electrostatics, Magnetostatics and Electromagnetism
CO2	Learn all basic terminologies and applications of Electric field and Magnetic field.
CO3	Study the behaviour of charges with respect to different mediums and Time varying fields.
CO4	Grasp the concepts of Transmission Lines, Waveguides and their applications.
CO5	Know the Types of Antennas and Identify the advance applications of Antennas.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the various theorems related to Electrostatics, Magnetostatics and Electromagnetism	PO1	U,	C
CO2	Learn all basic terminologies and applications of Electric field and Magnetic field.	PO2	U and E	F, P and C
CO3	Study the behaviour of charges with respect to different mediums and Time varying fields.	PO2/PSO1	U, An and Ap	P and M
CO4	Grasp the concepts of Transmission Lines, Waveguides and their applications.	PO3/PSO5	An, Cr and Ap	P and M
CO5	Know the Types of Antennas and Identify the advance applications of Antennas.	PO5/PSO5	Ap, An and Cr	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I:
Electrostatic fields in matter and Electrodynamics
Review of Electrostatics and Magnetostatics, Time varying fields and Maxwell's equations, Potential formulations-Scalar and Vector Potential, Gauge transformations, boundary conditions, wave equations and their solutions, Poynting theorem, Maxwell's stress tensor.

Electromagnetic waves
Maxwell's equations in phasor notation. Plane waves in conducting and non-conducting medium, Polarization, Reflection and transmission (Normal and Oblique incidence), Dispersion in Dielectrics, Superposition of waves, Group velocity.

Module II
Propagation of Electromagnetic Waves in conducting medium and non- conducting medium

Electromagnetic Radiation
Retarded potentials, Point charges, Lienard-Wiechert potential, Fields of a moving point charge, Electric dipole radiation, Magnetic dipole radiation, Power radiated by point charge in motion. Radiation reaction, Physical basis of radiation reaction, Radiation resistance of a short dipole, Radiation from quarter wave monopole or half wave dipole.

Module III
Wave Guides and Antenna
Antenna parameters. Waves between parallel conducting plane TE, TM and TEM waves, TE and TM waves in Rectangular wave guides, Impossibility of TEM waves in rectangular wave guides. Dipole arrays, Folded Dipole and Yagi-Uda Antenna (VHF).
Microwave Antennas: Antenna with parabolic reflectors, Horn antenna, Microwave detectors - PIN and Schottky diodes.

Transmission Lines-Principles-Characteristic impedance, Classification of Transmission lines: Coaxial Cable, Twin wire line, Strip and Microstrip line, standing waves-quarter and half wavelength lines.
.

References:

1. Electromagnetic Fields T.V.S.Arun Murthy (S.Chand Publications)
2. Electronics Communications Systems George Kennedy (McGraw Hill International Edition.,N.Y., USA)
3. Electromagnetism (Theory and Applications) Ashutosh Pramanik (Prentice Hall of India Pvt. Ltd., New Delhi, INDIA)
4. Elements of Electromagnetics Matthew N.O.Sadiku (Oxford Publication)
5. Microwave Engineering and Applications O.P.Gandhi (Maxwell Macmillan International Edition.)
6. Classical electrodynamics J.D.Jackson (Willey Eastern Ltd., New Delhi, INDIA)
7. Classical Electrodynamics S.P.Puri (Tata McGraw Hill Publishing Co. Ltd., New Delhi, INDIA)
8. Introduction to Electrodynamics David J. Griffith (Prentice Hall of India Pvt. Ltd., New Delhi, INDIA)
9. Modern Microwave technology Victor F. Velley (Prentice Hall Inc. N.Y., USA)
10. Electromagnetic Field Theory Fundamentals Bhag Guru (Cambridge Publications)
11. Electromagnetic Field theory and Transmission Lines G.S.N.Raju (Pearson Education, South Asia)
12. Antenna Handbook Joseph J.Carr (Galgotia Publication pvt.ltd.
13. Electromagnetic Concepts and Applications Stanley V. Marshall, Gabriel G.Skitek (Prentice-Hall International Editions)Martin A. Green, Solar Cells: Operating principles, Technology and System Applications, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.

Semester: I	Course Code: OPE-CC-515
Course Title: ANALOG AND DIGITAL CIRCUITS LAB	**Credits: 3**

Prerequisite : Basic knowledge in electronic circuits.

Objective : To empower the students with hands-on experience and to providepracticalknowledge about analog and digital circuits and its design and characteristics.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Design and construct different electrical circuits using Op-amp.
CO2	Analyse the various parameters of circuits using Op-amp.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Design and construct different electrical circuits using Op-amp.	PSO1	E, Cr	P,M
CO2	Analyse the various parameters of circuits using Op-amp.	PO3/PSO5	Cr, E, An	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

<u>COURSE CONTENT</u> (List of Experiments)

1. Differential amplifier- inverting, non-inverting- operational amplifier parameters (IC 741)
2. Op-amp - Adder, Integrator, Differentiator, Clipper and Clamper circuits
3. Voltage regulator using op-amp
4. Series pass voltage regulator with short circuit protection
5. RC coupled CE amplifier
6. Wien bridge oscillator using op-amp
7. First order low pass and high pass filter
8. Second order low pass and high pass filter
9. Waveform generators using op-amp
10. Schmitt trigger using op-amp
11. Instrumentation amplifier
12. AC DC milli-voltmeter construction and calibration.
13. Study of the I-V Characteristics of UJT and relaxation oscillator
14. Design of astable multivibrator
15. Design of monostable multivibrator
16. Study of single slope ADC
17. Study the operation of frequency synthesizer using PLL
18. Study of 8-bit DAC.
19. Design D/A and A/D Converters IC.
20. Design and Verify the Truth Table for Half Adder and Full Adder Logic Circuits.
21. Study of Multiplexer and De-multiplexer.
22. Flipflops using gates
23. Shift Registers

(At least 10 experiments should be provided)

Semester: I	Course Code: OPE-CC-516
Course Title: GENERAL LAB	**Credits: 3**

Prerequisite : Basic knowledge in Semiconductors, Antennas and Lasers.

Objective : To empower the students with hands-on experience and to providepracticalknowledge about semiconductor devices, sensors, antennas and lasers.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the characteristics of solar cell and laser beam properties.
CO2	Analyzethe arc spectra.
CO3	Evaluateband gap, fermi energy, resistivity of semiconductors.
CO4	Verify hysteresis

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the characteristics of solar cell and laser beam properties.	PSO1	U	P
CO2	Analyzethe arc spectra.	PO4/PSO2	An, Ap	P
CO3	Evaluateband gap, fermi energy, resistivity of semiconductors.	PO2/PSO1	E	P
CO4	Verify hysteresis	PO3/PSO5	Cr, E	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	

Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT (List of Experiments)

1. Characteristics of solar cell
2. Energy bandgap of Silicon
3. Fermi energy of Copper and fermi temperature
4. Determination of Planck's constant using LED
5. Hall effect – carrier concentration, mobility and hall coefficient
6. Antennas – parameters
7. Resistivity- Four Probe and determination of bandgap
8. Constant Deviation Spectrometer:Arc spectra- Iron, Copper, Brass
9. Constant Deviation Spectrometer:Arc spectra- Identification of elements
10. Ultrasonics- Acoustic grating – Compressibility of liquids
11. e/m – Thomson's method
12. Measurement of beam characteristics of lasers
13. Goniometer – Angle of contact
14. Pull – Frich refractometer
15. Hysteresis- BH Curve using CRO
16. Particle Size Analyzer (Using Diode Laser)
17. Calibration of Scale Using He-Ne Laser
18. Michelson's Interferometer - wavelength of the laser source

(At least 10 experiments should be provided)

Semester: II	Course Code: OPE-CC-521
Course Title: COMMUNICATION SYSTEMS	**Credits: 4**

Prerequisite : Basic knowledge in signals and systems.

Objective : To familiarize students on basic concepts of a communication system, the signals and its transmission.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the elements of an electrical communication system.
CO2	Develop modulators and demodulators.
CO3	Understand the multiplexing technique.
CO4	Analyse signals and its transmission
CO5	Understand the effect of noise on the different modulation schemes and describe an optimum receiver.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the elements of an electrical communication system.	PO1	U	C
CO2	Develop modulators and demodulators.	PO2/PSO4	Ap, An and Cr	C, P and M
CO3	Understand the multiplexing technique.	PSO1	U, Ap and An	P and M
CO4	Analyse signals and its transmission	PO2/PSO4	U, Ap, An and E	P and M
CO5	Understand the effect of noise on the different modulation schemes and describe an optimum receiver.	PO3/PSO4	U, Ap, An and E	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Elements of an electrical communication system, Primary communication resources, communication channels and their characteristics, mathematical models for communication channels.

Analog signal transmission and reception: Amplitude Modulation-Double sideband suppressed carrier AM, Conventional AM, Single sideband AM, Vestigial sideband AM, Implementation of AM modulators and demodulators. Angle Modulation-Representation of FM and PM signals, Spectral characteristics of angle modulated signals, Implementation of angle modulators and demodulators. Radio & Television broadcasting. Mobile communication: basic principles of cellular communications, principle and block diagram of GSM. Effects of noise on linear and angle modulation systems.

Module II

Pulse Modulation-Sampling theorem, Nyquist rate, Aliasing, Pulse amplitude modulation and other forms of analog pulse modulation, Quantisation process, Pulse code modulation, Transmission bandwidth in a PCM system, Noise considerations in PCM systems, Delta modulation, Differential PCM, Adaptive DPCM.

Multiplexing: Time division multiplexing, Frequency division multiplexing, PAM/TDM system. Digital multiplexing, bit rate, bit error rate, transmission band width and bandwidth efficiency, PCM-TDM system. Various Line coding formats.

Module III

Digital Transmission: Matched filter and inter symbol interference, Optimum filter, Bit timing recovery, Eye diagram. Concept of Additive White Gaussian Noise channel, Optimum receiver, geometric representation of signals.

Digital modulation formats: Coherent binary modulation techniques-Generation, Signal space diagram and demodulation of Binary amplitude shift keying, Generation, Signal space diagram and demodulation of Binary phase shift keying, Generation, Signal space diagram and demodulation of Binary frequency shift keying. Noncoherent binary modulation techniques. Quadrature phase shift keying. Minimum phase shift keying. Error control coding: Parity coding, Linear block codes, Hamming codes.

References:

1. John G. Proakis, Masoud Salehi, "Communications Systems Engineering", 2nd edition, Pearson Education.

2. Simon Haykin, "Communication Systems", 4th edition, John Wiley & Sons, Inc.
3. Dennis Roddy, John Coolen, "Electronic Communictions", 4th edition, Prentice Hall of India Pvt. Ltd.
4. Sanjay Sharma, "Communication Systems", 4th edition, S. K. Kataria& Sons, New Delhi.

Semester: II	Course Code: OPE-CC-522
Course Title: PROGRAMMING IN PYTHON	**Credits: 4**

Prerequisite : Basic knowledge in programming.

Objective : To enhance the knowledge in Python.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand programming syntax of Python.
CO2	Demonstrate handling different type of data in Python
CO3	Write Python programs
CO4	Apply various regressions in Python
CO5	Evaluate different regression methods and its implementation in Python

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand programming syntax of Python.	PO1/PSO1	U	C
CO2	Demonstrate handling different type of data in Python	PO2	Ap, An and E	C, P and M
CO3	Write Python programs	PO3/PSO2	Cr and E	P and M
CO4	Apply various regressions in Python	PO5	Ap, An and E	P and M
CO5	Evaluate different regression methods and its implementation in Python	PO5/PSO5	Ap, An and E	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Identifiers, Keywords, Variables, Input, Output and Import Functions, Operators, Numbers, String, Built-in Functions and Methods - List, Tuple, Set and Dictionary. Running Python Programs-Writing Python Code.

Loops, Nested Loops, Control Statements, Types of Loops, Comprehensions – List, Set and Dictionary, Nested Dictionaries. Function Definition - Function Calling, Function Arguments, Anonymous (Lambda) Functions, *filter()* function, *reduce()* function, Recursive Functions, Function with more than one return value. Built-in Modules, Creating Modules, *import* Statement, Locating Modules, Namespaces and Scope, The *dir()* function, The *reload()* function.

Module II

Opening a file, closing a file, writing to a File, *with* statement, reading from a file, file methods, renaming a file, deleting a file, directories in Python. Object Oriented Programming advantages. Class definition, Creating objects, Built-in attribute methods, Built-in class attributes, Destructors, Encapsulation, Data hiding, Inheritance, Method overriding, Polymorphism. Built-in Exceptions, Handling Exceptions, Exception with arguments, Raising an Exception, User- defined Exception, Assertions in Python.

Expressions:Introduction, *match()* function, *search()* function, search and replace, regular expression modifiers, regular expression patterns, Character classes, special character classes, repetition cases, *findall()* method, *compile()* method.

Module III

Introduction to numpy – Creating arrays, indexing, data types. Plotting with matplotlib – bar plot, histogram, pie chart, scatterplot.

Pandas Series, Data Frames, Multi-index and index hierarchy, Working with Missing Data, Group by Function, Merging, Joining and Concatenating Data Frames, Pandas Operations, Reading and Writing Files

Regression Analysis using Python: Linear regression, Logistic regression, Ridge regression, Lasso regression, Polynomial regression, Stepwise regression

References:

1. McKinney, Wes. Python for Data Analysis. " O'Reilly Media, Inc.", 2013.
2. Sweigart, Al. Automate the boring stuff with Python: practical programming for total beginners. No Starch Press, 2015.
3. Albon, Chris. Machine learning with python cookbook: Practical solutions from preprocessing to deep learning. " O'Reilly Media, Inc.", 2018.
4. Beazley, David, and Brian K. Jones. Python Cookbook: Recipes for Mastering Python 3. "

O'Reilly Me- dia, Inc.", 2013.
5. Hands-On Machine Learning with Scikit-Learn and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems
6. Jeeva Jose, Taming Python by Programming, Khanna Publishers, New Delhi,2016.

Semester: II	Course Code: OPE-CC-523
Course Title: LINEAR CONTROL SYSTEMS	**Credits: 4**

Prerequisite : Basic knowledge in signals and systems.

Objective : To develop skill in analysis and modeling of control systems.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand models and components of control systems.
CO2	Analyse various techniques for analysis of control systems.
CO3	Analyse the stability of discrete time systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand models and components of control systems.	PSO1	U	C
CO2	Analyse various techniques for analysis of control systems.	PO3	Ap, An and E	C, P and M
CO3	Analyse the stability of discrete time systems.	PSO5	Cr, E and An	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Introduction to open and closed loop systems-Mathematical models of control systems. Linear time invariant systems-Electrical analogies of mechanical systems-Transfer function- block diagram algebra-signal flow graphs- Mason's gain formula - characteristic equation.

Components of control systems: Servo motors (DC & AC) – synchro - gyroscope - stepper motor - Tacho generator.

Time domain analysis: Specifications, first and second order systems and their step responses.

Module II

Performance analysis: Steady state error analysis - static error coefficient of type 0,1, 2 systems - Dynamic error coefficients.

Stability: Time response for various pole locations - stability of feedback system - Routh's stability criterion

Root locus Techniques: Construction of Root loci – stability from root loci - effect of addition of poles and zeros.

Module III

Frequency domain analysis: Specifications- Correlation between time and frequency responses- Bode plot - Log magnitude vs. phase plot.

Polar plot: Nyquist stability criterion-Nichols chart - Non-minimum phase system - transportation lag.

References:

1. Ogata K., Modern Control Engineering, Prentice Hall of India, New Delhi, 2010.
2. Dorf R. C. and R. H. Bishop, Modern Control Systems, Pearson Education, 2011.
3. Kuo B. C., Automatic Control Systems, Prentice Hall of India, New Delhi, 2002.
4. Nagarath I. J. and Gopal M., Control System Engineering, Wiley Eastern, 2008

Semester: II	Course Code: OPE-CC-524
Course Title: PYTHON PROGRAMMING LAB	**Credits: 3**

Prerequisite : Basic knowledge in Python.

Objective : To empower the students with hands-on experience and to implement the basic concepts of python programming like math function, Strings, List.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Learn basics of PYTHON.
CO2	To implement the programs using conditional and loop statements.
CO3	To implement file handling techniques.
CO4	To implement concepts of OOPS

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Learn basics of PYTHON.	PSO1	U	P
CO2	To implement the programs using conditional and loop statements.	PO4/PSO2	An, Ap	P
CO3	To implement file handling techniques.	PSO1	E	P
CO4	To implement concepts of OOPS	PO3/PSO2	Cr, E	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15

Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT (List of Experiments)

Write a program to

1. Demonstrate different number data types in Python.
2. Perform different Arithmetic Operations on numbers in Python.
3. Create, concatenate and print a string and accessing sub-string from a given string.
4. Print the current date in the following format "Mon June 20 02:26:23 IST 2022"
5. Create, append, and remove lists in python.
6. Demonstrate working with tuples in python.
7. Demonstrate working with dictionaries in python.
8. Find largest of three numbers.
9. Convert temperatures to and from Celsius, Fahrenheit. [Formula: c/5 = f-32/9]
10. Construct the stars(*) pattern, using a nested for loop
11. Print prime numbers less than 20.
12. Find factorial of a number using Recursion.
13. Accept the lengths of three sides of a triangle as inputs.
14. Define a module to find Fibonacci Numbers and import the module to another program.
15. Calculate the multiplication of two matrices
16. Search the given number in the list of numbers by using binary search
17. Convert the given decimal number into binary number by using recursion.
18. Sort the list of records in a file.

(At least 10 experiments should be provided)

Semester: II	Course Code: OPE-CC-525
Course Title: COMMUNICATION, SIGNAL ANALYSIS AND CIRCUIT DESIGN LAB	Credits: 3

Prerequisite : Basic knowledge in signals and systems.

Objective : To empower the students with hands-on experience and to providepracticalknowledge about signal generation and its analysis.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Generation of AM, FM signals
CO2	Analysethe modulation and demodulation schemes.
CO3	Analyse the signals from various spectral sources.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Generation of AM, FM signals	PO4/PSO2	An, Ap	P
CO2	Analysethe modulation and demodulation schemes.	PSO1	E	P
CO3	Analyse the signals from various spectral sources.	PO3/PSO5	Cr, E	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35

Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT (List of Experiments)

1. AM generation using discrete components
2. AM generation using envelope detector
3. AM detection using envelope detector
4. IF tuned amplifier
5. FM using 555 IC
6. Study of 565 PLL – measurement of lock range and capture range
7. FM generation and demodulation using 565
8. Frequency multiplier using 565
9. PAM modulator and demodulator
10. PWM generation and demodulation using 555 IC
11. PPM generation and demodulation using 555 IC
12. Pseudo Random Binary Sequence generator
13. Delta modulation and demodulation
14. ASK modulation and demodulation
15. FSK modulation and demodulation
16. Digital pulse detector
17. TDM generation
18. BPSK modulation and demodulation
19. Determination of band gap from UV
20. Determination of a compound and its crystalline size from XRD
21. Determination of morphological and structural parameters of a compound from XRD
22. FFT and wavelet analysis of biomedical signals
23. Determination of CIE coordinates and colour parity from PL
24. Curve fitting

(At least 10 experiments should be provided)

Semester: III	Course Code: OPE-CC-531
Course Title: DIGITAL SIGNAL PROCESSING	**Credits: 4**

Prerequisite : Basic knowledge in signals and systems.

Objective : To enhance the knowledge in analysis and design of various digital Filters associated with DSPs and DSP processor architecture.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Apply linear and circular convolution.
CO2	Evaluate DFT of discrete signals.
CO3	Design a digital filter.
CO4	Understand the architecture of a DSP processor

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Apply linear and circular convolution.	PSO1	U and Ap	C and P
CO2	Evaluate DFT of discrete signals.	PO3	Ap, An and E	C, P and M
CO3	Design a digital filter.	PO5/PSO4	Cr and E	P and M
CO4	Understand the architecture of a DSP processor	PO5/PSO5	U, Ap, An and E	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35

Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Discrete Fourier Series, Discrete Time Fourier Transform, Convolution; Linear and circular convolution, Practical implementation, Overlap-save and overlap-add methods.

Approximation of Fourier transform through DFT, Fast algorithms for DFT -The FFT algorithm – DIT & DIF algorithms, inverse DFT using FFT

ModuleII

Digital filter design:FIR Filters: Impulse response, Transfer function, Linear phase properties, Design: window-based design, frequency sampling design. IIR Filters: Impulse response, Transfer function, Pole-zero representation; Butterworth, Chebyshev, elliptic filter concepts, Approximation problem for IIR filter design - Impulse in variance method, bilinear transform method, matched z-transform method. Frequency transformations, Realization structures: Direct form 1 and 2, parallel and cascade

Module III

Digital Signal Processors:TMS320C6x Architecture, Functional units, Linear and circular addressing modes, TMS320C6x instruction set, Changing the sampling rate using discrete time processing, Sampling rate reduction by an integer factor, Compressor, Time and frequency domain relations, Sampling rate increase by an integer factor, Expander, Time and frequency domain relations, Changing the sampling rate by a rational factor

References:

1. John G. Proakis, Dimitris G. Manolakis, “Digital Signal Processing: Principles, Algorithms and Applications,” Pearson Education, 4th edition, 2007.
2. RulphChassaing, “Digital Signal Processing and Applications with the C6713 and C6416 DSK", John Wiley & Sons, Inc., 2005
3. Mitra S. K., “Digital Signal Processing: A Computer Based Approach,” McGraw-Hill Publishing Company, 1998.
4. Oppenheim A. V., Schafer R. W., “Discrete-Time Signal Processing,” Prentice Hall India, 1996.
5. Chi-Tsong Chen, “Digital Signal Processing: Spectral Computation and Filter Design,” Oxford University Press, 2001.
6. Lonnie C. Ludeman, “Fundamentals of Digital Signal Processing,” John Wiley& Sons, NY, 1986.
7. R. E. Bogner, A. G. Constantinidis, (Editors), “Introduction to Digital Filtering,” John Wiley & Sons, NY, 1975.
8. Emmanuel C. Ifeacher, Barry W. Jervis, “Digital Signal Processing: A Practical Approach,” 2nd edn., Pearson Education, 2004.
9. Boaz Porat, “A Course in Digital Signal Processing,” Prentice Hall Inc, 1998.

Semester: III	Course Code: OPE-CC-532
Course Title: VLSI DESIGN	**Credits: 4**

Prerequisite : None.

Objective : To provide knowledge in VLSI design, fabrication of CMOS circuits and Lithographic technique.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the VLSI design methodologies
CO2	Understand the basic complementary CMOS circuits and their fabrication
CO3	Explain Dynamic Logic Designs
CO4	Discuss the material preparation techniques
CO5	Understand and apply lithographic technique

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the VLSI design methodologies	PO1	U	F, C
CO2	Understand the basic complementary CMOS circuits and their fabrication	PO2/PSO1	U, Ap	F, C, P
CO3	Explain Dynamic Logic Designs	PO3	U, Ap	P, M
CO4	Discuss the material preparation techniques	PSO5	Ap, An	P, M
CO5	Understand and apply lithographic technique	PSO5	U, Ap, An	C, P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I
VLSI Design Methodologies: Moore's law. Introduction to ASIC design-Full custom ASICs, Standard cell-based ASICs, Gate array-based ASICs, SoCs. Introduction to FPGA technology. Comparison between ASIC and FPGA solutions. ASIC Design flow- Logical and Physical design. Speed, power and area considerations in VLSI design.
MOSFET Logic Design - NMOS logic (Static analysis of Basic gates only), CMOS logic, Static (Static analysis of Basic gates only). Transient analysis and Switching power dissipation of CMOS inverter. Realization logic functions in static CMOS logic, Pass transistor logic, and transmission gate logic (Static analysis only)

Module II
Dynamic Logic Design- Pre-charge- Evaluate logic, Domino Logic, NP domino logic. Read Only Memory-4x4 MOS ROM Cell Arrays (OR, NOR, NAND). Random Access Memory –SRAM-Six transistor CMOS SRAM cell, DRAM –Three transistor and One transistor Dynamic Memory Cell.

Module III
Material Preparation (qualitative analysis only), Purification and Crystal growth (CZ process), wafer preparation. Thermal Oxidation- Growth mechanisms, Dry and Wet oxidation. Diffusion and ion implantation techniques. Epitaxy: molecular beam epitaxy.
Lithography- Photo lithographic sequence, Electron Beam Lithography, Etching and metal deposition techniques. MOSFET Fabrication techniques (qualitative analysis only). Twin-Tub fabrication sequence, Fabrication process flow.

References:

1. Michael John Sebastian Smith, Application Specific Integrated Circuits, Pearson Education,2001.
2. Sung –Mo Kang & Yusuf Leblebici, CMOS Digital Integrated Circuits- Analysis & Design, McGraw-Hill, Third Ed., 2003
3. Wayne Wolf, Modern VLSI design, Third Edition, Pearson Education,2002.
4. S.M. SZE, VLSI Technology, 2/e, Indian Edition, McGraw-Hill,2003.

Semester: III	Course Code: OPE-CC-533
Course Title: DIGITAL SIGNAL PROCESSING LAB	**Credits: 3**

Prerequisite : Basic knowledge in signal processing.

Objective : To empower the students with hands-on experience in signal and image processing using MATLAB.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Generate elementary waveforms in signal processing.
CO2	Simulate systems related to Digital Signal Processing
CO3	Analyse the biomedical signals.
CO4	Apply histogram analysis and edge detection using image processing

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Generate elementary waveforms in signal processing.	PSO1	U	P
CO2	Simulate systems related to Digital Signal Processing	PO3/PSO5	An, Ap	P
CO3	Analyse the biomedical signals.	PSO1	E	P
CO4	Apply histogram analysis and edge detection using image processing	PO3/PSO5	Cr, E	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15

Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

<u>COURSE CONTENT</u> (List of Experiments)

Using MATLAB

1. Generation of standard waveforms
    a) Unit Impulse
    b) Unit Step
    c) Ramp
    d) Sine Wave
    e) Cosine wave
    f) Square Wave
2. Analog modulation schemes (a) AM (b) FM (c) PM (d) PAM(e)PWM(f)PPM
3. Digital modulation schemes (a) ASK (b) FSK (c) PSK
4. Design and simulation of various PSK systems-BPSK,DPSK,M-Ary PSK
5. Design and simulation of Channel Coding theorems
6. DFT & IDFT
7. Convolution (with & without conv)
8. Scaling & Shifting
9. Digital Butterworth filters
10. Digital Chebyshev filters
11. Digital filters using FIR
12. Radon transforms
13. Histogram analysis of image
14. Image compression and resizing
15. Edge detection
16. Filtering of images
17. Image encryption and decryption using transforms
18. Image coding using ANN
19. Pattern classification using ANN
20. Loss measurements in image compression

(At least 10 experiments should be provided)

Semester: III	Course Code: OPE-CC-534
Course Title: ELECTIVE LAB - OPTOELECTRONICS	**Credits: 3**

Prerequisite : Basic knowledge in optoelectronic devices.

Objective : To empower the students with hands-on experience and to providepracticalknowledge about Optoelectronic sources, detectors, devices, fibers.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the characteristics of optical sources and detectors.
CO2	Analysethe diffraction pattern through various optical devices.
CO3	Design optical systems and optical fibers
CO4	Determine the losses and dispersion in optical fiber

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the characteristics of optical sources and detectors.	PSO1	U	P
CO2	Analysethe diffraction pattern through various optical devices.	PO5/PSO5	An, Ap	P
CO3	Design optical systems and optical fibers	PSO1	E	P
CO4	Determine the losses and dispersion in optical fiber	PO5/PSO5	Cr, E	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15

Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT (List of Experiments)

1. Characteristics of laser diode
2. Diffraction through Single slit, Double slit, Circular aperture
3. Diffraction - reflection grating, transmission grating
4. Refractive index of mirror and liquid
5. Determination of Brewster's angle
6. Mach – Zehnder interferometer
7. Determination of Stefan's constant
8. Characteristics of LED, opto-coupler and LDR
9. Characteristics of photodiodes and phototransistors
10. Malu's law
11. Electronic speckle pattern analysis
12. Dynamic speckle pattern analysis
13. Design and analysis of various FBGs using OPTIGRATING
14. Design and analysis of different types of optical fibers using OPTIFIBER
15. Design and performance analysis of optical communication systems using OPTISYSTEM and OPTSIM
16. Design and performance analysis of various optical networks using OPTISYSTEM and OPTSIM
17. Design and analysis of various types of photonic crystal fibers using COMSOLMultiPhysics
18. Measurement of NA and losses- attenuation, bending in optical fibers.
19. Measurement of power gain using Erbium Doped fiber amplifier
20. Study of dispersion in optical fibers
21. Wavelength division multiplexing of signals
22. Characterization of FBG and circulator
23. Analog and digital fiber optic links
24. Time division multiplexing of digital signals
25. WDM fiber optic link
26. Optical amplification in a WDM link

27. Adding and dropping of optical channels in a WDM link
28. Testing and analysis of OTDR
29. Testing and analysis of bit error rate & eye pattern analysis
30. Testing and analysis of power budgeting

(At least 10 experiments should be provided)

Semester: IV	Course Code: OPE-CC-541
Course Title: PROJECT	Credits: 12

Prerequisite **:** None.

Objective **:**To enable the students to develop deep knowledge, understanding, capabilities in the specialization subject. It should improve their subject knowledge level, experimental and report making skills. It should also enhance aptitude for research and assist career growth.

Learning Outcomes **:**At the end of 4thsemester, each student has to submit a project report consistingof the work they have done and findings obtained during their project.

Semester: IV	Course Code: OPE-CC-542
Course Title: SEMINAR	**Credits: 2**

Prerequisite : None.

Objective : To perform a seminar relevant to the field of specialization.

Learning Outcomes : To carry out a seminar presentation relevant to the field of specialization. The students have to submit a report, exhibit (if any) and have to make a presentation before the expert committee.

Semester: IV	Course Code: OPE-CC-543
Course Title: VIVA-VOCE	Credits: 2

Prerequisite **:** None.

Objective **:**To enable the students to develop deep knowledge, understanding, capabilities in the project and with all the core courses. It should improve their subject knowledge level, experimental and communication skills. It should also enhance aptitude for research and assist career growth.

Learning Outcomes **:**At the end of 4thsemester, each student has to prepare for the viva-voce based on theproject report consistingof the work they have done and findings obtained during their project and the topics covering all semesters and awareness of current and advanced topics.

ELECTIVES - OPTOELECTRONICS

Semester:	**Course Code: OPE-DE-501(O)**
Course Title: FIBER OPTICS TECHNOLOGY	**Credits: 4**

Prerequisite : Knowledge in optics.

Objective : To familiarize students on fiber optics technology and make them knowledgeable about the present communication technology.

Learning Outcomes :On completion of the course the student will be able to

CO No.	**CO Statement**
CO1	Understand the important fiber parameters and fiber drawing techniques
CO2	Analysevarious transmission characteristics and V-parameter
CO3	Discusspassive optical components and jointing techniques
CO4	Apply active components used in optical fiber communication
CO5	Evaluate important fiber parametric measurements
CO6	Measure attenuation using OTDR and spectrum analysis.

Tagging Course Outcomes

CO	**CO Statement**	**PO/ PSO**	**CL**	**KC**
CO1	Understand the important fiber parameters and fiber drawing techniques	PSO1	R	F, C
CO2	Analysevarious transmission characteristics and V-parameter	PSO1	An	C, P
CO3	Discusspassive optical components and jointing techniques	PO3/ PSO2	Ap	P
CO4	Apply active components used in optical fiber communication	PSO2	Ap	P

CO5	Evaluate important fiber parametric measurements	PSO5	An	P, M
CO6	Measure attenuation using OTDR and spectrum analysis.	PO5/ PSO5	E, Cr	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:
Introduction to optical fibers-Total internal reflection-acceptance angle, numerical aperture, Fractional refractive index difference, skew rays, Classification of fibers: based on refractive index profiles, modes guided applications and materials. Mode theory of fibers- Different modes in fibers. Dominant mode, Derivations for modal equations for SI and GI fibers. Approximate number of guided modes in a fiber (SI and GI fibers). Comparison of single mode and multimode fibers for optical communications. Fiber drawing and fabrication methods: - Modified chemical vapor deposition (MCVD)and VAD techniques.

MODULE II:
Transmission characteristics of optical fibers: Attenuation, absorption,scattering losses, bending losses. Phase and group velocities- V-parameter, Cut-off wavelength,Dispersion parameter, bandwidth, rise time and Non linearity coefficient. Impairments infibers: Group velocity dispersion (GVD), Wave guide and modal dispersions. Polarizationmode dispersion (PMD), Birefringence- linear and circular.
LED and LD modulators. Coupling of light sources to fibers- (LED and LD) –Derivations. Theory and applications of Passive optical components: Connectors, couplers,splices, Directional couplers, gratings: FBGs and AWGs, reflecting stars: optical add dropmultiplexers and SLMs.
Active components: Optical Amplifiers (OAs) - Comparative study of OAs-SLA, FRA, FBA EDFA and PDFA based on signal gain, pump efficiency, Noise figure,insertion loss and bandwidth. Design and Characterization of forward pumped EDFA.

MODULE III:

Fiber measurements: Attenuation measurement – cut back method.Measurement of dispersion-differential group delay, Refractive index profile measurement.Numerical aperture (NA) measurement, diameter measurement, Mode Field Diameter (MFD)measurement, V- parameter, cut off wavelength measurement, splicing and insertion losses-Eye diagram analysis.

OTDR- working principle and applications. OSA- basic block schematic andapplications in measurements. Fibers for specific applications: Polarization maintaining fibers(PMF), dispersion shifted and dispersion flattened fibers, doped fibers. Photonic crystal fibers,Holly fibers.

REFERENCES

1. Allen H Cherin, "An introduction to Optical Fibers", McGraw Hill Inc., Tokyo, 1995.
2. Gerd Keiser, Optical Fiber Communications, McGraw Hill, 2000
3. Govind P.Agrwal, "Fiber Optic Communication systems", John Wiley & Sons Inc., New York, 1997.
4. John M senior, Optical Fiber Communications, PHI, 1992
5. Maynbav, Optical Fiber Technology, Pearson Education, 2001.

ADDITIONAL REFERENCES

1. AjoyGhatak and K. Thyagarajan. Introduction to Fiber optics: Cambridge University press, 1999.
2. David Bailey and Edwin Wright, Practical Fiber Optics, Elsevier, 2003.
3. Dennis Derikson, Fiber optic test and measurement, Prentice Hall, 1998.
4. Franz and Jain, Optical Fiber Communication systems: Systems and Components, Narosa Publishers, 2004
5. Joseph C Palais, Optical fiber Communications, Pearson Education.1998.

Semester:	Course Code: OPE-DE-502(O)
Course Title: MODERN OPTICS	Credits: 4

Prerequisite : Knowledge in optics.

Objective : To develop a thorough understanding of the underlying physical principles of various modern optical phenomena and their applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Define phase velocity and group velocity.
CO2	Understand the behaviour of Gaussian beams in a homogeneous medium.
CO3	Use Gaussian beam focussing.
CO4	Discuss the propagation of light in isotropic dielectric medium and crystals.
CO5	Compare Fraunhofer and Fresnel diffraction.
CO6	Classify the Fraunhofer and Fresnel diffraction patterns in different aperture.
CO7	Evaluate Fourier transforms in optics.
CO8	Develop a hologram.
CO9	Apply the concept of coherence and non-linear optics.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Define phase velocity and group velocity.	PO1	R	F, C
CO2	Understand the behaviour of Gaussian beams in a homogeneous medium.	PSO1	U	C
CO3	Use Gaussian beam focussing.	PO3/ PSO4	Ap	P

CO4	Discuss the propagation of light in isotropic dielectric medium and crystals.	PSO1	U	P
CO5	Compare Fraunhofer and Fresnel diffraction.	PSO1	An	C
CO6	Classify the Fraunhofer and Fresnel diffraction patterns in different aperture.	PO5/ PSO4	Ap	M
CO7	Evaluate Fourier transforms in optics.	PSO5	E	P
CO8	Develop a hologram.	PO5/ PSO5	Cr	M
CO9	Apply the concept of coherence and non-linear optics.	PO3	Ap	C

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:
Harmonic waves, phase velocity and group velocity. Matrix representation of polarization, Jones vector, Jones matrices, Jones calculus, orthogonal polarization. Reflection and refraction at a plane boundary, Fresnel's equations, Brewster angle, total internal reflection, evanescent wave in total reflection.
Ray vectors and ray matrices, lens waveguide, identical-lens waveguide, Rays in lens like media, Gaussian beams in a homogeneous medium, fundamental Gaussian beam in a lens like medium- ABCD law, Gaussian beam focusing as an example.

MODULE II:
Propagation of light in isotropic dielectric medium, dispersion, Sellmeier's formula, propagation of light

in crystals, wave-vector surface, Ray-velocity surface.
Diffraction – Kirchoff integral theorem, Fresnel-Kirchoff formula, Babinet's principle, Fraunhofer and Fresnel diffraction, Fraunhofer diffraction patterns, single slit, rectangular aperture, circular aperture, double slit, multiple slits, Fresnel diffraction patterns, zone plate, Cornu's spirals.

MODULE III:

Fourier transforms in optics, application to diffraction, apodization, spatial filtering, phase contrast and phase grating, reconstruction of wave front – holography. Fourier transforming property of a thin lens. Fabry Perot etalon, Optical spectrum analyser.
Coherence- Theory of partial coherence, fringe visibility, temporal coherence, spatial coherence, coherence time and coherence length, intensity interferometry. Nonlinear optics-on the physical origin of nonlinear polarizations, nonlinear optical coefficients, second harmonic generation, phase matching, parametric amplification, phase matching, parametric oscillation, frequency tuning.

REFERENCES

1. Amnon Yariv, Optical Electronics, Fourth Edition, Holt, Rinehart and Winston, 1991.
2. E.Hecht and A.R.Ganesan, Optics, 4th Edition, Pearson, 2011.
3. Fowles G.R., Introduction to Modern Optics, 2nd Edition, Holt, Rienhart and Winston, 1975.
4. Ghatak A and Thyagarajan K, Optical Electronics, Cambridge University Press, 1993.

ADDITIONAL REFERENCES

1. Joseph N Goodman, Introduction to Fourier optics, McGraw Hill, 1996.
2. Stark H, (Ed.), Applications of Optical Fourier Transforms, Academic Press, 1982.

Semester:	Course Code: OPE-DE-503(O)
Course Title: INTEGRATED OPTICS	**Credits: 4**

Prerequisite :Knowledge in Optics.

Objective : To provide information regarding principle of optical amplifiers, wave guides, construction and working of integrated circuits.

Learning Outcomes :On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand the principle of optical amplification.
CO2	Discuss the theory of optical waveguides and mode coupling.
CO3	Apply fabrication techniques for optical waveguides.
CO4	Fabricate optical integrated circuits.
CO5	Develop integrated optical detectors.
CO6	Design photonic circuits for optical sensing.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the principle of optical amplification.	PSO1	R,U	F, C
CO2	Discuss the theory of optical waveguides and mode coupling.	PO1/PSO2	Ap, E	P
CO3	Apply fabrication techniques for optical waveguides.	PO3/ PSO2	Ap, Cr	P, M
CO4	Fabricate optical integrated circuits.	PO5/PSO5	Ap	M

CO5	Develop integrated optical detectors.	PO1/PSO5	Ap, Cr	P, M
CO6	Design photonic circuits for optical sensing.	PO5/PSO5	An	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:
Optical amplifiers: principles of optical amplification, semiconductor optical amplifier, applications, merits and demerits, photonic switching principles.
Theory of planar (2-D), channel (3-D) and coupled waveguides, step index2-D, graded Index 2-D, 3-D optical waveguides- step index and graded index 3-D waveguide devices, general theory of mode coupling, gratings. Guided-wave control-electro optic, acousto-optic magneto-optic and nonlinear optics. Recent trends in optical integrated circuits.

MODULE II:
Materials and fabrication techniques of optical waveguides, guided wave excitation and wavelength evaluation, passive waveguide devices, functional optical waveguide devices.
Fabrication techniques of optical integrated circuits, patterning and processing techniques, fabrication of 3-D waveguides. Waveguide evaluation, propagation constant waveguide parameters, transmission losses, scattering.

MODULE III:
Design of directional couplers, phase, interferometric travelling wave, balanced bridge, Bragg type, switches, electro optic, magneto optic and thermo optic bistable integrated optical devices, multiplexers, demultiplexers, integrated diode laser structures, integrated optical detectors, integrated quantum well detectors.
System design using photonic circuits, application DIC in telecommunication, switching, sensing, signal

processing and computing, integrated optic sensors.

REFERENCES

1. Nishihara. H, Haruna M. and Suhara T, Optical Integrated Circuits, McGraw Hill, New York, 1989.
2. Hunsperger R.G, Integrated Optics Theory and Technology, 3rdEdn, Springer Verlag, New York. 1991.
3. Marcel Dekker, Integrated Opto Circuits, 1982.

ADDITIONAL REFERENCES

1. D.K. Mynbaev and L.L. Scheiner," Fiber-optic Communications Technology", Pearson Education, New Delhi,2001.
2. B.E.A. Saleh and M.C.Teich., "Fundamentals of Photonics", John Wiley, New York,1991.
3. G. Keiser, "Optical Fiber Communications", McGraw Hill, New Delhi, 1983.
4. P. Bhattacharya, "Semiconductor optoelectronic devices", Prentice-Hall India, New Delhi,1998.
5. A. Ghatak and K. Thyagarajan, "Optical electronics", Cambridge Univ. Press, New Delhi,2002.

Semester:	Course Code: OPE-DE-504(O)
Course Title: LASERS	**Credits: 4**

Prerequisite : Knowledge in Electromagnetic Theory, Optics.

Objective : To introduce the fundamental theories and technological aspects of Lasers and its applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts in Lasers.
CO2	Understand the principles and design of laser cavities and population inversion techniques
CO3	Understand different types of laser systems and their working
CO4	Analyse Laser cavity parameters, line broadening mechanisms
CO5	Design mode locked and Q switched lasers and various optical modulation techniques.
CO6	Applications of Laser systems in various fields of Science and Technology
CO7	Design aspects and working of various Laser systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts in Lasers.	PSO1	R	F and C
CO2	Understand the principles and design of laser cavities and population inversion techniques	PSO1	U	C
CO3	Understand different types of laser systems and their working	PSO1	U	C
CO4	Analyse Laser cavity parameters, line broadening mechanisms	PO2	An	M

CO5	Design mode locked and Q switched lasers and various optical modulation techniques.	PO3/PSO5	Cr	M
CO6	Applications of Laser systems in various fields of Science and Technology	PO1/PSO2	Ap	P
CO7	Design aspects and working of various Laser systems.	PO5/PSO5	Cr	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:

Black body radiation, Planck's law, spontaneous and induced transitions- Einstein's coefficients, gain coefficient, Coherence – Spatial and Temporal coherence- Line broadening mechanisms- homogenous andinhomogeneous broadened systems

Laser oscillation conditions - population inversion - three and four level systems - rate equations Optical resonators, rectangular cavity- open planar resonators- sphericalresonators, modes and mode stability criteria, losses in optical resonators-quality factor,unstable optical resonators.

MODULE II:

Q-switching, methods of Q-switching- methods, optomechanical methods oflight- electro optic modulation- Pockel and Kerr modulators – magneto- optic modulators, acousto-optic modulators. Giant pulse lasers, mode locking in homogeneously andinhomogeneously broadened systems, passive and active mode locking.

Laser applications- thermal lensing effects – photothermal – photoacoustics – techniques and applications- Descriptive and qualitative studies of laser applications in communication,remote sensing – Lasers in speckles and holography (introductory ideas), Laser material processing - Pulsed laser ablation.

MODULE III:

Lasers in mechanical Engineering and industry, metrology, defense andsecurity, laser cooling, lasers in biology and medicine, satellitecommunications, LIDAR. Working principle of Ruby laser, dye laser, Argon ion laser, Tunable solid-state lasers, semiconductor lasers, Nd: YAG laser- flash lamp pumped anddiode pumped lasers, He-Ne laser, CO2 laser, Excimer laser, Nitrogen laser,free electron laser,Fiber laser. Frequency convertors and Parametric Oscillators.

REFERENCES

1. OrazioSvelto, Principles of Lasers, 4thEdn, Plenum Press, 1998.
2. Silfvast. W T., Laser Fundamentals, Cambridge University Press, New Delhi, 1998
3. Thyagarajan .K&Ghatak A K Lasers, Theory and Applications Macmillan, 1991
4. Yariv A, Optical Electronics, 4thEdn, Holt, Rinehart and Winston, 1991.

ADDITIONAL REFERENCES

1. Bahaa E. A Saleh &Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, 1991.
2. Jeff Hecht, The Laser Guide Book, McGraw Hill, 1986.
3. Koechner (Walter), Solid State Laser Engineering, Springer-Verlag, 1992.
4. Marvin J. Weber, Hand Book of Lasers, CRC Press, 2001.

Semester:	Course Code: OPE-DE-505(O)
Course Title: OPTOELECTRONIC DEVICES AND OPTICAL COMMUNICATION	**Credits:**

Prerequisite : Basic knowledge aboutsemiconductors.

Objective : To enhance the knowledge in optoelectronic materials, mode propagation through optical fibers and fiber measurement techniques.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the concept of optoelectronic materials
CO2	Understand the fundamental principles and properties of different optoelectronic devices.
CO3	Understand the mode theory in optical communication
CO4	Analyse the transmission characteristics of optical fiber
CO5	Design the optical components.
CO6	Analyse the fiber measurement techniques

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the concept of optoelectronic materials	PO1	U,	C
CO2	Understand the fundamental principles and properties of different optoelectronic devices.	PSO1	U and E	F, P and C
CO3	Understand the mode theory in optical communication	PO2	U, An and Ap	P and M
CO4	Analyse the transmission characteristics of optical fiber	PSO5	An, Cr and Ap	P and M
CO5	Design the optical components.	PSO5	Ap, An and Cr	P and M

CO6	Analyse the fiber measurement techniques	PO5/PSO5	Ap, An and Cr	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I:

Optoelectronic materials, Semiconductors, compound semiconductors, III-V and II-VI compounds, ZnO, ITO, GaN, direct and indirect band gap, electronic properties of semiconductors, Fermi level, density of states, life time and mobility of carriers, invariance of Fermi level at equilibrium, diffusion, continuity equation, excess carriers, Quasi-Fermi levels.

LED, Blue LED, Laser diodes. Quantum well lasers, VCSEL, DFB and DBR lasers. Photodetectors, photoconductors and photodiodes, PIN diodes, heterojunction diodes and APDs, photomultiplier tube, Solar cell materials and their properties.

Module II

Mode theory of fibers- Different modes in fibers. Dominant mode, Derivations for modal equations for SI and GI fibers. Approximate number of guided modes in a fiber (SI and GI fibers). Comparison of single mode and multimode fibers for optical communications.

Transmission characteristics of optical fibers: Attenuation, absorption, scattering losses, bending losses. Phase and group velocities- V-parameter, Cut off wavelength, Dispersion parameter, bandwidth, rise time and Non linearity coefficient. Impairments in fibers: Group velocity dispersion (GVD), Wave guide and modal dispersions. Polarization mode dispersion (PMD), Birefringence- linear and circular.

LED and LD modulators. Coupling of light sources to fibers- (LED and LD) – Derivations. Theory and applications of Passive optical components: Connectors, couplers,splices, Directional couplers, gratings: FBGs and AWGs, reflecting stars: optical add drop multiplexers and SLMs.

Module III

Active components: Optical Amplifiers (OAs) - Comparative study of OAs- SLA, FRA, FBA EDFA and PDFA based on signal gain, pump efficiency, Noise figure, insertion loss and bandwidth. Design and Characterization of forward pumped EDFA.

Fiber measurements: Attenuation measurement – cut back method. Measurement of dispersion-differential group delay, Refractive index profile measurement. Numerical aperture (NA) measurement, diameter measurement, Mode Field Diameter (MFD) measurement, V- parameter, cut off wavelength

measurement, splicing and insertion losses- Eye diagram analysis.
OTDR- working principle and applications. OSA- basic block schematic and applications in measurements. Fibers for specific applications: Polarization maintaining fibers (PMF), dispersion shifted and dispersion flattened fibers, doped fibers. Photonic crystal fibers, Holly fibers.

References:

1. AmnonYariv, Optical Electronics, Holt Rine hart & Winston, Philadelphia, 1991
2. Ben G. Streetmann& Sanjay Banerjee, Solid State Electronic Devices, 5thEdn, 2000.
3. Bhattacharya P., Semiconductor Optoelectronic Devices, PHI, New Delhi.1995
4. Martin A. Green, Solar Cells: Operating principles, Technology and System Applications, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.
5. Poortmans J and Arkhipov V Thin Film Solar Cell: Fabrication, Characterizations and Applications, John Wiley & Sons, England 2006.
6. Allen H Cherin, “An introduction to Optical Fibers”, McGraw Hill Inc., Tokyo, 1995.
7. Gerd Keiser, Optical Fiber Communications, McGraw Hill, 2000.
8. Govind P.Agrwal, “Fiber Optic Communication systems”, John Wiley & Sons Inc., New York, 1997.
9. John M senior, Optical Fiber Communications, PHI, 1992
10. Maynbav, Optical Fiber Technology, Pearson Education, 2001.

Semester:	Course Code: OPE-DE-506(O)
Course Title: FIBER OPTIC SENSORS AND APPLICATIONS	**Credits: 4**

Prerequisite : Knowledge in fibreoptics.

Objective : To familiarize the applications of fiber optics in various fields such as civil structures, aircrafts, nuclear power plants, chemical and petroleum industries and biomedical applications.

Learning Outcomes :On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concept of fiber optic sensors and types
CO2	Understand the Fiber Bragg Grating based sensors and their commercial applications
CO3	Design interferometry sensors
CO4	Designand develop fiber optic gyroscopes
CO5	Analyse biomedical sensors and spectral sensors.
CO6	Fabricate distributed fiber optic sensors.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concept of fiber optic sensors and types	PSO1	R	F, C
CO2	Understand the Fiber Bragg Grating based sensors and their commercial applications	PSO1	U, Ap	C, P
CO3	Design interferometry sensors	PO3/ PSO2	Ap, Cr	P
CO4	Designand develop fiber optic gyroscopes	PSO2	E, Cr	P, M
CO5	Analyse biomedical sensors and spectral sensors.	PSO2	An	M

CO6	Fabricate distributed fiber optic sensors.	PO5/ PSO5	Ap, Cr	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:

MM and SM fibers for sensing, Lasers & LEDs suitable for sensing, PIN & APDs for fiber optic sensing. Principles of electro optic modulators bulk & integrated optic modulators. Optical sensor types, advantages and disadvantages of fiber optic sensors, Sensor system performance: basic specifications, Sensor functions. Intensity modulated sensors, reflective concept, micro-bend concept, evanescent fiber sensors, polarization modulated sensors.

In-fiber Bragg grating based sensors – sensing principles – temperature and strain sensing, integration techniques, cross sensitivity, FBG multiplexing techniques. Long period fiber grating sensors- temperature and strain sensing, refractive index sensing, optical load sensors and optical bend sensors, Signal processing techniques for fiber optic sensor.

MODULE II:

Interferometric sensors, Mach-Zehnder& Michelson interferometric sensors, Theory-expression for fringe visibility, Fabry-Perot fiber optic sensor – theory and configurations, optical integration methods and multiplication techniques, applications – temperature, pressure and strain measurements, encoded sensors.

Sagnac interferometers for rotation sensing Fiber gyroscope sensors – Sagnac effect – open loop biasing scheme – Closed loop signal processing scheme – fundamental limit – performance accuracy and parasitic effects – phase-type bias error – Shupe effect – anti-Shupe winding methods – applications of fiber optic gyroscopes. Faraday effect sensors. Magnetostriction sensors. Lorentz force sensors.

MODULE III:

Biomedical sensors, sensors for physical parameters, pressure, temperature, blood flow, humidity and radiation loss, sensors for chemical parameters. pH, oxygen, carbon dioxide, spectral sensors.

Distributed fiber optic sensors – intrinsic distributed fiber optic sensor – optical time domain reflectometry-based Rayleigh scattering – optical time domain reflectometry-based Raman scattering – optical time domain reflectometry-based Brillouin scattering – optical frequency domain reflectometry – quasi-distributed fiber optic sensor. An overview on the optical fiber sensors in nuclear power industry, fly-by-light aircraft, oil field services, civil and electrical engineering, industrial and environmental monitoring.

REFERENCES

1. Allen Dakin J and Culshow B., (Ed), Optical fiber sensors, Vol I,II, III, Artech House, 1998.
2. Francis T.S Yu, Shizhuo Yin (Eds), Fiber Optic Sensors,Marcel Dekker Inc., New York,2002.
3. Pal B. P, Fundamentals of fiber optics in telecommunication and sensor systems, 14, Wiley Eastern, 1994.

ADDITIONAL REFERENCES

1. Anna Grazia Mignani and Francesco Baldini, Bio-medical sensors using optical fibers, Report on Progress in Physics Vol 59.1, 1996.
2. B.D Gupta, Fiber optic sensors: Principles and applications, New India Publishing Agency, New Delhi., 2006.
3. Eric Udd (Ed), Fiber optic sensors: An introduction for engineers and scientists, John Wiley and Sons Ltd., 1991.
4. Jose Miguel Lopez-Higuera (Ed), Handbook of optical fiber sensing technology, John Wiley and Sons Ltd., 2001.

Semester:	Course Code: OPE-DE-507(O)
Course Title: OPTICAL FIBER COMMUNICATION SYSTEMS	Credits: 4

Prerequisite : Basic knowledge in optical fiber.

Objective : To provide basic understanding and knowledge about various types of optical fiber communication systems.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in optical fiber.
CO2	Discuss nonlinear effects in optical fiber.
CO3	Discuss the soliton wave generation and its application.
CO4	Design Erbium doped fiber amplifier (EDFA)
CO5	Construct dense wavelength division multiplexing(DWDM).
CO6	Design power budget and rise time budget.
CO7	Apply software practice for designing of optical fiber communication systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in optical fiber.	PSO1	R	C
CO2	Discuss nonlinear effects in optical fiber.	PO1	U	F
CO3	Discuss the soliton wave generation and its application.	PO1/PSO1	Ap,Cr	C
CO4	Design Erbium doped fiber amplifier (EDFA)	PO2/PSO3	Cr	M
CO5	Construct dense wavelengthdivision multiplexing(DWDM).	PSO4	Cr	P

CO6	Design power budget and rise time budget.	PO5/ PSO5	Ap	M
CO7	Apply software practice for designing of optical fiber communication systems.	PO3/PSO5	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:

Classification of light wave systems, need for fiber based and all-optical systems. Nonlinear effects in fibers: Kerr effect, SPM, XPM and FWM, SRS, SBS, nonlinear effects in PCF-super continuum generation and its application in DWDM, nonlinear optical switching, modulation instabilities.
Soliton based systems: introduction to soliton theory and its applications, free space optical communication systems-applications. Noise in laser diodes relative intensity noise (RIN), phase noise and amplified spontaneous emission (ASE) noise. Effects of laser diode nonlinearity and noise in fiber communications, noises in detection, signal to noise ratio, optical fiber cable construction.

MODULE II:

Optical amplifiers (overview), design and characterization of EDFA, pumping schemes, noise in EDFA – ASE and noise factor. Transmitters - Fiber to source coupling, driving circuits, direct modulation, limitations, external modulation, electro-optic, acousto-optic modulators, dispersion management, pre-compensation and post compensation schemes. Receivers: front end, post detection circuit and data recovery. Quantum limit of performance-noise and jitter, extinction ratio and BER performance.
Wavelength division multiplexing, WDM components- add/ drop multiplexers, tunable filters, optical cross connects, system performance parameters, BER, eye diagram, SNR, ASE noise, cross talk, dense wavelength division multiplexing technology – need and requirements- concept of polarization division multiplexing.

MODULE III:

Systems: IMDD systems-design of systems with and without repeaters. – Power budget and rise time budget. Coherent Systems: sensitivity of a coherent receiver – ASK, FSK and PSK systems- comparison with IMDD systems. Overview of Digital Transmission Systems.

Various Types Higher Order Digital Multiplexing, hierarchy for PDH systems, PDH multiplexer, Frame structure of 2Mb/s, 34 Mb/s & 140 Mb/s, Limitations of PDH, SDH evolution , SDH standards, Merits of SDH, Advanced features of SDH, Principles of SDH, SDH hierarchy, STM1 (155 Mbps) to STM-64 (10 Gbps), frame representation, SDH Network Elements, Multiplexers, Digital Cross Connect, Regenerators, Network Management System, SDH network topologies, SONET, IP over WDM, Ethernet over fiber, classic SDH to data centric NGSDH, OTN, Passive optical networks, FTTH, GPON and GEPON.

REFERENCES

1. Franz and Jain, Optical Fiber Communication systems: Systems and Components, NarosaPublishers, New Delhi, 2004.
2. Gerd Keiser- Optical Fiber Communications- McGraw Hill, 2013.
3. Govind P Agrawal, Optical Communications- John Wiley, 2008.
4. John. M. Senior, Optical Fiber Communications, PHI, 1992

ADDITIONAL REFERENCES

1. Harold Kolimbiris- Fiber Optics Communications – Pearson education, 2004.
2. Joseph C. Palais, Fiber Optic Communications, Pearson Education, 2001.
3. Liu, Principles and applications of optical communication, TMH, 2010.

Semester:	Course Code: OPE-DE-508(O)
Course Title: NANO SENSORS AND DEVICES	**Credits: 4**

Prerequisite :Basic knowledge about nanotechnology.

Objective : To enhance the knowledge of nanosensors and fabrication of nano devices in the era of technology.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the fundamentals of nano sensors.
CO2	Use the different types of nano sensors
CO3	Understand the concepts of actuators.
CO4	Integrate the sensor with actuators and electronic circuitry.
CO5	Understand the types of nanodevices.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the fundamentals of nano sensors.	PO1/PSO1	U	F, C
CO2	Use the different types of nano sensors	PSO4	Ap	C, P
CO3	Understand the concepts of actuators.	PO4	U	C, P
CO4	Integrate the sensor with actuators and electronic circuitry.	PSO5	Ap, An, Cr	P, M

CO5	Understand the types of nanodevices.	PO2	U, Ap, An	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module 1

Fundamentalsof sensors,biosensor, microfluids,MEMSandNEMS, Packagingandcharacterizationofsensors**:**Methodofpackaging atzero level,dyeleveland firstlevel. ActiveandPassivesensors–Staticcharacteristic-Accuracy,offsetandlinearity–Dynamiccharacteristics- Firstand secondorder sensors – Physicaleffectsinvolved insignaltransduction. Nanomaterials in biochemical sensor design,Nanomaterialbasedcolorimetricsensors,metallicnanoparticlesinsensing,surfacefunctionalizationofgoldnanoparticle,Fluorescencebasedsensoring,electricalandelectrochemicalsensing.Differenttypeofsensors: Electrochemical,Masssensitivesensor,biochemical sensors and their applications. Gold nanoparticle-based surface plasmon resonancesensors, physical properties of gold nano particle: size dependent electronic and optoelectronicproperties,fluorescencequenching,limitofdetectionandlimitofquantification,sensitivityofthe sensor,selectivityofmeasurements,lineararrange.

Module II

Mechanical Sensors and Actuators: Accelerometers (capacitive, piezoelectric, piezoresistive, thermal), Force sensors (strain gauges, tactile sensors), Pressure sensors (semiconductor, piezoresistive, capacitive, VRP), Gyroscopes (mechanical, optical, fiber-optics). Night Vision, System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry, for other civil applications: metrology, bridges etc., gas sensors. Photodiodes, phototransistors and photoresistors based sensors, Photomultipliers, light-to-light detectors, infrared sensors (thermal, PIR, AFIR, thermopiles), CCD sensors and detectors. Surface Plasmon sensors,SERS Sensors

ModuleIII

Environmental monitoring sensors:mercury and arsenic contamination in water, atmosphericpollutionmonitoringsensors.

Metal Insulator Semiconductor devices, molecular electronics, information storage,molecular switching, Schottky devices, Quantum Structures and Devices: Quantum layers, wells, dots and wires, Mesoscopic Devices, Nanoscale Transistors, Single Electron Transistors, MOSFET and NanoFET, Resonant Tunneling Devices,Carbon Nanotube based logic gates, optical devices. Connection with quantum dots.

References:

1. Nanosensors:Physical,Chemical,andBiological,VinodKumarKhanna,CRCPress,2011.
2. Chemical Sensors: An Introduction for Scientists and Engineers, Peter Grundler, Springer.
3. SmartSensors for industrial Applications,KrzysztofIniewski,CRC Press.
4. IntroductiontoNanoelectronics, Science, Nanotechnology, Engineering, and Applications, Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Cambridge University Press, 2007.
5. Nanotechnology and Nanoelectronics,Fahrner, Wolfgang (Ed.), 2005, Springer.
6. Introduction to the Physics of Nanoelectronics, Tan & Jalil 2012. Woodhead publishing.
7. Fundamentals of Nanoelectronics, George W. H, pearsoneducationindia 2009.
8. Currentat the Nanoscale Colm Durkan University of Cambridge2008.
9. Nanotechnology and Nanoelectronics, - Prof. Dr. W. R. Fahrner, Springer,2005
10. Nanoelectronics andinformationtechnology,RainerWeiser,2012,Wiley.

Semester:	Course Code: OPE-DE-509(O)
Course Title: LASER SPECTROSCOPY	**Credits: 4**

Prerequisite : Knowledge in Lasers, Electromagnetic Theory

Objective : To provide knowledge of the fundamentals of spectroscopy and about different types of spectroscopy and applications of laser spectroscopy in various fields

Learning Outcomes :On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the characteristics of laser.
CO2	Understand the different laser level systems.
CO3	Discuss nonlinear spectroscopy.
CO4	Analyse laser Raman and fluorescence spectroscopy.
CO5	Illustrate time resolved spectroscopy
CO6	Design spectroscopy aspects of lasers in various fields of Science and Technology.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the characteristics of laser.	PO1	R	F and C
CO2	Understand the different laser level systems.	PSO1	U	C
CO3	Discuss nonlinear spectroscopy.	PO2	Ap	P
CO4	Analyse laser Raman and fluorescence spectroscopy.	PSO4	An	P, M
CO5	Illustrate time resolved spectroscopy	PSO4	Ap, Cr	M
CO6	Design spectroscopy aspects of lasers in various	PSO5	Cr	M

	fields of Science and Technology.			

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I
Laser Fundamentals-Characteristics of Lasers - spontaneous and induced transitions, Einstein's coefficients, homogenous population inversion, three and four level systems, rate equations.
Nonlinear Spectroscopy-Linear and nonlinear absorption- Harmonic generation- saturation, polarization and multiphoton spectroscopy.

Module II
Laser Raman and Fluorescence Spectroscopy-Luminescence- Fluorescence and Phosphorescence-Lifetime measurements- Raman effect – Classical and Quantum theory of Raman effect – Raman spectrometer – applications – Fundamentals of SERS, CARS and PARS- Applications of Raman Spectroscopy in Medicine
Photothermal spectroscopy-Photothermal (PT) generation- Different photothermal phenomena-Thermal lensing- beam deflection- photoacoustics-theory and application.

Module III
Time resolved spectroscopy-Q-switching, Mode locking -Time resolved spectroscopy: generation of short optical pulses-generation of ultra-short optical pulses-measurement techniques for optical transients – Measurement of ultra-short pulses- Pump-and-Probe Spectroscopy of Collisional Relaxation in Liquids
New Developments in Laser Spectroscopy-Optical Cooling and Trapping of Atoms- Atom Laser-Squeezing- Laser-Induced Breakdown Spectroscopy (LIBS) - Measurements of Flow Velocities in Gases and Liquids - Spectroscopic Detection of Water Pollution- Optogalvanic spectroscopy, spectroscopy aspects of lasers in medicine- laser remote sensing LIDAR techniques.

References:
1. S. Svanberg, "Atomic and Molecular Spectroscopy". Springer Verlag, Germany,1992.

2. J.R. Lakowicz, “Principles of Fluorescence Spectroscopy”, Kluwer Academic/ Plenum Publishers, New York,1999.
3. Z. Wang and H. Xia,” Molecular and Laser Spectroscopy “Springer series in chemical physics, Vol.50,1991.

Additional References

1. F.T. Arecchi, “Laser Handbook”, Vol.2, North Holland Publication, 1974.
2. R. E. Lidder, McGraw Hill, London, “Fundamental and Applied Laser Physics”, John Wiley, New York, 1985.
3. W. W. Duley, “Laser Processing and Analysis of Materials”, Plenum Press, New York, 1983.
4. William M. Steen, “Laser Material Processing”, Springer-Verlag, Berlin, Third Edn., 2005.
5. Wolfgang Demtröder, Laser, Spectroscopy- Vol. 1- Basic Principles, Springer, Fourth edition, 2014.
6. Wolfgang Demtröder, Laser, Spectroscopy- Vol. 2 Experimental Techniques, Springer, Fourth edition, 2014.
7. B.B. Laud, Lasers and Nonlinear Optics, New Age International Publishers, 3rd Edition, 2011.

Semester:	Course Code: OPE-DE-5010(O)
Course Title: LASER MATERIAL PROCESSING	Credits: 4

Prerequisite :Knowledge in lasers.

Objective : To provide fundamental exposure to students in understanding application of lasers in material processing

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts in Lasers.
CO2	Understand the principles of laser cavities and population inversion techniques.
CO3	Discuss different methods of high-power generation in laser systems
CO4	Apply laser systems for material characterisation.
CO5	Apply lasers for welding in industry.
CO6	Designlaser systems in various fields of Science and Technology.
CO7	Apply lasers for cutting in industry.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts in Lasers.	PSO1	R	F and C
CO2	Understand the principles of laser cavities and population inversion techniques.	PO2	U	C
CO3	Discuss different methods of high-power generation in laser systems	PO5/PSO5	Ap	P
CO4	Apply laser systems for material characterisation.	PO5/PSO5	Ap, E	P, M

CO5	Apply lasers for welding in industry.	PSO5	Ap, Cr	M
CO6	Designlaser systems in various fields of Science and Technology.	PSO5	Cr, E	M
CO7	Apply lasers for cutting in industry.	PSO5	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:
Characteristics of Lasers - spontaneous and induced transitions, Einstein's coefficients, homogenous population inversion, three and four level systems, rate equations.
Q-switching, methods of Q-switching- methods, - electro optic modulation- Mode locking- Different types of lasers – Nd YAG, He-Ne, Fibre lasers

MODULE II:
Laser assistedsynthesis ofnanomaterials- Laser assisted thin film deposition – Methods – experimental techniques – Laser applications, Models of laser heating- choice of laser for material processing-laser welding, drilling, machine and cutting.
Laser assisted material characterizations – applications to study the thermal and optical property of materials-Photothermal and Photoacoustics- Defects in materials – photothermal imaging – Photoacoustic imaging.

MODULE III:
Laser welding: different modes of laser beam welding- comparison between laser beam and electron beam welding-influence of different parameters-absorptivity-welding speed-focusing conditions-

advantages and limitations of laser welding-laser welding of industrial materials-recent developments in laser welding techniques.

Laser cutting and drilling: laser energy density for cutting and drilling-melt flash mechanism-various assisting gases and their importance-advantages of laser cutting-laser instrumentation for cutting and drilling-factors affecting cutting rates- effect of laser pulse energy on diameter and depth of drilled hole.

REFERENCES

1. Ian. W.Boyd," Laser Processing of Thin films and Microstructures",Springer-Verlag,1987.
2. W.W.Duley, " Laser Processing and Analysis of Materials", Plenum Press, New York, 1983.
3. D. P Almond and P.M Patel, Photothermal Science and Techniques, Chapman and Hall, 1996
4. Jeffrey A. Sell, Photothermal Investigations of Solids and fluids,Academic Press, Inc, 1989.

ADDITIONAL REFERENCES

1. Rykalni, A.Ugloo and A.Kokona, "Laser and Electron Beam Material Processing Hand Book",, MIR Publishers,1987.
2. J. Wilson &J.F.B.Hawkes," Optoelectronics- An Introduction", Prentice Hall of India Pvt.Ltd., NewDelhi, 1996.
3. J.F.Reddy," High Power Laser Applications", Academic Press, 1977.
4. William M. Steen," Laser Material Processing", Springer- Verlag, Berlin, Third Edn.,2005

Semester:	Course Code: OPE-DE-5011(O)
Course Title: LASER REMOTE SENSING	Credits: 4

Prerequisite :Knowledge in lasers.

Objective : To expertise students on the fundamentals of laser remote sensing and its design considerations.

Learning Outcomes :On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand the structure and composition of Earth's atmosphere.
CO2	Discuss about different types of clouds and its properties.
CO3	Explain laser remote sensing methods.
CO4	Apply lidar inversion methods for atmospheric measurements.
CO5	Design lidar system components.
CO6	Analyseairborne and space borne (satellite) lidar systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the structure and composition of Earth's atmosphere.	PO1	R	F, C
CO2	Discuss about different types of clouds and its properties.	PO2	U	P
CO3	Explain laser remote sensing methods.	PO4	Ap, Cr	C
CO4	Apply lidar inversion methods for atmospheric measurements.	PSO5	Ap	M

CO5	Design lidar system components.	PO5/PSO5	Ap, E	P, M
CO6	Analyseairborne and space borne (satellite) lidar systems.	PSO5	An	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I
Earth's atmosphere – basics of different regions of atmosphere, composition, structure and dynamics of atmosphere, important meteorological parameters and their influence in climate. Aerosols, optical properties and their role in Earth's climate and radiation budget.
Clouds: different types of clouds, clouds properties, high altitude cirrus clouds, influence of clouds on weather and climate modification. Atmospheric pollution, different types of pollutants and the sources conventional methods of measurements and limitations. Importance of air quality measurement and environmental monitoring.

Module II
Remote sensing of atmosphere, passive and active methods, laser remote sensing fundamentals, advantages. Laser remote sensing methods, interaction of laser radiation with atmosphere, various scattering methods, back scattering configurations, absorption methods, basics of long path absorption and differential absorption methods.
Rayleigh, Raman and Mie lidar configurations, differential absorption lidar (DIAL) system. Lidar equation lidar inversion methods, application of lidar for atmospheric measurements, characterization atmospheric aerosols, minor constituent trace gases and pollutants.

ModuleIII
Lidar system components and design, monostatic and bistatic configurations, lidar systems for the measurement of aerosols, clouds, ozone, water vapor, temperature etc. Essential elements of a lidar and DIAL system. Typical lidar systems in operation, Brief description on lidar systems for oceanic applications, lidar system for vegetation studies.
Advanced lidar systems: airborne and space borne (satellite) lidar for regional and global studies. Lidar

altimetry – terrain mapping, lidar for interplanetary studies. Laser altimetry for lunar studies. Mars orbiting laser altimetry – CALISPO and other lidar missions. Air borne and space borne lidars: Basic structures design and technology requirements and optimization of system parameters.

References:

1. E.D. Hinkley (Editor), Laser Monitoring of Atmosphere, Springer Verlag, 1976.
2. J. McCarteny, Optics of Atmosphere, E. John Wiley & Sons, 1982.
3. Monte Ross, Laser Applications, Academic Press, 1973.
4. Raymond M. Measures, Laser Remote Sensing and Applications, John Wiley & Sons, 1984.

Additional References:

1. Raymond M. Measures (Ed) Laser Remote Chemical Analysis, John Wiley & Sons, 1988.
2. Fiocco G., Lidar Systems of Aerosol Studies, An Outline in Handbook for MAP, Vol.13, 56-68, SCOSTEP Secr., University of III. Urbana, III, 1984.
3. P. Caagani and S. S Sandroni (Editor)Optional Remote Sensing of the Air Pollution, Elsevier science Publisher B. V, pp. 123-142, 1984.
4. Reagan. J.A., McCormick, M.P., and Spinhirne, J.D., Lidar Sensing of clouds in the atmosphere and Stratosphere, Proc. IEEE, 77, pp. 433-448, 1989.
5. Winker, M.D., Couch, R.H., and McCormick, M.P., Proc. IEEE, 84, pp. 164-180, 1996.
6. Muller, D., K. Franke, F. Wagner, D. Althausen, A. Ansmann, and J. Heintzenberg, Vertical Profiling of Optical and Physical Particle Properties over the Tropical Indian Ocean with six wavelength lidar, I. Seasonal cycle, J. Geophysics. Res. 106, 28,567-575, 2001.

Semester:	Course Code: OPE-DE-5012(O)
Course Title: HOLOGRAPHY AND SPECKLE INTERFEROMETRY	Credits: 4

Prerequisite :Knowledge in optics.

Objective :To understand the basic concepts, theory and applications of Holography andSpeckle Interferometry.

Learning Outcomes: To provide theoretical fundamentals and conditions for realization ofHolographic andSpeckle Interferometric techniques.

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in optics.
CO2	Development of construction and recording of holographic image.
CO3	Evaluate the quantitative measurement of holographic image quality.
CO4	Discuss about Speckle pattern and its application.
CO5	Construction of speckle pattern.
CO6	Apply the technique of speckle interferometry in different research area.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in optics.	PO1	U	C
CO2	Development of construction and recording of holographic image.	PSO2	Ap,An	M

CO3	Evaluate the qualitative measurement of holographic image .	PO2/PSO2	E	P
CO4	Discuss about Speckle pattern and its application.	PO2	Ap	P
CO5	Construction of speckle pattern.	PO5	Cr	P
CO6	Apply the technique of speckle interferometry in different research area.	PSO5	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Optical Holography: basic principle, recording and reconstruction, types of holograms: transmission hologram, reflection hologram, phase holograms, rainbow hologram (qualitative analysis only).
Experimental techniques, detectors and recording materials, holographic optical elements, holographic scanners, application of holography: pattern recognition, information storage.

Module II

Holographic interferometry: theory of fringe formation and measurement of displacement vector, Holographic nondestructive testing, Different Techniques: double exposure, real time, time average, sandwich, acoustic, comparative and TV holography.
Loading methods, holographic contouring/shape measurement, dual wavelength method, dual refractive index method, digital holography, holographic photo elasticity, optical coherence tomography.

ModuleIII

Speckle Metrology: speckle phenomena, statistics of speckle pattern, classification, objective speckle pattern, subjective speckle pattern, speckle techniques: speckle photography, speckle interferometry, speckle shear interferometry.
Electronic speckle pattern interferometry, theory of fringe formation and measurement of displacement

vector, out of plane and in plane measurements, surface roughness measurement, vibration measurement, detection of defects.

References:

1. Goodman J.W , Speckle phenomena in optics, Robert & company 2007
2. Hariharan, Optical Holography, Academic Press, 1983
3. Sirohi R.S., (Ed), Speckle Metrology, Mercel Dekker, 1993
4. Vest.C.M., Holographic Interferometry, John Wiley & Sons Inc., 1979.

Additional References:

1. Graham Saxby, Practical Volume Holography, 3rdEdn, Marcal Dekker, 1994
2. H. J. Caulfield, Handbook of Optical Holography, Academic Press. 1979
3. J. C. Dainty ed., Laser Speckle and Related Phenomena, Springer-Verlag, 1984.
4. John Wiley & Sons, 2001
5. Pierre Jacquot& Jean-Marc Fournier,(Eds) Interferometry in Speckle Light: Theory and Applications, Springer-Verlag, 2000
6. Promod K Rastogi (Ed), Digital Speckle Pattern Interferometry and Related Techniques,
7. Robert K Erf, Holographic Non-destructive Testing, Academic Press, 1974
8. Wolfgang Steinchen&Lianxiang Yang, Digital Shearography, Spei Press, 2003.
9. Yu.Iostrovsky, Holography and its Application, MirPublishers,1977.

Semester:	Course Code: OPE-DE-5013(O)
Course Title: OPTICAL SIGNAL PROCESSING	Credits: 4

Prerequisite :None.

Objective : To expertise students on the fundamentals of optical signal processing and its design considerations.

Learning Outcomes :On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in optical signal processing.
CO2	Design and development of a soliton based optical clock generator
CO3	Evaluate Fourier transforms in optics.
CO4	Discuss about optical spectrum analyzer(OSA).
CO5	Design and fabricate photo detector arrays.
CO6	Apply optical computing based on optical polarizations

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in optical signal processing.	PO1	R	F, C
CO2	Design and development of a soliton based optical clock generator	PO2/PSO1	Ap, Cr	M
CO3	Evaluate Fourier transforms in optics.	PO4	E	P
CO4	Discuss about optical spectrum analyzer(OSA).	PO4	U	C

CO5	Design and fabricate photo detector arrays.	PSO5	Cr	P
CO6	Apply optical computing based on optical polarizations	PO5	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I
Need for optical signal processing (OSP), fundamentals of OSP. A briefintroductory study on digital signal processing (DSP), and mixed signal processing (MSP) andoptical signal processing(OSP).Optical clock generation, design of a soliton based optical clock generator, optical bistability, applications-optical gates.

Module II
The Fresnel transform, convolution and impulse response, transform of a slit,Fourier transforms in optics, transforms of aperture functions, inverse Fourier transform,resolution criteria. A basic optical system, imaging and Fourier transform conditions.
Cascaded systems, scale of Fourier transform condition, maximum informationcapacity and optimum packing density. Block schematic of an optical spectrum analyzer(OSA): description of working.

ModuleIII
Ideal photo detector, noise in detection. CCD arrays: fabrication and layout,specifications, challenges faced in fabrication and design of photo detector arrays.
Optical computing based on optical polarizations. Encoding and decoding ofbinary data using polarization states. Design of decoding and encoding systems.

References:

1. Anthony Vander Lugt, Optical Signal Processing, John Wiley & Sons. 2005.
2. Damask and Jay, Polarization Optics in Telecommunications, Springer, 2005.

Additional References:

1. D. Casasent, Optical Data Processing-Applications Springer- Verlag, Berlin, 1978.
2. J. Horner, Optical Signal Processing, Academic Press 1988.
3. P.M. Dufffieux, The Fourier Transform and Its Applications to Optics, John Wiley and sons 1983.

Semester:	Course Code: OPE-DE-5014(O)
Course Title: OPTICAL NETWORKS	**Credits: 4**

Prerequisite :Basic knowledge about optical devices and electronic circuits.

Objective : To learn the components, architecture, topologies, design and operations in optical network communication.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts of optical networking.
CO2	Understand the optical network architecture and topologies
CO3	Differentiate the types of optical networking systems
CO4	Design optical network for wavelength routing
CO5	Detect the problems and faults in the devices used in optical network communication
CO6	Fabricate the components of optical networks

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the basic concepts of optical networking.	PO1	R	F and C
CO2	Understand the optical network architecture and topologies	PSO1	U	C
CO3	Differentiate the types of optical networking systems	PO2	An	M
CO4	Detect the problems and faults in the devices used in optical network communication	PO2/PSO5	Ap	P
CO5	Design optical network for wavelength routing	PSO5	Ap	P

CO6	Fabricate the components optical networks	PO4	Cr	P

(**CL- Cognitive Level:** R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, C- create, **KC- Knowledge Category:** F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I
SONET & SDH: brief history of SONET & SDH, multiplexing hierarchy, multiplexing structure – functional components, problem detection, virtual tributaries & containers, concatenation. Architecture of OTN: digital wrapper, control planes, control signaling, multiplexing hierarchies, current digital hierarchy, revised hierarchies, optical & digital transport hierarchies, functionality stacks, encapsulation & decapsulation.
GFP, WDM, DWDM topologies: relationship with SONET / SDH, EDF, WDM amplifiers, multiplexers, WADM I/P & O/P ports, spanloss& chromatic, dispersion, tunable DWDM lasers, network topologies & protection schemes: non-negotiable requirements of robust networks, line & path protection switching, type of topologies, optical channel concatenation, meshed topologies, PONs, optical ethernets, wide area backbones, metro optical networking.

Module II
MPLS & optical networks: label switching, FEC, scalability &granuility: labels & wavelength, MPLS nodes, distribution & binding methods, MPLS support of virtual private networks, traffic engineering, MPLS, relationships of OXC, MPLS operation, MPLS & optical traffic engineering, similarities.
Control & data planes interworking, architecture of IP & MPLS based optical transport networks: IP, MPLS & optical control planes- interworking, three control planes, framework for IP Vs Optical networks, generalized MPLS use in optical networks, bidirectional LSP‟s in optical network, next horizon of GMPLS, ODVK general communication channels, traffic parameters.

Module III
Link management protocol (LMP):data bearing links, basic function of LMP, LMP messages, LMP message header, TLW‟s control channel management, LPC, LCV, fault management, extending LMP operations to optical links optical routers management: switching in optical internets: state of art in optical switching, clarification of key terms, evolution of switching technologies, speeds of electronics & photonics, optical routers, control element, switching technologies MEMS, OSP, setting up protection paths between nodes H, G & J, expanding the role of nodes G & I, node failure, coupling, decoupling,

node to node wavelengths, approach to problem of LSP & OSP interworking, thermo-optic switches, bubble switch.

References:

1. Rajiv Ramaswami, Kumar N. Sivarajan, Optical Networks 2nd Edn. Morgan Kaufmann Publishers, Elsevier.
2. Biswanath Mukherjee, Optical WDM Networks, Springer.
3. Thomas E.Stern, Georgios Ellinas, Krishna Bala, Architectures,Design and Control, 2nd Edn. Cambridge University Press.

Additional References:

1. Achyut K. Dutta, Niloy K. Dutta, Masahiko Fujiwara WDM Technologies, Optical Networks, Academic Press, Elsevier.

Semester:	Course Code: OPE-DE-5015(O)
Course Title: ADVANCED SPECTROSCOPY	**Credits: 4**

Prerequisite : Basic knowledge aboutatomic and molecular concepts.

Objective : This course provides an overview of concepts of atomicspectra, Photoelectron and photo acoustic spectroscopy, rotational, vibrational, electronic, Raman, Mossbauer, nuclear and electron spin resonance spectroscopic techniques.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the concept of atomic spectra
CO2	Understand the principle of NMR-ESR spectrometer.
CO3	Understand the concept of photoacoustic spectroscopy
CO4	Analyse the spectroscopic techniques

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the concept of atomic spectra	PO1	U,	C
CO2	Understand the principle of NMR-ESR spectrometer.	PSO1	U and E	F, P and C
CO3	Understand the concept of photoacoustic spectroscopy	PSO1	U, An and Ap	P and M
CO4	Analyse the spectroscopic techniques	PSO5	An, Cr and Ap	P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's	Continuous Assessment Tests	Terminal

Category	1	2	3	Examination
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I:

General tools of experimental spectroscopy:

General components of absorption measurements-dispersing elements-prisms-grating and interferometers-tools in different regions of the electromagnetic spectrum-atomic absorption spectroscopy-inductively coupled plasma emission spectroscopy-recording spectrophotometers for IR,visible and UV regions

Molecular symmetry:

Symmetry operators-symmetry elements-algebra of symmetry operationsmultiplication tools-matrix representation of symmetry operators-molecular point groups-reducible and irreducible representations-great orthogonality theoremcharacter tables for point groups-symmetry species of point groups-IR and Raman activity

Molecular rotational spectroscopy:

Classification of molecules-rotational spectra of diatomic molecules-isotope effect and intensity of rotational lines-non rigid rotator-linear polyatomic molecules-symmetric and asymmetric top molecules-microwave spectrometer-analysis of rotational spectra.

ModuleII:

IR spectroscopy:

Vibrational spectra of diatomic molecules-characteristics IR spectra-vibrations of polyatomic molecules-anharmonicity-Fermi resonance-hydrogen bonding-normal modes of vibration in a crystal-interpretation of vibrational spectra-Fourier transform IR spectroscopy

Electronic spectra of molecules:

Vibrational coarse structure and analysis of bound systems-Deslanders table-Frank Condon principle-vibrational electronic spectra-rotational fine structure-Fortrat parabola-electronic angular momentum in diatomic molecules

Raman spectroscopy:

Theory of Raman scattering-rotational and vibrational Raman spectra-Raman spectrometer-structure determination using Raman and IR spectroscopy-nonlinear Raman effects-Hyper Raman effect-stimulated Raman scattering –coherent anti-stokes Raman scattering

ModuleIII:

ESR and NMR spectroscopy:

Principle of NMR-ESR spectrometer-Hyperfine structure-ESR spectra of Free radicals-Magnetic properties of nuclei-resonance condition-NMR instrumentationchemical shift-NMR spectra of solids-NMR imaging-interpretation of NMR spectra

Mossabauerspectroscopy:

Recoilless emission and absorption-Mossbauer spectrometer-experimental techniquesisomer shift-quadrupole interaction-magnetic hyperfine interaction

Photoelectron and Photo-acousticspectroscopy:

Photoelectron spectroscopy-experimental methods-photoelectron spectra and their interpretation-Auger electron and X ray Fluorescence spectroscopy-Photo-acoustic effect-basic theory-experimental arrangement-applications.

References:

1. J.M.Hollas,ModernSpectroscopy,FourthEdition,John Wiley &Sons (2004)
2. G.Aruldas,Molecular Structure and Spectrocopy,PHI learning Pvt Ltd (2007).
3. Suresh Chandra, Molecular Spectroscopy,Narosa Publishing Co (2009)
4. C.N.Banwell and E.M.McCash,Fundamentals of Spectroscopy,Fourthedn,TataMcGrawHill (1995).
5. D.N.Satyanarayana,Vibrational spectroscopy-Theory and applications,New Age International Pvt Ltd (2004).
6. J.L.McHale,MolecularSpectroscopy,Pearson education Inc (2008).

Semester:	Course Code: OPE-DE-5016(O)
Course Title: OPTICAL INSTRUMENTATION	Credits: 4

Prerequisite :Basic knowledge in geometrical optics and optical phenomena.

Objective : To learn the basic concepts, theories and applications of optical instruments.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts of optical phenomena and optometry
CO2	Understand the theories in optical instrumentation
CO3	Analyze optical devices and materials
CO4	Design optical components and interferometers
CO5	Apply interferometry and ellipsometry in research
CO6	Fabricate opto-medical instruments, lenses, camera and projector

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts of optical phenomena and optometry	PSO1	R	F and C
CO2	Understand the theories in optical instrumentation	PSO1	U	C
CO3	Analyze optical devices and materials	PO2	An	M
CO4	Design optical components and interferometers	PO2	E	M
CO5	Apply interferometry and ellipsometry in research	PO1/PSO2	Ap	P

CO6	Fabricate opto-medical instruments, lenses, camera and projector	PO4/PSO5	Cr	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:
Critical angle, linear and angular magnifications, cardinal points, optical aberrations-corrections. Optical materials, optical components, polarizing components. Basics of optical design, ray tracing, fabrication and testing of optical components. Types of optical glass - IR materials - gallium arsenide - optical glass making, IR materials manufacturing- abrasives, polishing compounds - tools and fixtures - spherical and plano tools - optical fabrication.

MODULE II:
Image intensifiers and night vision devices. Telescopes and microscopes-reflecting and refracting telescopes, eyepieces, microscope-objectives, binocular, stereoscopic, phase contrast, polarizing and atomic force microscopes – Airy's disc, resolving power of a telescope and microscope and brightness.

Stops and photographic systems-theory of stops – aperture stop – entrance and exit pupils, tele-centric stop and applications, requirements for photographic objectives – eye as an optical instrument, defects of eye and correction methods, space optics, adaptive optics, large space structures.

MODULE III:
Lens design optimization, opto-medical instruments, optical coherence tomography, infrared instrumentation; holographic camera; IR telescopes; Moire self- imaging and speckle metrology.
Spectroscopes and interferometers- Fourier transform spectroscopy, gratings and its application in spectroscopes, double beam and multiple beam interferometry – Fabry-Perot interferometer –Michelson and Twyman and Green interferometers – Zygo, MachZehnder, Jamin and Sagnac interferometers – applications –optical spectrum analyzer.Photometry, projection systems and refractometers -different sources for optical experiments – lasers – basic laws of photometry, Abbe and Kohler illuminations –

episcope, epi-dioscope, slide and overhead projectors – computer-based projection systems – polarizing instruments. Ellipsometry and applications in materials research.

REFERENCES

1. Fowles G.R., Introduction to Modern Optics, 2nd Edition, Holt, Rienhart and Winston, 1975.
2. Bruce H &Walkar, Optical Engineering Fundamentals, PHI, 2003
3. Warren J. Smith, Modern Optical Engineering: The Design of Optical System, 2nd Edn, Mc Grew Hill, 1990
4. Douglas A. Skoog, F James Holler and Timothy A Nieman, Principles of Instrumental Analysis, 5th Edn, Hartcourt Image Publishers, 1998
5. Donald F. Jacob, Fundamentals of Opticals Engineering, Mc Grew Hill, 1943
6. Hank H. Karow, Fabrication Methods for Precision Optics, John Wiley and Sons, New York, 1993.
7. David Malacara, Optical Shop Testing, John Wiley and Sons, New York, 1992.

ADDITIONAL REFERENCES

1. Rudolf Kingslake, Applied Optics and Optical Engineering, Vol: I-V, Academic Press, 1985
2. Daniel Malacara&ZacariaMalacara, Handbook of Optical Design, Marcel Dekker, 2004
3. Albert T Helfrack& William D Cooper, Modern Electronic Instrumentation and Measurement Techniques PHI, 1990
4. K. Lizuka, Engineering Optics, Springer-Verlag, 1983.

Semester:	Course Code: OPE-DE-5017(O)
Course Title: NANOPHOTONICS	Credits: 4

Prerequisite :Basic knowledge in nanoscience.

Objective : To learn fundamentals of nanotechnology and its applications in Photonics.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts of nanoscale interactions, photonic band gap, nanolithography and biomaterials
CO2	Understand the nature and properties of nanophotonic materials
CO3	Differentiate quantum - wells, wires, dots, rings, confinements and cutting
CO4	Analyse XRD, Raman, IR, XPS, SEM, TEM and SPM.
CO5	Fabricate nanostructures, photonic crystals, nanophores and carbon nanotubes
CO6	Apply nanophotonics in biotechnology and nanomedicine
CO7	Develop thin films using MBE, PLD and CVD

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concepts of nanoscale interactions, photonic band gap, nanolithography and biomaterials	PSO1	R	C
CO2	Understand the nature and properties of nanophotonic materials	PO1	U	C
CO3	Differentiate quantum - wells, wires, dots,	PO4	Ap	M

	rings, confinements and cutting			
CO4	Analyse XRD, Raman, IR, XPS, SEM, TEM and SPM.	PO5/PSO5	An	M
CO5	Fabricate nanostructures, photonic crystals, nanophores and carbon nanotubes	PSO5	Ap	P
CO6	Apply nanophotonics in biotechnology and nanomedicine	PSO5	Cr	P
CO7	Develop thin films using MBE, PLD and CVD	PO5/PSO5	Cr	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Introduction to nanoscale interaction of photons and electrons. Near fieldinteraction and microscopy- near field optics and microscopy- single molecule spectroscopynonlinearoptical process. Mesoscopic physics and nanotechnologies - trends inmicroelectronics and optoelectronics, characteristic lengths in mesoscopic systems, quantummechanical coherence.

Materials for nanophotonics -quantum confined materials -inorganicsemiconductors-quantum wells, wires dots and rings-quantum confinement-optical propertieswith examples-dielectric confinement- super lattices. Compound semiconductors- propertiesapplications-white light-GaN properties-blue LED-white light.

Module II

Plasmonics-metallic nanoparticles and nanorods-metallic nanoshells-localfieldenhancement-plasmonic wave guiding-applications of metallic nanostructures. Nanocontrol ofexcitation dynamics-nanostructure and excited states-rare earth doped nanostructures-upconverting nanophores-quantum cutting.

Growth and characterization of nanomaterials- epitaxial growth-MBE-PLDCVD-nanochemistry-XRD-Raman-IR-XPS-SEM- TEM- SPM.

ModuleIII

Organic quantum confined structures- carbon nanotubes-graphenecharacterization,properties and applications. Concept of photonic band gap – photonic crystals-theoretical modelling-features-optical circuitry-photonic crystal in optical communicationnonlinearphotonic crystal-applications.

Current at the nanoscale-nanoelectronic devices-introduction-single electrontransistor. Basic ideas of nanolithography and biomaterials-nanophotonics for biotechnologyand nanomedicine-nanophotonics and the market place.

References:

1. Colm Durkan, Current at the Nanoscale, Imperial College Press, 2007.
2. J.M. Martinez-Duart,R.J. Martin Palma,F. Agulle Rueda, Nanotechnology for Microelectronics and Optoelectronics , Elsevier,2006.
3. Lukas Novotny and Bert Hecht, Principles of Nano-Optics, Cambridge University Press, 2006.
4. Paras N. Prasad, Nanophotonics, Wiley Interscience,2004.
5. Herve Rigneault, Jean-Michel Lourtioz, Claude Delalande, Juan Ariel Levenson,Nanophotonics, ISTE Publishing Company, 2006.
6. John D. Joannopoulo, Robert D. Meade and Joshua N. Winn, Photonic Crystals, Prienceton University Press, 2008.

Semester:	Course Code: OPE-DE-5018(O)
Course Title: NANOBIOPHOTONICS	Credits: 4

Prerequisite :Basic knowledge in nanoscience.

Objective : To learn fundamentals of nanotechnology and its applications in Photonics.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts of nanoscale interactions, photonics.
CO2	Understand about the interaction of light with cells and tissues.
CO3	Discuss the different bio-imaging techniques.
CO4	Understand the concepts of optical biosensors.
CO5	Analyse the laser activated therapy.
CO6	Develop photonics for bio-imaging.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concepts of nanoscale interactions, photonics.	PO1	R	C
CO2	Understand about the interaction of light with cells and tissues.	PO2/PSO1	U	F, C
CO3	Discuss the different bio-imaging techniques.	PO4	Ap	P

CO4	Understand the concepts of optical biosensors.	PO2	U	C
CO5	Analyse the laser activated therapy.	PO5	An, Cr	P, M
CO6	Develop photonics for bio-imaging.	PSO5	Ap, Cr	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I
Introduction to Nanoscience and Nanotechnology- classification of nanomaterials – Fundamentals of Nanobiophotonics. Photobiology: interaction of light with cells and tissues, photo-processes in biopolymers, human eye and vision, photosynthesis. photo-excitation: free space propagation, optical fiber delivery system, articulated arm delivery, hollow tube wave-guides. Optical coherence tomography, special and time-resolved imaging, fluorescence resonance energy transfer (FRET) imaging, nonlinear optical imaging. Bio-imaging: transmission microscopy

Module II
Application of nanoparticles in imaging -Kohler illumination, microscopy based on phase contrast, dark-field and differential interference contract microscopy, fluorescence, confocal and multi-photon microscopy. Applications of bio-imaging: bio-imaging probes and fluorophores, imaging of microbes, cellular imaging and tissue imaging.
Optical biosensors: fluorescence and energy transfer sensing, molecular beacons and optical geometries of bio-sensing, biosensors based on fibre optics, planar waveguides, evanescent waves, interferometry and surface plasmon resonance. Flow cytometry: basics, fluorochromes for flow cytometry.

Module III
DNA analysis. Laser activated therapy: photodynamic therapy, photo-sensitizers for photodynamic therapy, applications of photodynamic therapy, two photon photodynamic therapy. Tissue engineering

using light: contouring and restructuring of tissues using laser, laser tissue regeneration, femto-second laser surgery.
Laser tweezers and laser scissors, design of laser tweezers and laser scissors, optical trapping using non-Gaussian optical beam, manipulation of single DNA molecules, molecular motors, lasers for genomics and proteomics, semiconductor quantum dots for bio imaging, metallic nano-particles and nano-rods for bio-sensing. Photonics and biomaterials: bacteria as bio-synthesizers for photonic polymers.

References:

1. Introduction to Biophotonics-V N Prasad (Wiley-Interscience April 2003)
2. Biomedical Photonics: A Handbook-Tu Vo Dinh (CRC Press, Boca Raton, FL 2003)
3. Understanding Biophotonics, Ed. Kevin K Tsla, Pan Stanford Publishing, 2015
4. A Handbook of Optical Biomedical diagnostics, SPIE press monograph vol pm 107
5. Biomedical Optics-Principles and Imaging -Lihong V and Hsin-IWU, Wiley Interscience 1st ed, 2007
6. Optical Coherence Tomography-Principles and Applications –Mark E.Brezinski, (Academis Press 1sted 2006)
7. Biophysics –An Introduction-Rodney Cotterill, (John Wiley Student edition)
8. P.N. Prasad, "Nanophotonics", John Wiley & Sons, New York (2004).
9. P.N. Prasad, "Introduction to Biophotonics", John Wiley & Sons, New York (2003).
10. M. Bruchez, Jr., M. Moronne, P. Gin, S. Weiss, and A.P. Alivisatos, Science 281, (1998) 2013-2016
11. Photon-based Nanoscience and Nanobiotechnology, Ed. Jan J. Dubowski and Stoyan Tanev, Springer, 2005.
12. Colm Durkan, Current at the Nanoscale, Imperial College Press, 2007.
13. J.M. Martinez-Duart,R.J. Martin Palma,F. Agulle Rueda, Nanotechnology for Microelectronics and Optoelectronics , Elsevier,2006.

Semester:	Course Code: OPE-DE-5019(O)
Course Title: SOLAR PHOTOVOLTAICS	**Credits: 4**

Prerequisite :Basic Knowledge in semiconductor Physics.

Objective : To introduce the fundamental theories and technological aspects of powergeneration using solar photovoltaic technology.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts in solar photovoltaic field.
CO2	Understand different types of photovoltaic materials and their properties
CO3	Apply the fabrication techniques of thin film technology
CO4	Analyse solar cell parameters
CO5	Design solar cells and PV modules
CO6	Develop materials for solar photovoltaic applications
CO7	Measure losses and quantum efficiency in a solar cell

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts in solar photovoltaic field.	PO1	R	F and C
CO2	Understand photovoltaic materials and their properties	PO2/PSO1	U	C
CO3	Apply the fabrication techniques of thin film	PO4	Ap	P

	technology			
CO4	Analyse solar cell parameters	PO4	An	M
CO5	Design solar cells and PV modules	PSO5	Ap	M
CO6	Develop materials for solar photovoltaic applications	PO5	Cr	P
CO7	Measure losses and quantum efficiency in a solar cell	PO5	E	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Solar cell materials and their properties. Solar cell research: technology (silicon,organic, Dye sensitized, perovskites), applications and limitations. Device fabrication:Semiconductor junctions: P-N junction, P-I-N junction and its properties. Solar cell structures:homo & hetero junction solar cells, single & multi-junction solar cells. Substrate andSuperstrate configuration.

Fabrication techniques: Diffusion, Electrodeposition, Thin film technology:physical vapour deposition (PVD) techniques, chemical vapour deposition (CVD) techniques-MOCVD and PECVD.

Module II

Solar cell parameters, Losses in a solar cell: optical losses and electrical losses.Effects of series & parallel resistance, solar radiation and temperature on efficiency.Minimization of optical losses and recombination.

Design of solar cells: high Isc, high Voc, high FF. Characterization of solarcells: Measurements of solar cell parameters, Solar Simulator- I-V measurement, L-I-Vcharacteristics, quantum efficiency measurement.

ModuleIII

PV Modules: solar PV Modules from solar cells, series and parallel connections,design and structure of PV Modules, power output, batteries for PV systems.

DC-DC converters, DC-AC converters, PV system configurations, Hybrid PVsystems. Photovoltaic system design and applications.

References:

1. Chetan Singh Solanki, Solar Photovoltaic: Fundamentals, Technologies and Applications, PHI, New Delhi, 2011.
2. Larry D Partain (ed.), Solar Cells and their Applications, John Wiley and Sons, Inc, NewYork, 1995.
3. Martin A. Green, Solar Cells: Operating principles, Technology and System Applications, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.
4. Poortmans J and Arkhipov V, Thin Film Solar Cell: Fabrication, Characterizations andApplications, John Wiley & Sons, England 2006.
5. Ben G. Streetman, Solid State Electronic Devices, Prentice-Hall of India Pvt. Ltd.,1995.
6. H. J. Moller, Semiconductors for Solar Cells, Artech House Inc, MA, USA, 1993.
7. J. Nelson, The physics of Solar Cells, Imperial College Press, 2006.
8. M. D. Archer, Clean Electricity from Photovoltaics, R. Hill, Imperial College Press, 2001.
9. R. Brendel, Thin-Film Crystalline Silicon Solar Cells: Physics and Technology, Wiley-VCH, Weinheim, 2003.
10. Richard H Bube, Photovoltaic Materials, Imperial College Press, 1998.

Semester:	Course Code: OPE-DE-5020(O)
Course Title: NONLINEAR OPTICS	**Credits: 4**

Prerequisite :Basic concepts in optics.

Objective : To introduce the theory of Nonlinear Optics and its impact on technological applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts and quantities in nonlinear optics
CO2	Understand theories of nonlinear optical phenomena and propagation of electromagnetic wave
CO3	Analyse nonlinear optical coefficients
CO4	Formulate nonlinear interactions and parametric amplification
CO5	Apply degenerate four wave mixing and Z-scan
CO6	Fabricate experimental set up for optical harmonic generation and frequency tuning

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concepts and quantities in nonlinear optics	PSO1	R	F and C
CO2	Understand theories of nonlinear optical phenomena and propagation of electromagnetic wave	PSO1	U	C
CO3	Analyse nonlinear optical coefficients	PO2	An	M

CO4	Formulate nonlinear interactions and parametric amplification	PO2	E	M
CO5	Apply degenerate four wave mixing and Z-scan	PO1/PSO2	Ap	P
CO6	Fabricate experimental set up for optical harmonic generation and frequency tuning	PO4/PSO5	Cr	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I:

Nonlinear optical susceptibility tensor, on the physical origins of the nonlinearoptical coefficients, electromagnetic formulation of nonlinear interactions- harmonicgeneration, sum and difference frequency generation. Optical second harmonic generation-experimental set up.

Parametric generation of light, Basic equations of parametric amplification,parametric oscillation, frequency tuning, experimental arrangement, frequency up and downconversion.

MODULE II:

Third order optical nonlinearities: nonlinear absorption- Saturable and reversesaturable absorption, two photon absorption, optical limiting, nonlinear refractive index -intensity dependent refractive index, self-focusing and defocusing, optical bi-stability- absorptiveand dispersive, optical switching.

Stimulated Raman Scattering, Stimulated Brillouin scattering. Nonlinearoptical materials: growth and characterization- Degenerate four wave mixing and Z-scantechnique.

MODULE III:

Propagation through a distorting medium, image transmission in fibers, theoryof phase conjugation by four wave mixing, optical phase conjugation by four wave mixing,OPC by stimulated nonlinear scattering.Beam coupling and phase conjugation by photorefractive effect, self- inducedtransparency, self- phase modulation.

REFERENCES

1. Ammon Yariv, Quantum Electronics 3rdEdn, John Wiley, New York, 1989.
2. Govind P. Agrawal, Nonlinear Fiber Optics, 3rdEdn, Academic Press, New Delhi, 2001.
3. Pochi Yeh, Introduction to Photorefractive Nonlinear Optics, John Wiley & Sons, New York, 1993

ADDITIONAL REFERENCES

1. Fischer R.A (Ed), Optical Phase Conjugation, Academic Press, San Diego, 1983.
2. R.D. Guenther, Modern Optics, John Wiley & Sons, 1990.
3. Rampal V.V, Photonics, Elements and Devices, Wheeler, Allahabad, 1992.
4. Richard L. Sutherland, Handbook of NonLinear Optics, Marcal Dekker, 1996.
5. Robert W Boyd, NonLinear Optics, 2ndEdn, Academic Press, 2003.
6. Singh N.B, Growth and characterization of Nonlinear Optical Materials, Pergamon, 1990.

Semester:	Course Code: OPE-DE-5021(O)
Course Title: ENERGY SCIENCE	**Credits: 4**

Prerequisite :Basic knowledge about energy sources

Objective : To enhance the knowledge about different energy sources and its applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the energy sources
CO2	Understand the typesofhydropowerplantsandschemes.
CO3	Understand the types of thermal power turbines
CO4	Explain the nuclear reactors
CO5	Understand the photovoltaic cell technologies

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the energy sources	PSO1	U	F
CO2	Understand the typesofhydropowerplantsandschemes.	PSO1	U, Ap	F, C
CO3	Understand the types of thermal power turbines	PO2	U	F, C
CO4	Explain the nuclear reactors	PO4	U, Ap	C, P and M
CO5	Understand the photovoltaic cell technologies	PO4	U, An	C, P and M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I

Energy sources: Conventional and Non-Conventional Energy, Sources of Non-conventionalenergy,Historical,EconomicandEnvironmentalPerspective,NeedofNon-conventional Energy Sources, Types of Non-conventional Energy Sources, BasicsofNonconventional EnergySources,theirdistribution andlimitations.
Hydroelectricpower:Typesofhydropowerplantsandschemes,hydrology:runoffstudies,floodestimation studies, assessment of hydropower potential of a basin, storage and pondage, loadstudies,elementsofhydropowerplantsandtheirhydraulicdesign:dams,intakes,conveyancesystem,typesofpowerhouse,hydraulicturbinesandpumps,Componentsanddesignofhydraulicturbines,Standardizationandselectionof turbine,ComponentsanddesignofhydraulicPumps.
Wind Energy:Wind turbines, aerodynamics, types of turbines wind energy conversion system,Windturbinegeneratortypes.Advantages anddisadvantages
Tidal energy:Principle,powercalculation,Tidal modesofoperation.

Module II

Types of thermal power turbines, Gas turbines; Open and closed cycles,constant pressure and constant volume cycles, cycles with inter cooling, reheating and heatexchanger,compressorandturbineefficiencies, pressure losses, performancecharacteristicsofvariouscycles,practical problems. Jet Propulsion: Calculation ofthrust,Power,speedandefficiency,turbo-jetandturbopropulsion systems.Compressors,CombustionSystems,Steamturbines;Principleandworking,typeofturbines,stagetoblade,speedratioforoptimumefficiency,diagramefficiency,steamsperformance.Energylossesin steam turbine, turbine performanceat various loadsandgoverningofsteamturbines.
Nuclear Reactors and its Components, General Problems of Reactor Operation, DifferentTypesofReactors,PressurizedWaterReactors(PWR),BoilingWaterReactors(BWR),HeavyWater–cooledandModeratedCANDU(CanadianDeuteriumUranium)TypeReactors, Gas-cooled Reactors,Breeder Reactors, Reactor Containment Design,LocationofNuclearPowerPlant.

ModuleIII

Photo-voltaic cell – characteristics- cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-chargeregulators,Construction concepts.PVcelltechnologies1st,2ndand3rd generations, Electrical characteristics, PV Module and array, PV system components anddesign

Solar thermal power: Solar radiation characteristics, flat plate collector, Tubular Collector,solaraircollector,solarconcentrator.
Biofuels:Biomasscharacteristicsandtheiravailability,Biofuelproductionprocesses:Biomethane,Biohydrogen,Alcoholicfermentation,Biodiesel,MicrobialFuelCell,Biomassbasedsteampowerplant, combinedcycle powerplant,cogenerationplant.

References:

1. Renewableenergy resources.J.TwidellandT.Weir,TaylorandFrancis.
2. Renewableandefficientelectricpowersystems.G.M.Masters,John WileyandSons.
3. RenewableenergysourcesandEmergingtechnology.D.P.Kothari,K.C.SingalandR.Ranjan,Prantice Hall.
4. Renewableenergy engineering andTechnology.Ed.VV NKishore,TERI.
5. BiofuelsEngineeringProcessTechnology byCayeM.Drapcheo,N PNhuan,T.HWalkar
6. Biohydrogenproduction:FundamentalsandTechnologyAdvantagesbyD.Das,N.Khanna,C.Nag
7. JohnF.Walker&Jenkins.N.,“WindEnergyTechnology”,JohnWileyandsons,Chichester,1997.

******