



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE

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SPHB8010	RADIATION PHYSICS	L	T	P	EL	C
		3	0	0	0	3

Course Objectives:

- To expose the students of M.Sc. class to the relatively advanced topics Radiation Physics and nuclear reactions.
- They understand the details of the underlying aspects Of nuclear detectors and spectroscopy.
- This can use the techniques if they decide to be radiation or nuclear physicists in their career.

UNIT 1 INTERACTION OF ELECTROMAGNETIC RADIATIONS WITH MATTER

9 Hrs.

Different photon interaction processes viz. photoelectric effect, Compton scattering and pair production. Minor interaction processes, Energy and Z dependence of partial photon interaction processes. Attenuation coefficients, Broad and narrow beam geometries. Multiple scattering.

UNIT 2 INTERACTION OF CHARGED PARTICLES WITH MATTER

9 Hrs.

Elastic and inelastic collisions with electrons and atomic nucleus. Energy loss of heavy charged particles. Range-energy relationships, Straggling. Radiative collisions of electrons with atomic nucleus.

UNIT 3 NUCLEAR DETECTORS AND SPECTROSCOPY

9 Hrs.

General characteristics of detectors, Gas filled detectors, Organic and inorganic scintillation detectors, Semi-conductor detectors [Si(Li), Ge(Li) HPGe]. Room temperature detectors, Gamma ray spectrometers. Gamma ray spectrometry with NaI(Tl) scintillation and semiconductor detectors.

UNIT 4 NUCLEAR SPECTROMETRY AND APPLICATIONS

9 Hrs.

Analysis of nuclear spectrometric data, Measurements of nuclear energy levels, spins, parities, moments, internal conversion coefficients, Angular correlation, Perturbed angular correlation, Measurement of g-factors and hyperfine fields.

UNIT 5 ANALYTICAL TECHNIQUES

9 Hrs.

Principle, instrumentation and spectrum analysis of XRF, PIXE and neutron activation analysis (NAA) techniques. Theory, instrumentation and applications of electron spin resonance spectroscopy (ESR). Experimental techniques and applications of Mossbauer Effect, Rutherford backscattering. Applications of elemental analysis, Diagnostic nuclear medicine, Therapeutic nuclear medicine.

Max. 45 Hrs

COURSE OUTCOMES:

Upon successful completion of this course, students should be able to

- CO1:** Understand various modes of interaction of electromagnetic radiations and charged particles with matter.
- CO2:** Distinguish various types of radiations based on their interaction with matter.
- CO3:** Learn and understand about different detectors and their use for spectroscopy.
- CO4:** Use different analytical technique such as XRF, PIXE, neutron
- CO5:** Activation analysis and electron spin resonance spectroscopy.
- CO6:** Understand various analysis techniques and way to apply the materials in suitable manner

TEXT/REFERENCE BOOKS:

1. The Atomic Nucleus: R.D. Evans, Tata McGraw Hill, New Delhi.
2. Nuclear Radiation Detectors: S. S. Kapoor and V. S. Ramamurthy, New Age, International, New Delhi.
3. Radiation Detection and Measurements: G. F. Knoll, Wiley & Sons, New Delhi.
4. Introductory Nuclear Physics: K. S. Krane, Wiley & Sons, New Delhi.
5. An Introduction to X-ray Spectrometry: Ron Jenkin, Wiley.
6. Techniques for Nuclear and Particle Physics Experiments: W. R. Leo, Narosa Publishing House, New Delhi.
7. Introduction to experimental Nuclear Physics: R.M. Singru, Wiley & Sons, New Delhi

END SEMESTER EXAMQUESTION PAPER PATTERN



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Max. Marks: 100

Exam Duration: 3 Hrs.

PART A: 5 Questions of 6 mark each - No choice.

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14 marks.

70 Marks



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SPHB8006	THIN FILM TECHNOLOGY	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVES:

- Understanding the basics of Thin film technology

Understanding the chemical methods involved in thin film deposition Knowledge about the characterization methods of thin film.

UNIT 1 VACUUM TECHNOLOGY

9 Hrs.

Fundamentals of vacuum, basic definition and pressure regions of vacuum, kinetic theory of gases mean free path, types of flow, conductance, vacuum pumps and systems, rotary mechanical pump, roots pump, diffusion pump, turbo molecular pump, sputter ion pump, measurement of vacuum, concept of different gauges, capacitance gauges, Pirani gauge, ionization gauge and penning gauge, vacuum system components and operation.

UNIT 2 PHYSICAL METHODS OF THIN FILM DEPOSITION

9 Hrs.

Thermal evaporation, resistive heating, flash evaporation, laser evaporation, rf-heating, coevaporation, electron bombardment heating, sputtering plasma, discharges and arc, sputtering variants, sputtering yield low pressure sputtering, rf-sputtering, reactive sputtering, magnetron sputtering, magnetron configurations, bias sputtering, evaporation versus sputtering

UNIT 3 CHEMICAL METHODS OF THIN FILM DEPOSITION

9 Hrs.

Electrodeposition, electrolytic deposition, electro less deposition, anodic oxidation, spray pyrolysis, spin and dip coating, chemical vapor deposition (CVD), homogenous and heterogeneous process, CVD reactions, pyrolysis, hydrogen reduction, halide disproportionation, transfer reactions, CVD processes and systems, low pressure CVD, laser enhanced CVD, metalorganic CVD (MOCVD).

UNIT 4 GROWTH OF THIN FILMS AND THICKNESS MEASUREMENTS

9 Hrs.

Introduction: nucleation and early stages of film growth, thermodynamic aspects of nucleation, capillary theory, thin film growth modes Volmert, Weber (VW) growth, Frank-van der Merwe (FM) growth, Stranski-Krastanov growth, thickness measurement, electrical methods, microbalance monitors, quartz crystal monitor, mechanical method (stylus), optical interference methods, ellipsometry, interference fringes.

UNIT 5 CHARACTERIZATION METHODS OF THINFILMS

9 Hrs

x-ray diffraction (XRD), scanning electron microscopy, transmission electron microscopy, energy dispersive analysis, Auger electron spectroscopy, X-ray photoelectron spectroscopy, Rutherford backscattering spectroscopy, secondary ion mass spectrometry.

Max. 45 Hrs

Course Outcomes:

At the course end, the students will be able to

CO1: Understand the Vacuum process and they can know how to create Technology.

CO2: Identify the physical synthesis of thin film methods

CO3: Identify the chemical synthesis of thin film methods

CO4: Analyze the Basic sciences behind the thin film growth and the thickness factor

CO5: Characterize the thinfilm in various methods.

CO6: Growth analysis has been detail analyzed with some

TEXT /REFERENCE BOOKS:

- Maissel and Glang, Hand Book of Thin Film Technology
- K.L. Chopra, Thin Film Phenomena
- Dupy and Kachard, Physics of Non-Metallic Thin Films –
- S. Dushman and J.M. Lafferty, Scientific Foundations of Vacuum Technology
- M. Ohring, Materials Science of Thin Films: Deposition and Structure, 2nd Ed., Academic Press, 2002.
- S. Campbell, The Science and Engineering of Microelectronic Fabrication, 2nd Ed., OUP, 1996. 3. Kaufmann, Characterization of Materials, 2 nd Ed., Wiley, 2003.



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SPHB8005	INTELLECTUAL PROPERTY LAW	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVES:

- This course is intended to introduce the different categories of Intellectual Property, the minimum standard to identify the items of protection.
- Bundle of rights conferred to the right holder and remedies available in the case of infringement are also examined.
- Students can understand the trademark and designs act

UNIT 1 INTRODUCTION

9Hrs

Meaning and concept of intellectual Property and the need for protection - The world Intellectual property Organization (WIPO) Convention - Origin and functions of World Trade Organisation (WTO) - Trade Related Intellectual property Rights (TRIPS) Agreement of WTO and its effects on Intellectual Property law in India; Dispute Settlement Mechanism.

UNIT 2 COPYRIGHT ACT

9Hrs

The Copyright Act (1957) and recent amendments-works in which copyright subsist-Authorship And Ownership-Different Rights-Registration of copyright-Term of copyright-Administration of copyright law-Performer's rights-Broadcaster's rights- Collective administration of copyrights-Moral rights-Copyright infringements-Remedies-Composition of Copyright Board.

UNIT 3 TRADEMARK & DESIGNS ACT

9Hrs

The Trade Mark Act (1999), object, definitions, salient features- Distinctiveness, deceptive similarity- Assignment and transmission - Registration: Procedure-Term-Effects-Grounds for refusal- Powers and functions of Registrar- collective marks-certification marks- Trade mark agents - Appellate board - Infringement action, passing off action -Well known marks- The designs Act 2000; definitions, registration of designs, copyright in registered designs, piracy of registered designs, remedies, powers and duties of Controller - Semi conductor integrated circuit layout-Trade secrets.

UNIT 4 LAW OF PATENTS

9 Hrs

The Patents Act (1970):object definitions, salient features-Invention: patentable and non- patentable inventions-product and process patents- -Rights of patentees-assignment and transmission-term of patent-Registration-opposition to grant of patent, anticipation-Revocation of patents- Compulsory licences- Exclusive marketing rights-Infringement- exclusive marketing rights- Patent office and power of Controller, patents of addition-Patenting of biotechnology-Nanotechnology.

UNIT 5 FARMERS AND BREEDERS RIGHT & GEOGRAPHICAL INDICATION

9 Hrs

The Protection of Plant Varieties And Farmers' Rights Act, 2001: object definitions, salient features The Geographical Indications Of Goods (Registration And Protection) Act, 1999- object definitions, salient features

Max. 45 Hrs

COURSE OUTCOME:

CO1:To introduce fundamental aspects of Intellectual property Rights.

CO2:Understanding of the IPR Acts.

CO3:Explain the basic principles of patents, trademarks, geographical designs, industrial designs, and copyright.

CO4:The course follows an international perspective and examines the international IP legal regime rather than focusing solely or predominantly on the national framework.

CO5:Revolves around the protection of plant varieties and farmers right act

CO6: Equip the students with the required Professional Skills.

TEXT / REFERENCE BOOKS

1. V.K. Ahuja, Law Relating to Intellectual Property Law, Lexis Nexis, 2nd ed., 2013.
2. N.S. Gopalakrishnan & T.G. Ajitha, Principles of Intellectual Property, Eastern Book Company, 2nd ed., 2014
3. B.L. Wadhwa, Law Relating to Intellectual Property, Universal Law Publishing, 5th ed., 2014.
4. S. Narayan, Intellectual Property Law in India, Gogia Law Agency, Hyderabad, 3rd ed., 2005.
5. Holyoak & Torremans, Intellectual Property Law, Oxford University Press, New York, 2010.



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SPHB8004	INDUSTRY 4.0	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVES

- To obtain an overview of various renewable energy sources
- Study the exists and gives insight to the actual status of various renewable energy sources.
- Knowledge about Bio energy ocean energy

UNIT 1 ADVANCED TECHNOLOGY AND MATERIALS

9 Hrs.

Advanced electro-optical sensing technology-active, passive multi-spectral and hyper spectral imaging; electronic beam steering; vacuum technology, surface and coating technology, health care technology, Nanotechnology- Nanomechanics,Nano optoelectronics; energy storage technology-next generation Li-based Batteries, Hydrogen storage, solar photovoltaic's, Flexible electronics. Intellectual Property Rights - case studies governing/pertaining to Materials/Technology.

UNIT 2 ADVANCEMENTS IN SUSTAINABLE BUILT ENVIRONMENT

9 Hrs.

Introduction – Technological developments in Architectural, Engineering and Construction (AEC) - Building Information Modelling (BIM) using Cloud computing technology and Internet of things (IoT) – Unmanned Aerial Vehicles, sensors – Additive manufacturing in construction – Concrete 3D printing - Materials used - Lightweight and functionally graded structures - Net Zero Energy buildings, Bioswales, Biofiltration pond, Ecosan systems- Recent developments in Waste water Management, Air pollution control, waste disposal, public health issues-improving water management in surface and overhead irrigation- Integration of energy, water and environmental systems for a sustainable development

UNIT 3 SMART MANUFACTURING

9 Hrs.

Smart factories and interconnection, Smart Manufacturing – automation systems, Additive Manufacturing, Smart grids, Micro Electro Mechanical Systems (MEMS), Stealth technology, Metal Finishing, Self propelled vehicles, e mobility, Green fuels, drones – unmanned aerial vehicles(UAVs), aerodynamics. Robotic Automation and Collaborative Robots – Augmented reality and haptics, engineering cybernetics and artificial intelligence (AI), Disruptive Technologies – Frugal Innovations – Intellectual Property Rights (IPR): Case Studies.

UNIT 4 SMART WORLD

9 Hrs.

Smart Sensors and IIOT, Smart grid, Hybrid renewable energy systems, Electronics in Smart city, Integration of Sensors in Robots and Artificial Intelligence, 5G Technology, Communication protocols, Human-Machine Interaction, Virtual Reality, Quantum Computing: Changing trends in transistor technology: Processor, Intellectual Property Rights- Case Studies.

UNIT 5 CYBER PHYSICAL SYSTEMS

9 Hrs.

Introduction to Cyber Physical Systems (CPS), Architecture of CPS, Data science and technology for CPS, Prototypes ofCPS, Emerging applications in CPS including social space, crowd sourcing, healthcare and human computer interactions, Industrial Artificial Intelligence, Networking systems for CPS applications, Wearable cyber physical systems and applications, Domain applications of CPS: Agriculture, Infrastructure, Disaster management, Energy, Transportation, Intellectual Property Rights (IPR) : CaseStudies.

Max. 45 Hrs

Course Outcomes:

At the course end, the students will be able to

CO1: Understand the advanced Materials/Technology

CO2: Acquire knowledge about environmental systems for a sustainable development

CO3: Covers many different technologies from Smart Manufacturing

CO4: Effectively learning the smart technology

CO5: Understand various modeling formalisms for CPS, such as hybrid automata, state-space methods, etc

CO6: To know about the cyber physical systems.

TEXT / REFERENCE BOOKS

1. William D. Callister, "Materials Science and Engineering, An Introduction, John Willey and Sons Inc.Singapore, 2001.

2.V. Raghavan, "Physical Metallurgy: Principle and Practice,, Prentice Hall India Pvt Ltd, 2006.



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3. Flavio Craveiro, Jose Pinto Duarte, Helena Bartolo and Paulo Jorge Bartolo, "Additive manufacturing as an enabling technology for digital construction: A perspective on Construction 4.0", Automation in Construction, Vol. 103, pp. 251-267, 2019.

END SEMESTER EXAM QUESTION PAPER PATTERN

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SPHB8003	RENEWABLE ENERGY RESOURCES	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVE

- To obtain an overview of various renewable energy sources
- Study the exists and gives insight to the actual status of various renewable energy sources.
- Knowledge about Bio energy ocean energy.

UNIT 1 INTRODUCTION TO ENERGY

9Hrs.

Definition and units of energy, power, Forms of energy, Conservation of energy, second law of thermodynamics, Energy flow diagram to the earth. Origin and time scale of fossil fuels, Conventional energy sources, Role of energy in economic development and social transformation.

UNIT 2 SOLAR ENERGY FUNDAMENTALS

9Hrs.

Solar constant –Solar radiation at the earth's surface – Solar radiation Geometry – Solar Radiation measurements – Estimation of average solar radiation – Solar radiation on tilted surface. Physical principles of the conversion of solar radiation into heat – Flat plate collectors – Transmissivity of the cover system – Energy balance equation and collector efficiency – Concentrating collector – Focusing type – Advantages and disadvantages of concentrating collectors over flat-plate collectors.

UNIT 3 SOLAR ENERGY APPLICATIONS

9Hrs.

Solar photovoltaic – Solar distillation – Solar pumping – Solar furnace – Solar cooking – Solar energy storage systems – Solar pond (quantitative study only). Wind Energy: Basic principles of wind energy conversion – Basic components of wind energy conversion system – Classification of wind energy conversion systems – Wind energy collectors – Performance of wind machines.

UNIT 4 BIO ENERGY

9Hrs.

Biomass conversion techniques – Biogas generation – Factors affecting bio digestion – Classification of biogas plants – Types of biogas plants – Materials used for biogas generation. Geothermal Energy: Nature of Geothermal fields – Geothermal sources – Vapour dominated systems – Liquid dominated systems – Magma resources – Geothermal exploration – Geothermal energy in India.

UNIT 5 OCEAN ENERGY CONVERSION

9Hrs

Ocean Energy: Introduction, Principle of ocean thermal energy conversion (OTEC), Tidal power generation, Tidal energy technologies, Energy from waves, Wave energy conversion, Wave energy technologies, advantages and disadvantages.

Max. 45 Hrs

Course Outcomes:

At the course end, the students will be able to

CO1: Understand the importance of renewable energy sources

CO2: Acquire the knowledge of solar energy

CO3: Learn the solar energy application in different form like solar voltaic, solar furnace, solar energy storage system etc.

CO4: Illustrate the biomass conversion technique and geothermal energy

CO5: Understand the concept of ocean thermal energy and hydrogen energy **CO6:** Knowledge about the natural resources.

TEXT / REFERENCE BOOKS

- G.D.Rai, Non-conventional Sources of energy, Fourth edition, Khanna Publishers, New Delhi, 2000.
- S Rao and Dr.B.B.Parulekar, Energy Technology: Nonconventional, Renewable and Conventional, Third edition, Khanna Publishers, New Delhi, 1999.
- S P Sukhatme, Solar Energy: Principles of thermal collection and storage, 2nd Edn, Tata McGraw-Hill Publishing Co. Ltd.1996. M V R Koteswara Rao, Energy Resources: Conventional and non-conventional BS Publications, 2nd Edn, 2006.



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70Marks



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SPHB5301	MATERIALS PHYSICS & PROCESSING TECHNIQUES	L	T	P	EL	Credits	Total Marks
		3	0	0	0	4	100

COURSE OBJECTIVES

- The syllabus gives a brief idea of the physical parameters and their relevance in our day-to-day life.
- To introduce the students to the principles of batteries, super capacitors and carbon nanotubes.
- To introduce the students to the principles of optical and electron microscopy, X-ray diffraction and various spectroscopic techniques.

UNIT 1 BATTERIES

9 Hrs.

Basic concepts of Batteries, Supercapacitors and Fuel cells, Thermodynamics and kinetics involved in electrochemical reactions, Primary and rechargeable batteries, Li-ion Battery, Components and processes in batteries (Battery operations), Cell characterization: (Charging/discharging cycles, overpotential, battery capacity, state of charge, state of health, impedance spectroscopy), Large scale applications, Plot of Energy Vs Power Density.

UNIT 2 SUPERCAPACITORS

9 Hrs.

Different types of supercapacitors (Electrochemical double layer capacitor, pseudo capacitor and hybrid capacitor), Components of supercapacitors, Electrochemical properties (Charging/discharging cycles, Cyclic Voltammetry and impedance spectroscopy, lifetime stability), Different applications.

UNIT 3 THERMOELECTRIC MATERIALS & CATALYSIS

9 Hrs.

Fundamentals of thermoelectricity, Thermoelectric Effects and Transport Properties, Basics of Thermoelectric devices, Heat Conduction in Bulk Thermoelectric Materials, Thermoelectric Devices. Catalysis-Concepts of Electrocatalysis and Photocatalysis, Basic principles and properties for photocatalytic and electrocatalytic water splitting, Few examples of Electro and photo catalysts.

UNIT 4 CARBON NANO TUBES: INTRODUCTION TO GRAPHENE

9 Hrs.

Structure of graphene; Preparation of graphene Electronic Properties CNT: The Structure of Carbon Nanotubes- Nomenclature, Structure of Single-Walled Carbon Nanotubes and Structure of Multiwalled Carbon Nanotubes; Structure and Production of Carbon Materials- Spectroscopic Properties of Carbon Nanotubes- Raman and Infrared Spectroscopy of Carbon Nanotubes, Absorption and Emission Spectroscopy of Carbon Nanotubes.

UNIT 5 CHARACTERIZATION TECHNIQUES

9 Hrs.

Electron Microscopy: Scanning electron microscopy- Transmission electron microscopy and specimen preparation techniques-, X-ray diffraction techniques, Surface Analysis: Atomic force microscopy, Atomic absorption spectroscopy, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy: Thermo gravimetric analysis, Differential thermal analysis.

Max:45 Hrs

COURSE OUTCOME

On completion of the course, student will be able to

- CO1 - To apply appropriate characterization techniques for microstructure examination at different magnification level and use them
- CO2 - To understand the microstructure of various materials
- CO3 - To choose an appropriate electron microscopy technique to investigate microstructure of materials at high resolution
- CO4 - To Understand the Fundamentals of thermoelectric Effects
- CO5 - To Differentiate the diverse CNT
- CO6 - To Understand the Importance of various characterization Techniques

TEXT BOOK / REFERENCES

- Materials principles and characterization methods by Chen Liao, 2021
- Electrochemical Supercapacitors for Energy Storage and Delivery: Fundamentals and Applications (Electrochemical Energy Storage and Conversion), Aiping Yu, Victor Chabot, Jiujun Zhang



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3. Charge Density and Structural Characterization of Thermoelectric Materials: 1 (Materials Research Foundations), R. Saravanan, 2016

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PART A: 5 Questions of 6 marks each - No choice

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14 marks

70 Marks



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SPHB5205	SEMICONDUCTOR DEVICES & MICROPROCESSOR	L	T	P	EL	Credits	Total Marks
		3	0	0	0	3	100

COURSE OBJECTIVES

- To understand the physics of junction diodes and to learn to implement them in various applications
- To explore the various applications
- To study the modern day transistor technology involving MOS devices

UNIT 1 BIPOLAR TRANSISTORS

9 Hrs.

Bipolar transistor action and minority carrier distribution Field Effect Transistors: JFET; concept and characterization, MOSFET; MOS structure, energy band diagrams, depletion layer thickness-Light- Emitting Diodes: Principles and device structure, Homojunction and Heterostructure LEDs, LED characteristics.

UNIT 2 MODERN DAY TRANSISTOR TECHNOLOGY

9 Hrs.

MOSFET, C-MOS & CCD, HEMT MOSFET structure, MOS capacitor band diagram-quantitative analysis, I-V characteristics, small signal equivalent circuit, C-MOS technology, **CCD structure and its operational principle, CCD applications.**

UNIT 3 OPERATIONAL AMPLIFIER

9 Hrs.

Characteristics, Definitions, Differential amplifier, common mode gain, Differential mode gain, CMRR, Introduction of Feedback principle & properties, Four Basic Feedback Topologies, Voltage series feedback amplifier, Voltage shunt feedback amplifier. Differential amplifier with one op-amp. Op-Amp as an inverter, summer, Integrator, Differentiator.

UNIT 4 POWER ELECTRONICS

9 Hrs.

UJT, Basic construction and working, Equivalent circuit, intrinsic Standoff Ratio, Characteristics and relaxation oscillatorexpression. **SCR, Construction, Working and Characteristics, TRIAC, DIAC, Circuit symbols, Basic constructional features, Operation and Applications.**

UNIT 5 MICROPROCESSOR

9 Hrs.

Microprocessor 8085 (10 Lec) Introduction to microprocessors & microcomputers, Microprocessor Architecture, **Introduction to Assembly language Programming**, Operation Bus, Timing (Read/ Write) Cycles, I/O Addressing.

Max. 45 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Understand the fundamental principles and concepts governing classical nuclear and particle physics and have a

CO2 - working knowledge of their application to real-life problems.

CO3 - Understand alpha, beta and gamma decay theories and how to detect and measure types of radiation.

CO4 - Induce nuclear fission process and their effects.

CO5 - Understand how scattering process, scattering cross section and amplitude will change with respect to various reactions.

CO6 - Understand, how to identify elementary particles based on their properties

TEXT / REFERENCES BOOK:

1. S M Zee, Solid State Devices, Wiley Publication
2. S M Zee, Physics of Semiconductor Devices, Wiley Publication
3. David A.Bell, Electronic Devices and Circuits, Prentice Hall of India, 4th edition, 2003.
4. Jacob Millman, Christos C. Halkias, Electronic Devices and Circuits, Tata McGraw-Hill edition, 1991.
5. Kittel, Solid State Physics, Wiley Publication
6. Robert Boylestad, Louis Nashelsky, Electronic Devices and Circuit Theory, Pearson Education, 9th edition.



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SPHB5105	PHYSICS OF THIN FILMS	L	T	P	EL	Credits	Total Marks
		3	1	0	0	4	100

COURSE OBJECTIVES

- To make the students to understand about the difference between bulk and thin film, the optical, electrical, dielectric and magnetic properties of thin film.
- To understand the theories explaining the formation of thin film
- To know about the fabrication and advantages of thin film devices.

UNIT 1 PHYSICS OF SURFACES, INTERFACES AND THIN FILMS

9 Hrs.

Mechanism of thin film formation: Condensation and nucleation, growth and coalescence of islands, Crystallographic structure of films, Properties of thin films:- Transport and optical properties of metallic, semiconducting and dielectric films; Application of thin films.

UNIT 2 THIN FILMS: FORMATION & MEASUREMENT

9 Hrs.

Vacuum Techniques: Review - Production of low pressures; Measurement of pressure, Leak detections, Materials used Preparation of Thin Films: Thermal evaporation, Cathode Sputtering, Chemical Deposition.

UNIT 3 THICKNESS MEASUREMENT

9 Hrs

Stylus Method, Electrical Method, Quartz Crystal Method, Optical Methods, mass measurements (microbalance), Stress measurement by optical method, Gravimetric method.

UNIT 4 PROPERTIES OF THIN FILMS

9 Hrs.

Electrical Properties: Source of Resistivity in Metallic conductors, Influence of thickness on the resistivity of thin films, Magneto resistance in thin films, Fuch-Sondheimer theory, TCR and its effects. Mechanical properties: Adhesion & its measurement with mechanical and nucleation methods, stress measurement by using optical method.

UNIT 5 EMERGING THIN FILM MATERIALS AND APPLICATIONS

9 Hrs.

Patterning techniques (Photolithography), Diamond Films, Thin film resistors, capacitors, Junction devices (Diodes, Transistors, Solar cells), ICs, Thin film sensors (gas and humidity), Thin films for information storage (Magnetic and optical recording), Metallurgical applications, Photo thermal converters, Optical coatings.

Max. 45 Hrs

COURSE OUTCOMES

By the end of this course students will be able to:

- CO1 - Apply the knowledge of basic principles of material science in thin film technology.
- CO2 - Use various techniques to synthesize thin films of desired characteristics.
- CO3 - Characterize thin films employing various techniques
- CO4 - Acquire skills required for entrepreneurship or jobs in the field of thin films
- CO5 - Make applications of thin films for devices fabrication.
- CO6 - Acquire the knowledge of thin film materials.

TEXT / REFERENCES BOOKS

1. K.L. Chopra, "Thin Film Phenomena", First Edition, McGraw-Hill, 1969.
2. George Hass, "Physics of Thin Films", Volumes 1, Academic Press Inc., 1963.
3. K. L. Chopra and S. R. Das, "Thin Film Solar Cells", Springer, 1983.
4. L. I. Maissel and Glang, "Handbook of Thin Film Technology", McGraw Hill Higher Education, 1970.
5. J. C. Anderson, "The Use of Thin Films in Physical Investigation", Academic Press Inc., 1966.
6. J. J. Coutts, "Active and Passive Thin Film Devices", Academic Press Inc., 1978.



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7. R.W. Berry, P.M. Hall and M.T. Harris, "Thin Film Technology", Van Nostrand, 1968.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100

3 Hrs.

Exam Duration:

PART A: 5 Questions of 6 marks each - No choice

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14 marks

70 Marks



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SPHB5104	INDUSTRIAL ELECTRONICS	L	T	P	EL	Credits	Total Marks
		4	0	0	0	4	100

COURSE OBJECTIVES

- To be able to describe in detail the inherent behavior and functionality of the many different types of modern lasers.
- To be able to formulate reasonably complicated problems in laser physics.
- Provide solutions to the complicated problems.

UNIT 1 AMPLIFIERS

9 Hrs.

Basic amplifier concept using BJT-CE mode.- reason for wide use of CE amplifier .concept of DC and AC load line- the Q-point- thermal runaway- need for proper biasing in amplifier circuits.-types of biasing circuits- stabilization in amplifier circuits- various stability factors.

UNIT 2 TRANSISTORS

9 Hrs.

Compare JFET and BJT- principle of operation of n-channel JFET -drain characteristics of JFET- pinch- off voltage of JFET- Important parameters of JFET -JFET classification -Construction and principle of - MOSFET.-Explain the construction and principle of operation of enhancement type MOSFET. - JFET and MOSFET Comparison - Principle of operation of CMOSFET.

UNIT 3 SEMICONDUCTING DEVICES

9 Hrs.

Optical absorption in a semiconductor, Solar cells - p-n junction, conversion efficiency, Photo detectors- photo conductors, photodiode, p-i-n diode-applications.

UNIT 4 OPTICAL DEVICES

9 Hrs.

Light emitting diode (LED) - generation of light, internal and external quantum efficiency. Modern semiconducting devices: CCD - introduction to nano devices, fundamentals of tunneling devices, design considerations, physics of tunneling devices.

UNIT 5 WIRELESS COMMUNICATION

9 Hrs.

Fundamental concepts in wireless, Basic Terminologies, cellular technology, Standards evolved, Mobile Radio Propagation, Mobile System and Network Architectures, Advanced Wireless IP network Architectures, Wireless Standards.

Max. 45 Hrs

COURSE OUTCOMES

By the end of this course students will be able to:

- CO1** - Explain the operational principles and construction of lasers
- CO2** - Describe optical components that can be used to tailor the properties of the laser
- CO3** - Distinguish between the different optical cavities/resonators.
- CO4** - Describe the conditions of producing a laser beam.
- CO5** - Describe how pulsed laser beams can be obtained from a laser cavity.
- CO6** - Acquire the knowledge of wireless communication.

TEXT / REFERENCES BOOKS

- Charles A. Schuler and William.L. Mc. Namee, "Industrial Electronics and Robotics", International McGraw Hill, 1986.
- S. K. Bhattacharya and S. Chatterjee, "Industrial Electronics & Control", Tata Mc Graw Hill, 2003.
- Terry. L. M. Bartell, "Industrial Electronics", Delmer Publishers, 1997.
- Thomas. E. Kissell, " Industrial Electronics", 2002.



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END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100

Exam Duration: 3 Hrs.

PART A: 5 Questions of 6 marks each - No choice

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14 marks

70 Marks



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SPHB3008	BIO PHYSICS	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVES:

- To emphasize the importance of different biomaterials in application.
- Understanding the problems in biology and medicine.
- Motivate the students to pursue research in the field of biophysics.

UNIT 1 MODERN BIOLOGY

(9 Hrs)

The reductionist program in biology - the use of physics and chemistry in biology - introduction to modern molecular biology - elementary description of the cell - DNA, proteins and the molecules of Life - the central dogma of information transfer within a cell - introduction to Darwinian evolution and prebiotic evolution.

UNIT 2 SEPARATION TECHNIQUES AND PHYSICO-CHEMICAL TECHNIQUES

(9 Hrs)

Chromatography - column chromatography - thin layer chromatography - Ion exchange, molecular exclusion and partition chromatography - electrophoresis - gel electrophoresis - SDS - PAGE - hydration of molecules - role of friction - diffusion - sedimentation - ultracentrifuge - viscosity - rotational diffusion - light scattering.

UNIT 3 EXPERIMENTAL TECHNIQUES

(9 Hrs)

General Introduction To Spectroscopic Techniques In Biology - UV - Visible Spectroscopy - Applications And Results In Biology - IR And Raman Spectroscopy - Applications And Results - Circular Dichroism And Optical Rotatory Dispersion - Fluorescence Spectroscopy - NMR - Use Of NMR In Biological Structure Determination And Medical Imaging - X-Ray Crystallography, Its Use To Determine The Structures Of Biological Molecules.

UNIT 4 STRUCTURES OF BIOLOGICAL MOLECULES

(9 Hrs)

Level of protein structure - amino acids and the primary structure of proteins - the peptide bond and the secondary structure of proteins - the Ramachandran Plot - tertiary and quaternary structure of proteins - the double helical structure of DNA - how it explains DNA function - the structure of viruses.

UNIT 5 BIOMECHANICS, NEURO- BIOPHYSICS

(9 Hrs)

Contractile proteins - mechanical properties of muscles - contraction mechanism - the cardiovascular system - blood pressure - electrocardiography - the nervous system, CNS and PNS - nerve cells - membrane potentials - sensory mechanisms - eye and ear - signal transduction.

Max. 45 Hrs

Course Outcomes:

Upon successful completion of this course students will be able to

CO1: Understand to modern molecular biology.

CO2: Know the principles of Separation techniques and physico - chemical techniques

CO3: Use spectroscopic techniques in biology

CO4: Explain Level of protein structure

CO5: Understand the Biomechanics of heart, eye, ear, nervous system

CO6: Identify the knowledge of the medical physics and their applications in various fields.

TEXT / REFERENCE BOOKS

1. VasanthaPattabhi and N. Gautham , Biophysics, Narosa Publishing Company, New Delhi, 2001.
2. P. Narayanan,. Introductory Biophysics, New Age Publishing Co., Mumbai. India, 1999.
3. E. Ackerman, L.B.M. Ellis and L.E. Williams, Biophysical Science, Prentice Hall Inc., New Jersey, USA, 1979.
4. C.N. Banwell, Fundamentals of Molecular Spectroscopy, Tata: McGraw Hill Publishing Co., Ltd., New Delhi, India, 1983.
5. C.R. Cantor and P. Schimmel, Biophysical Chemistry, Vol.I, II and III, W.H. Freeman and Co. New York, U.S.A. 1985.



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END SEMESTER QUESTION PAPER PATTERN

Max. Marks: 100

Exam Duration: 3 Hrs.

PART A: 6 Questions of 5 mark each - No choice.

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14 marks.

70 Marks



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SPHB3005	FUNDAMENTALS OF AGRICULTURAL PHYSICS	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVE

- The objective of this discipline is to educate students on
- Understanding of climate and weather elements, principles and processes, and their impact on agricultural activities.
- Agricultural Physics deals with the application of physical principles and processes in agriculture.

Unit I: Basic concepts of physics

9 hrs

Importance of physics related to agriculture- physical laws – Brownian movement – Tyndall effect – Raman Effect Spectroscopy – Adhesion and Cohesion properties – relevant to agriculture

Unit II: Soil physics

9 hrs

Soil moisture movement – physical classification of soil moisture – soil air movement – thermal diffusion in soils – thermal properties of soils – heat capacity – heat conductivity – specific heat. (6 Lectures)

Unit III: Nanophysics

9 hrs

Nano particles – physical properties of nanoparticles – Moore's law – semi conductors – diode – biosensors – quantum dots – working principles of Transmission Electron microscope – Scanning Electron Microscope – Scanning Tunneling

Unit IV: Soil

9 hrs

Plant - water continuum – capillary movement of water in soil and plant – tortuosity of water in soils – Hysteresis effect – osmosis – diffusion. (6 Lectures)

Unit V: Physical constraints in agriculture

9 hrs

Soil constraints – impermeability of soil – compaction methods – physical constants of soils – Soil physics as a factor in soil management.

Max. 45 Hours

Course outcomes:

CO1: Agrophysics is a science that studies physical processes

CO2: To know the properties affecting plant production.

CO3: The knowledge of physical phenomena in agricultural environment

CO4: It creates increasing efficiency of use of water and chemicals in agriculture and

CO5: Understanding the decreasing biomass losses during harvest, transport, storage, and processing.

CO6: They understand about the soil characteristics before starts cultivating,

CO7: To understand about the constraints of soil in agriculture

TEXT / REFERENCE BOOKS

1. William Lambe, T. and Robert V. Whitman. 1979. Soil Mechanics. Wiley Eastern Ltd. New Delhi.
2. Helmut Kohnke, 1979. Soil Physics. Tata McGraw-Hill Publishing Company Ltd. New Delhi.
3. Biswas, T.D. and Mukherjee, S.K. 1997. Text book of soil science. Tata McGraw-Hill Publishing Company Ltd. New Delhi.
4. Chinnamuthu, C.R., B.Chandrasekaran and C.Ramasamy, 2007. Nanotechnology Applications in Agriculture. TNAU Offset & Printing Press, Directorate of Open and Distance Learning, TNAU, Coimbatore.



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END SEMESTER EXAM QUESTION PAPER PATTERN

Max. Marks: 100

Exam Duration: 3 Hrs.

PART A: 6 Questions of 5 mark each - No choice.

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14

70 marks.



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SPHB3004	BASIC INSTRUMENTATION SKILLS	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVES

- To make the student familiar with measurement techniques of force, torque and speed
- To make the student familiar with measurement techniques of acceleration, Vibration and density
- To make the student familiar with pressure measurement techniques

UNIT I BASIC CONCEPT OF INSTRUMENTATION

9 HRS

Basic concepts of Instrumentation: Methods of measurement-direct method, indirect method, mechanical, electrical and electronic instruments; Measurement systems: static characteristics- accuracy, sensitivity, linearity, precision, resolution, threshold, range, hysteresis, drift; dynamic characteristics -measuring lag fidelity, speed of response, dynamic error; Definition and type of errors- systematic errors, instrumental errors, environmental errors, random errors; propagation of error; Error calculation.

UNIT II MEASUREMENT OF FORCE, TORQUE, SPEED, ACCELERATION

9 HRS

Force and torque measurement: Load cell, Different types of load cells: Hydraulic, Pneumatic, Magneto-elastic and Piezoelectric load cells (concept); Strain gauge- concept and required mathematical expression for measurement of force and torque; Speed measurement- capacitive tachometer, DC and AC tacho generators; Acceleration measurement – LDVT accelerometer and its mathematics, particle accelerometer.

UNIT III TEMPERATURE AND PRESSURE MEASUREMENT

9 HRS

Definition, standards and different temperature scales; Bimetallic thermometer, Resistance thermometers; Thermistors- types and their mathematical expression for R-T variation; Thermocouples- types, laws of thermocouple, cold junction compensation; Thermopiles in series and parallel connection; Pyrometer- radiation type; IC temperature sensors. Pressure - Definition and unit, Direct and indirect pressure gauges; Manometer types, U-tube manometer with derivation of pressure; Elastic type pressure transducer (concept); Electric pressure transducer – capacitive, resistive; Vacuum gauges- McLeod gauge with derivation of unknown pressure; Thermocouple gauge; hot and cold cathode ionization gauge.

UNIT IV MEASUREMENT OF FLOW, LEVEL, DENSITY, VISCOSITY, HUMIDITY

9 HRS

Types of flowmeter, Bernoulli's principle in flow measurement; Differential flowmeter- orifice plate, venturi tube; Electromagnetic flowmeter with mathematical expression of flow rate; Ultrasonic flowmeter; Level measurement- float gauge, resistive type level indicator, ultrasonic level gauging; Density measurement- hydrometer, Radioactive densitometer, gas densitometer; Viscosity measurement- Saybolt viscometer, rotameter type; Humidity measurement- Hygrometer (resistive and capacitive type); Electrolytic hygrometer.

UNIT V DIGITAL MEASUREMENT AND DISPLAYS

9 HRS

Digital Instruments: Block diagram, principle of operation and accuracy of measurement of -Digital Multimeter, Kilowatt Hour meter, Digital Tachometer, Ultrasonic Distance meter, Digital Thermometer, Frequency meter. Seven segment digital display devices- construction and operation.

Max. 45 Hours

COURSE OUTCOMES:

- CO1:** Applying the concept of measurement, error calculation while performing experiments practically
- CO2:** Acquire a detailed knowledge of industrial measurement
- CO3:** An exposure to various available techniques of temperature and pressure measurement
- CO4:** A detailed knowledge of fluid property measurement will be obtained
- CO5:** An idea of newly evolving digital measurement techniques is gained.
- CO6:** To handle the Thermometer and other devices.

TEXT / REFERENCE BOOKS

1. Patranabis D., "Principles of Industrial Instrumentation", Tata McGraw Hill, II Edition, New Delhi, Reprint 2009.
2. Singh. S.K., "Industrial Instrumentation & Control" 3rd Edition, Tata McGraw Hill, Reprint 2009.
3. Krishnaswamy. K & Vijayachitra. S, "Industrial Instrumentation" New age International, Reprint 2008.
4. Ernest O. Doebelin, Dhanish. N. Manik, "Measurement Systems Application & Design", TMH, 5th Edition, 2004.
5. Jain R.K, "Mechanical & Industrial Measurements", Khanna Publishers, 11th Edition, 2004.



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6. [T. S. Rathore](#), "Digital Measurement Techniques" CRC Press, 2003.

END SEMESTER EXAM QUESTION PAPER PATTERN

Max. Marks: 100

Exam Duration: 3 Hrs.

PART A: 6 Questions of 5 mark each - No choice.

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14

70 Marks.



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SPHB3002	DIGITAL, ANALOG AND MICROPROCESSOR SYSTEM	L	T	P	EL	C
		3	0	0	0	3

COURSE OBJECTIVES

- It introduces to the fundamentals of diode theory, P.N junctions and bipolar junction transistor (BJT).
- It covers the basics and design of field effect transistors (FET) and transistors amplifiers.
- It explains the various feedback transistor and operational amplifiers.

UNIT I: P-N Junctions and Bipolar Junction Transistors (BJT)

9 Hrs

Diode theory, forward and reverse-biased junctions, reverse-bias breakdown, diode applications - clippers, clampers, voltage multipliers, half wave & full wave rectification, Special purpose diodes - Zener diode, Varactor, light emitting diodes, Laser diodes, Transistor fundamentals, transistor configurations, DC operating point, BJT characteristics & parameters.

UNIT II: Field-Effect Transistors (FET) and Transistors Amplifier

9 Hrs

JFET- current-voltage characteristics, Small Signal BJT amplifiers: AC equivalent circuit, hybrid, re model and their use in amplifier design, Multistage amplifiers, frequency response of basic & compound configuration, Power amplifiers: Class A, B, AB, C and D stages, IC output stages.

UNIT III: Feedback & Oscillator Circuits and Operational Amplifiers

9 Hrs

Effect of positive and negative feedbacks, basic feedback topologies & their properties, Analysis of feedbacks, Sinusoidal Oscillators (RC, LC and Crystal), Multivibrators, The 555 timer, Op-Amp Basics, practical Op-Amp circuits, differential and Common mode operation, Inverting & Non Inverting Amplifier, differential and cascade amplifier, Op-Amp applications.

UNIT IV: Number Systems and Boolean Algebra

9 Hrs

Decimal, binary, octal, hexadecimal number system and conversion, binary weighted codes, signed numbers, 1s and 2s complement codes, Binary arithmetic, Binary logic functions, Boolean laws, truth tables, associative and distributive properties, DeMorgans theorems, realization of switching functions using logic gates.

UNIT V: Introduction to Microprocessor

9 Hrs

Basics of microcomputer - block diagram - types of memories - ROM - PROM - EPROM -EEPROM - dynamic RAM - static RAM 8085 microprocessor architecture - address, data and control buses - flag registers - generation of control signals - demultiplexing of address and data lines - interrupt signals - types of interrupt - hardware and software interrupts, multiple interrupts and priorities - stack and subroutine

Max. 45 Hrs

COURSE OUTCOMES

By the end of this course students will be able to

- CO1: Understand the fundamentals of diode theory, P.N junctions and bipolar junction transistor (BJT).
- CO2: Understand the basics and design of field effect transistors (FET) and transistors amplifiers.
- CO3: Study the principle and working of various feedback transistor and operational amplifiers.
- CO4: Acquire basic knowledge on various number systems and Boolean algebra.
- CO5: Acquire a broader understanding on analysis and
- CO6: Design of combinational logic systems.

TEXT / REFERENCE BOOKS

1. A.S. Sedra&K.C.Smith, Microelectronics Circuits, Oxford University Press (1997)
2. A.P. Malvino, Electronic Principles, Tata Mcgraw Hill Publications
3. Robert L. Boylestad& Louis Nashelsky, Electronic Devices & Circuit Theory
4. William Kleitz, Digital Electronics, Prentice Hall International Inc.
5. M. S. Tyagi, Introduction to Semiconductor Materials and Devices, John Wiley & Sons Inc.
6. Michael Shur, Introduction to Electronic Devices, John Wiley & Sons Inc., 2000.
7. R. T. Howe and C. G. Sodini, Microelectronics: An Integrated Approach, Prentice-Hall Inc. 1997.



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END SEMESTER EXAM QUESTION PAPER PATTERN

Max. Marks: 100

Exam Duration: 3 Hrs.

PART A: 10 Questions of 2 mark each - No choice.

30 Marks

PART B: 2 Questions from each unit of internal choice, each carrying 14 marks.

70 Marks



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SPHB1401	OPTICS	L	T	P	EL	Credits	Total Marks
		3	0	0	0	3	100

COURSE OBJECTIVE

- To learn the fundamental principles of optics.
- To be able to make approximate judgments about optical and other wave phenomena when necessary.
- To provide basic concepts of optics with interdisciplinary importance

UNIT 1 GEOMETRICAL OPTICS

9hrs

Propagation of light - Reflection, Refraction, Snell's Law (Basic definitions) - Thin lens equation - compound thin lenses - Thick lens formula - Power of a thick lens - Lens combination - Spherical aperture and stops - Single lens magnifier - Single lens camera - Two lens optical systems - The Microscope - The Telescope - Telephoto Lens.

UNIT 2 LENS ABERRATIONS

9hrs

Optical Aberration - Spherical aberration and lenses - Methods of minimizing spherical aberration - Condition for minimum spherical aberration in the case of two lenses separated by a distance - Chromatic aberration in lenses - Condition for achromatism of two thin lenses (in contact and out of contact) - coma - astigmatism - Curvature of the field.

UNIT 3 LIGHT WAVES

9hrs

Electromagnetic waves and characteristics - Maxwell's equation - The wave equation - plane wave solution - spherical and cylindrical wave solutions - energy density and Poynting vector - Dispersion produced by a thin prism - Angular dispersion - Dispersive power - Cauchy's formula

UNIT 4 INTERFERENCE

9hrs

Coherent sources and their production; Conditions for observing interference (mention); Conditions for constructive and destructive interference (mention) - Air wedge - Determination of diameter of a thin wire by air wedge - Test for optical flatness - Haidinger's fringes - Michelson's Interferometer - Theory - Applications - thickness of thin transparent material and resolution of spectral lines - Brewster's fringes - Jamin's & Rayleigh's Interferometers - Stationary waves in light - Colour photography (principle only), Holography (principle only).

UNIT 5 POLARIZATION AND DIFFRACTION

9hrs

Newton's corpuscular theory - Double refraction - Nicol prism - polarizer and analyzer - Huygen's explanation of double refraction in uniaxial crystals - Dichroism - Polaroids and their uses - Double image polarizing prisms - Fresnel diffraction - Diffraction at Circular aperture, Straight edge and Narrow wire - Fraunhofer diffraction - single slit - Double slit - Plane diffraction grating - theory and experiment to determine wave length.

Max. 45 Hrs

Course Outcomes

On completion of the course, student will be able to

CO1 - Understand the physical significance of Maxwell's equations and hence estimate the speed of light.

CO2 - To understand the various types of optical aberration.

CO3 - To know about the basics of electromagnetic waves and their characteristics.

CO4 - To know the principle of air wedge and Jamin's & Rayleigh's interferometers.

CO5 - To understand the basics of polarization and applications of polarization.

CO6 - To understand the basics of diffraction and applications of diffraction.

TEXT BOOK / REFERENCES

- Optics by Subramaniam, N. Brij Lal, S. Chand & Co. Pvt. Ltd., New Delhi.
- Optics by Khanna D.R. & Gulati H.R., R. Chand & Co. Pvt. Ltd., New Delhi.
- Optics by K.K. Sharma, Elsevier, New Delhi, 2006.
- Optics by Eugene Hecht, Tata McGraw Hill, New Delhi, 2011.



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Max. Marks : 100

Exam Duration : 3 Hrs.

PART A : 10 Questions of 2 marks each-No choice

20 Marks

PART B: 2 Questions from each unit with internal choice, each carrying 16 Marks

80 Marks