Rayat Shikshan Sanstha's

# YASHAVANTRAO CHAVAN INSTITUTE OF SCIENCE, SATARA

## (An Autonomous College)

**Reaccredited by NAAC with 'A+' Grade**

## New Syllabus For

## Master of Science

## Part - II

## Physics

## Syllabus

## to be Implemented from June, 2022 onward

**M.Sc. Part II Semester III**

| Nature of the Course | Course code | Name of the Course |
|---|---|---|
| Theory | MPT 301 | Experimental Techniques |
| | MPT 302 | Electro-dynamics |
| | MPT 303 | Solid State Physics- II (Semiconductor Physics) |
| | **Elective Paper** | |
| Theory | MPT 304A | Nanoscience and Nanotechnology |
| | MPT 304B | Optoelectronics and Photonics |
| Practical | MPP 305 | **SSPLAB I** |
| | MPP 306 | **SSPLAB II**+ Project |

**Semester IV**

| Nature of the Course | Course code | Name of the Course |
|---|---|---|
| Theory | MPT 401 | Nuclear and ParticlePhysics |
| | MPT 402 | Solid State Physics –III(Thin Solid Films: Deposition andProperties) |
| | MPT 403 | Solid State Physics- IV(Energy Conversion and Storage Devices) |
| | **Elective** | |
| Theory | MPT 404A | i) Electronic Devices |
| | MPT 404B | Laser Physics Special |
| Practical | MPP 405 | PRACTICAL COURSE : LAB III |
| | MPP 406 | PRACTICAL COURSE : LAB IV+Project |

## SEMESTER III

### MPT 301: EXPERIMENTAL TECHNIQUES

**Course Objectives: S**tudent will able to :-

1. understand the low pressure production techniques, measurement of low pressure
2. understand low temperature production and its devices.
3. study the working of Atomic Absorption Spectrometry (AAS).
4. understand various spectroscopy and resonance techniques.

| **Credits=4** | **SEMESTER-III**<br>**MPT 301: EXPERIMENTAL TECHNIQUES** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I UNIT I** | **Vacuum Techniques** | **(15)** |
| | Production of low pressures: Rotary Pump, Diffusion Pump, Sputter ion pump, Measurement of low pressure: McLeod Gauge, Pirani Gauge, Thermocouple gauge and Penning gauge. Leak detection: Simple methods of LD, Palladium barrier and Halogen leak detectors. | |
| **Credit –1 UNIT II** | **Low Temperature Techniques** | **(15)** |
| | Introduction, Production of low temperatures: Adiabatic cooling, The Joule-Kelvin expansion & Joule-Kelvin Coefficient, Adiabatic demagnetization, 3He cryostat, The dilution refrigerator,Principle of Pomerunchuk cooling, Principle of nuclear demagnetization. Measurement of low temperature, Gas thermometer, Resistance thermometer, Vapour pressure thermometer. *(relevant & necessary points added)* | |
| **Credit – 1UNIT III** | **Atomic Absorption Spectrometry (AAS)** | **(15)** |
| | Principle and block diagram of AAS, Operation, Monochromator action, Modulation. Apparatus: Double beam instrument, Radiation sources, Aspiration and Atomization; Interferences, Control of AAS parameters, Reciprocal sensitivity and Detection limit | |
| **Credit –1 UNIT IV** | **Spectroscopy and Resonance Techniques** | **(15)** |
| | Infrared spectroscopy: Instrumentation, Sample holding techniques, FTIR, Applications. Raman Spectroscopy: Quantum theory of Raman scattering, Raman spectrometer, Nuclear Magnetic Resonance: Resonance condition, NMR Instrumentation, Electron Spin Resonance: Principle of ESR, ESR Spectrometer.<br>Spectrometer. | |

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**Learning outcomes:** Students should able to

1. understand low pressure production techniques, measurement of low pressure and explain leak detection.
2. understand low temperature production, measurement of low pressure and cryostat.
3. understand principle and operation AAS, atomization.
4. differentiate Infrared spectroscopy, Raman Spectroscopy, Nuclear Magnetic Resonance, Electron Spin Resonance.

**Reference Books:**


1. K. MuraleedharVarier, Antony Joseph, P PPradhunam. 2018, *Advanced Experimental Techniques in Modern Physics* , Reprint, PragatiPrakashan.
2. Robert B. Braun, 2019, *Principles of Instrumental Analysis*.Secondedition , BSP BOOKS.
3. G. Aruldhas 2014, *Molecular Structure and Spectroscopy* ,second edition Prentice Hall India Learning Private Limited.
4. O.V.Lounasmaa, 1974, *Experimental principles & methods below 1K*, Academic Press.
5. J.Yarwood,1967, *High vacuum technique*s, 4th edition, Chapman & Hall.


# MPT 302: Electrodynamics

**Learning Objectives:** Students will able to

**1**. understand Maxwell's equations and applications.

2. study E.M. wave equations in waveguide.

3. study scalar and vector potentials.

4. understand field charge and its applications**.**

| **Credits=4** | **SEMESTER-III**<br>**MPT 302: Electrodynamics** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I UNIT I** | **Time Varying Fields** | **(15)** |
| | Time dependents field, Faraday's law for stationary and moving media, Maxwell's displacement current, Differential and Integral forms of Maxwell's equations, Maxwell's equation for moving medium, microscopic and macroscopic forms in Maxwell's equation. (B. B. Laud 144-165)<br>a. | |
| **Credit –1 UNIT II** | **Electromagnetic Waves and Waveguides** | **(15)** |
| | Introduction, differential equation of skin depth ,E.M. wave equations in | |

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|---|---|---|
| | waveguide of the arbitrary cross section: TE and TM modes; Rectangular and circular waveguides,hybrid modes, Elliptical waveguide | |
| **Credit – 1UNIT III** | **Time –Dependent Potentials and Fields** | **(15)** |
| | Scalar and vector potentials: coupled differential equations, Gauge transformations: Lorentz and Coulomb Gauges, Retarded Potentials, Lienard –Wiechert Potentials, Fields due to a charge in the arbitrary motion. (Griffiths P. 436-465, Jackson P.237-240 ) | |
| **Credit – 1UNIT IV** | **Radiation from Accelerated Charges and Radiation Reaction** | **(15)** |
| | Fields of charge in uniform motion, applications to linear and circular motions: cyclotron and synchrotron radiations, Power radiated by point charge – Larmor's formula, Angular distribution of radiated power, Cerenkov radiation and Bremsstrahlung (qualitative treatments). Radiation Reaction: criteria for validity, Abraham –Lorentz formula, Physical basis of radiation reaction – self force. (S.P. Puri P.12.1-12.30) | |

**Learning Outcomes :** Student should able to

1. understand the idea of waveguides.
2. differentiate Gauge transformations: Lorentz and Coulomb Gauges.
3. understand the concept of Fields of charge in uniform motion.
4. analyze power radiated by point charge – Larmor's formula.

**Reference books:**


1.S.P. Puri.2011.Classical Electrodynamics.3rd edition, Oxford:Narosa Publication

2. D.J. Griffiths.2002. Introduction to Electrodynamics. Upper Saddle River, 2nd edition, NJ : Prentics Hall

3. J. D. Jackson.2017.Classical Electrodynamics 2nd edition Singapore : John Wiley & Sons, Wiley Eastern

4. B. B. Laud.1988.Electromagnetics. New Delhi : Wiley Eastern


## MPT 303: SOLID STATE PHYSICS-II
## (Semiconductor Physics)

**Learning Objectives:**Students will able to

1. understand the energy bands in solids, direct and indirect semiconductors and Fermi level.
2. understand optical absorption, quasi Fermi levels and diffusion and drift of carriers.
3. study concept of p-n junction, Zener and avalanche breakdown.
4. study properties of photodiodes, photodetectors and Lasers.

| **Credits=4** | **SEMESTER-III** **MPT 303: SOLID STATE PHYSICS-II** | **No. of hours per** |
|---|---|---|

| | (Semiconductor Physics) | unit/ credits |
|---|---|---|
| **Credit –1 UNIT I** | **Energy Bands and Charge Carriers in Semiconductors** | **(15)** |
| | Bonding forces and energy bands in solids, Direct and Indirect semiconductors, Variation of energy bands with alloy composition, Charge carriers in semiconductors: electrons and holes, Effective mass, Intrinsic and Extrinsic materials, Electrons and holes in quantum wells, The Fermi level, Carrier concentration at equilibrium, Temperature dependence of carrier concentration, Space charge neutrality, Conductivity and Mobility, Drift and Resistance, Effects of temperature and doping on mobility, High field effects. | |
| **Credit –1 UNIT II** | **Excess Carriers in Semiconductors** | **(15)** |
| | Optical absorption, Luminescence, Direct recombination of electrons and holes, Indirect recombination and trapping, Steady state carrier generation and Quasi Fermi levels, Diffusion processes, Diffusion and Drift of carriers, Built-in fields, The continuity equation, Steady state carrier injection, Diffusion length, The Haynes-Shockley experiment. | |
| **Credit – 1UNIT III** | **Junctions** | **(15)** |
| | The p-n junction and it's fabrication, Thermal oxidation, Diffusion, The contact potential, Space charge at a junction, Qualitative description of current flow at a junction, Carrier injection, reverse bias breakdown, Zener and Avalanche breakdown**,** Capacitance of p-n junction**,** Schottky Barriers, Rectifying contacts, Ohmic contacts, Idea of homojunctions and heterojunctions. | |
| **Credit – 1UNIT IV** | **Optoelectronic Devices** | **(15)** |
| | Photodiodes: Current and Voltage in an illuminated Junction, Photodetectors: Gain, Bandwidth and Signal-to-Noise Ratio, Light-Emitting Diodes, Lasers: Semiconductor Lasers: Population Inversion at a Junction, Emission Spectra for p-n Junction Lasers, The Basic Semiconductor Laser, Heterojunction Lasers, Materials for Semiconductor Lasers**,** Energy level diagram of lasers and metastable states. | |

**Learning outcomes:** Students should able to

1. differentiate energy bands in solids, direct and indirect semiconductors concept of Fermi level.
2. understand optical absorption phenomenon, quasi Fermi level, diffusion and drift of carriers in semiconductors.
3. understand fabrication of p-n junction, Zener and avalanche breakdown, rectifying and ohmic contacts.
4. analyse properties of photodiodes, photodetectors, Lasers.

**References:**

1. Sanjay Banerjee, Ben G. Streetman, *Solid State Electronic Devices* (United Kingdom: Pearson, 2015) (Unit I, II, III, IV)
2. S. M. Sze, *Semiconductor Devices:Physics And Technology* 2nd Ed. (India: Wiley India Pvt. Limited, 2008) (Unit I, II, III, IV)
3. John Philip McKelvey, *Solid State and Semiconductor Physics* (United States: Krieger Publishing Company, 1982) (Unit II)
4. M. S. Tyagi, *Introduction To Semiconductor Materials And Devices* (India: Wiley India Pvt. Limited, 2008) (Unit III)
5. G. D. Baruah, *Lasers and nonlinear optics*, A Pragati Edition (Unit IV)
6. M. A. Wahab, *Solid State Physics*, (Narosa Publishing House Pvt. Ltd., 2015) (Unit I, II, III, IV)

## MPT 304A: NANOSCIENCE AND NANOTECHNOLOGY

**Learning Objectives:** Students will able to

1. study of nanoscience and its technological aspects.
2. understand the dimensions dependent properties of nanoscale materials.
3. study to familiarize with current and recent scientific and technological developments in nanotechnology based devices.
4. study the applications of nanomaterials in various fields.

| **Credits= 4** | **SEMESTER-III<br>MPT 304A: NANOSCIENCE AND NANOTECHNOLOGY** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I UNIT I** | **Quantum Mechanics of Low Dimensional Systems**: | **(15)** |
| | History and Introduction of Nanoscience and Nanotechnology, Density of states in Three Dimensional, Two-Dimensional, One-Dimensional and Zero-Dimensional Systems,Quantum Confinement in Quantum Wells, Quantum Wires, Quantum Dots, Summary. | |
| **Credit – 1 UNIT II** | **Properties of nanomaterials**: | **(15)** |
| | Mechanical properties, Structural properties, Electrical conductivity, Optical properties and Melting point of materials, Semiconductor | |

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| | materials, Luminescence in semiconductor materials.<br>**Special Nanomaterials**: Graphene, Carbon nanotubes and Types (CNT), Fullerenes, Aerogels, Core Shell Nanostructures. | |
| **Credit – 1 UNIT III** | **Magnetic Properties of nanomaterials:** | **(15)** |
| | Magnetism, Types of magnetic materials, Effect of Nanostructuring on magnetic properties, Dynamics of Nanomagnets, Giant and colossal magnetoresistance, Ferrofluids, Nanomagnetic Materials, Exchange interactions. | |
| **Credit – 1 UNIT IV** | **UNIT IV: Transport properties of Nanomaterials:** | **(15)** |
| | Excitons in nanomaterials, Coulomb Blockade, Coulomb Blockade in a tunnel junction, Observing the Coulomb Blockade, Quantum Transport in Quantum dots, Single electron transistor, Spin polarized transport, Spin logic, Spin field effect transistor (Spin-FET), Spin Diodes. | |

**Learning Outcomes:** Students should able to

1. differentiate the change in the properties of materials from bulk to nano level and quantum confinement in 0 D, 1 D and 2 D Materials.
2. understand technological importance of nanomaterials and replacement of bulk materials.
3. understand different applications of nanomaterials.
4. alnalyze pursue further higher education and research in Nanoscience and Nanotechnology.

**References**:


1. M.S. Ramachandra Rao and Shubra Singh, Nanoscience and Nanotechnology: Fundamentals to Frontiers (Wiley, 2013) 10-108. (Unit I,II,III,IV)
2. K. K. Choudhary, Nanoscience and Nanotechnology; (New Delhi, Narosa Publishing House Pvt. Ltd., 2016) 33-62. (Unit I,IV)
3. Sulabha K. Kulkarni, Nanotechnology: Principles and Practices; (Capital Publishing Company, 2017). 53-154. (Unit II,III)
4. Charles P. Poole Jr., Frank J Owens,,Introduction to Nanotechnology (Wiley-Interscience; 1st edition 2003) 111-145.(Unit III,IV)
5. Thomas Varghese and K.M. Balakrishna, Nanotechnology: An Introduction to Synthesis, Properties and Applications of Nanomaterials (Atlantic; Reprint 2016 edition, 2021) 4-190. (Unit I,II,)

## MPT304B: Laser Physics

**Learning Objectives:** Students will able to

1. understand principles of lasing action.
2. study different types of resonators.
3. studyswitching phenomenon's.
4. study different laser systems.

| Credits=2 | SEMESTER-III<br>**MPT304B: Laser Physics** | No. of hours per unit/ credits |
|---|---|---|
| **Credit –I UNIT I** | **Basic Laser Principle and Laser System:** | **(15)** |
| | Summary of black body radiation, Quantum theory for evaluation of the transition rates and Einstein coefficients-allowed and forbidden levels-metastable state; population inversion; rate equations for three level and four level lasers, threshold of power calculation, various broadening mechanism, homogeneous and inhomogeneous broadening.<br>**Basic Laser System:** Basic concept of construction of laser system, various pumping system, pumping cavities for solid state laser system, characteristics of host materials and doped ions. | |
| **Credit –1 UNIT II** | **Optical beam propagation and Resonators:** | **(15)** |
| | Paraxial ray analysis, wave analysis of beams and resonators, propagation and properties of Gaussian beam, Gaussian beam in lens like medium, ABCD law-Gaussian beam focusing<br>**Resonators:** Stability of resonators-'g' parameter, various types of resonators, evaluation of beam waist of such combination, design aspect of resonator for various types of lasers, unstable resonator and their application. | |
| **Credit –1 UNIT III** | **Q-switching and Ultrafast Phenomenon:** | **(15)** |
| | Giant pulse theory, different Q-switching techniques: mechanical Q-switching, electro-optic Q-switching, acousto-optic Q-switching, dye Q-switching, Raman-Nath effect.<br>**Ultrafast Phenomenon**: Principle of generation of ultrafast pulses (mode locking), basic concepts for measurement of fast processes, Streak technique, Stroboscopy, sampling technique, nonlinear optical methods for measuring ultrashort pulses. | |
| **Credit –1 UNIT IV** | **Different laser systems:** | **(15)** |
| | Gas Lasers: (i) Molecular gas lasers- $CO_2$ laser & $N_2$ (ii) ionic gas laser | |

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| | – Ar+ laser (iii) gas dynamic laser (iv) high pressure pulsed gas laser Solid State Laser: (i) Nd:YAG laser, (ii) Nd:Glass laser, comparison of performances (iii) Tunable solid state laser: Ti:sapphire laser; Alexandrite laser Chemical Laser: HF laser, HCl laser, COIL Excimer laser; Color centre laser; Free electron laser; semiconductor diode laser | |

**Learning Outcomes:** Students should able to

1. understand fundamental concepts related to LASING action like pumping systems, metastable state, population inversion and stimulated emission.
2. analyze the design aspect of resonator for various types of lasers.
3. understand Q switching and ultrafast phenomenon's.
4. differentiate lasing action in different types of lasers like $CO_2$, $N_2$, Nd:YAG etc.

**References:**


1. O Svelto,2016,Principles of lasers,5th edition,New York : Springer.
2. W Koechner,2006, Solid State Laser Engineering,6th edition,New York : Springer.
3. A Yariv,1989, Quantum Electronics, 3rd edition, New York : Wiley.
4. D R Hall & P E Jackson,1992, The Physics and Technology of Laser Resonator,Bristol ; Philadelphia : Institute of Physics Pub.
5. K A Jones ,1988, Introduction to optical electronics, West Sussex U.K. :Wiley.

## MPP 306:PRACTICAL COURSE – III: LAB – V

**Learning Objectives:** Students will able to

1.study the deposition of thin films by various methods such as CBD, Electrodeposition, Hydrothermal, Reflux, Sol-gel, SILAR,Spray Pyrolysis etc.

2. study the measurement of band gap energy by UV-Visible spectrophotometer, TEP, contact angle of thin films.

3. study the measurement of dielectric constant, magnetic susceptibility,

4. study the properties and shape of LASER.

5. understand XRD pattern

| **Credits=4** | **SEMESTER-III**<br>**MPP 306: LAB-I (Practical I+ Project)** | **No. of hours per unit (60) credits** |
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| | **EXPERIMENTS:**<br>1. Deposition of thin films by CBD method<br>2. Electrodeposition/ anodization of thin films<br>3. Synthesis of thin films by Hydrothermal/Solvothermal method<br>4. Preparation of thin films by Reflux method<br>5. Synthesis of material by Sol-gel method<br>6. Preparation of thin films by SILAR method<br>7. Synthesis of nanoparticles by Co-precipitation method<br>8. Preparation of thin films by Spray Pyrolysis method<br>9. Microwave synthesis of thin films<br>10. Preparation of film by Doctor Blade method | |
| | **MPP 307: LAB-II (**Practical II+ Project) | |
| | **EXPERIMENTS:**<br>1 Band gap energy Measurement of thin films by UV-Visible spectrophotometer<br>2 TEP measurement of thin film<br>3 Resistivity measurement of thin film by two probe method<br>4 Contact angle measurement of thin films<br>5 Crystal structure of thin film.<br>6 Measurement of dielectric constant by LCR<br>7 Magnetic Susceptibility (Gouy balance method)<br>8 To study the shape of the LASER beam: divergence angle, cross section and to evaluate beam spot.<br>9 Determination of physical density, X-ray density and porosity of given material<br>. 10 Data plotting using Origin 8 software. | |

**Learning Outcomes: Students should able to**

1. understand the thin films deposition techniques by various methods such as CBD, electrodeposition, hydrothermal, reflux, Sol-gel, SILAR, Spray Pyrolysis etc.
2. analyze band gap energy by UV-Visible spectrophotometer, TEP, contact angle of thin films.
3. differentiate shape of LASER.
4. understand the XRD pattern.

**References:**


1. K. L Chopra,1979,Thin Film Phenomena,McGraw -Hill Book Company, NY(Unit I, II, III, IV)
2. Sulabha K. Kulkarni , 2007, Nanotechnology principle and practice,Springer International Publishing(Unit II, IV)
3. Joy George, 1992, Preperation of Thin Films, New York ; Basel ; Hong Kong : Marcel Dekker(Unit I,II, III)
4. R. K. Pandey, S.N. Sahu, S. Chandra.,1996, Handbook of semiconductor electrodeposition, New York : Marcel Dekker, cop. (Unit II)

**SEMESTER IV**

## MPT 401: NUCLEAR AND PARTICLE PHYSICS (Credits: 04)

**Learning Objectives:** Students will able to

1. understand nucleon nucleon interaction.
2. study nuclear models and nuclear reactions.
3. study gaseous radiation detectors and semiconductor radiation detectors.
4. study elementary particles

| **Credits=4** | **SEMESTER-IV**<br>**NUCLEAR AND PARTICLE PHYSICS** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I UNIT I** | **Nuclear Models and Nuclear Reactions** | **(15)** |
| | Single Particle Shell Model: evidence of shell structure, magic numbers, Spin orbit coupling, parity, spin and moments of nuclear ground states, Schmidt lines,<br>Collective Models: evidence for collective motion, brief introduction to vibrational and rotational states, single particle motion in deformed potential.<br>Review of alpha, beta and gamma decays, Compound nucleus reaction: Origin of the compound nucleus, Hypothesis, Resonance scattering and reactions — Breit Wigner dispersion relation; optical model of particle induced nuclear reactions, Direct Reactions: Experimental characteristics, Direct inelastic scattering and Transfer reactions. | |
| **Credit –1 UNIT II** | **Nucleon -Nucleon Interaction:** | **(15)** |
| | Nature of the nuclear forces, Forms of nucleon-nucleon potential, Deuteron Problem :The theory of ground state of deuteron, Excited states of deuteron, n-p scattering at low energies (cross section), Phase shift analysis, Scattering length, n-p scattering for square well potential (effective range theory); p-p scattering at low energies, Symmetry and charge independence of nuclear forces, exchange forces (Bartlett, Majorana, Heisenberg forces) | |
| **Credit –1UNIT III** | **Radiation detectors** | **(15)** |
| | Basic principle of radiation detectors, Gaseous detectors, Ionization | |

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| | chamber, Multiwire proportional chambers, Planar drift chamber, Scintillation detectors, Different types of organic and inorganic scintillators, Semiconductor detectors, Position sensitive detectors , Lithium drifted silicon detectors, Lithium drifted germanium detectors, High purity germanium detectors. | |
| **Credit – 1UNIT IV** | **UNIT IV: Particle Physics** | **(15)** |
| | Classification of fundamental forces, Classification of elementary particles and their quantum numbers (Charge, Spin, Parity, Isospin, Strangeness, Baryon number, Lepton number), Gell-Mann-Nishijima formula, quark model [SU (3)], Charge conjugation, Time reversal invariance, CP violation, CPT invariance, Application of symmetry arguments to particle reactions, Parity-non-conservation in weak interaction. | |

## Learning Outcomes: Students should able to

1.analyze nucleon nucleon potential, deuteron problem n-p and p-p scattering at low energy and effective range theory.

2. understand the Shell model, collective model, nuclear decay process and direct and compound nuclear reactions.

3. differentiate basic principles of radiation detectors, organic detectors, inorganic detectors and different semiconductor detectors.

4. understandelementary particles, quark model, CPT invariance.

## Reference Books:


1. D. C. Tayal,2015, Nuclear Physics,Ist Edition, New Delhi :Himalaya Publishing House (Unit I, II, IV)

2. S. L. Kalani and ShubhraKallani , 2014, Nuclear and Particle Physics, IInd Edition, London: MV Learning (Unit I, II, IV)

3. S. S. Kapoor and V. S. Ramamurthy, 1986, Nuclear Radiation Detectors, New Delhi:Wiley Eastern Limited (Unit III)

4. Irving Kaplan , 1989,Nuclear Physics, IInd edition, Addison -Wesley (Unit I, II)

5. S. B. Patel, 2011, Nuclear Physics: An Introduction, IInd edition, India: New Age international Ltd (Unit II)

6. W.E. Burcham and M.Jobs, 2004 , Nuclear and Particle Physics, VIth Edition, England: Harlow: Pearson /Prentice Hall (Unit III, IV)

7. M.P. Khanna, 2004, Introduction to Particle Physics, New Delhi : Prentice Hall of India Private, (Unit IV)

8. Claus Grupen and Boris Shwartz, 2008, Particle Detectors, IInd edition, Cambridge: University Press. (Unit III)

# MPT 402: SOLID STATE PHYSICS-III
## (Thin Solid Films: Deposition and Properties)

**Learning Objectives:**Students will able to
1. understand thin film and its technological applications.
2. study Mechanism of thin film formation: Condensation and nucleation
3. study physical and chemical methods of thin film formation.
4. study properties of thin films and different methods of characterization

| Credits=4 | **SEMESTER-IV**<br>**MPT 402: SOLID STATE PHYSICS-III**<br>**(Thin Solid Films: Deposition and Properties)** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I UNIT I** | **Introduction: Thin Film** | **(15)** |
| | Introduction: Thin Film, Technological Applications of Thin Films, Mechanism of thin film formation: Condensation and nucleation, Growth and Coalescence of islands, Crystallographic structure of films, Factors affecting structure and properties of thin films; Epitaxial thin films. | |
| **Credit –1 UNIT II** | **Classification of Methods Used for Synthesis of Thin Films** | **(15)** |
| | **Physical methods:** Vacuum Techniques (i) Thermal evaporation methods: Resistive heating, Electron Beam Evaporation, (ii) Sputtering system: Glow discharge, DC sputtering, Radio frequency sputtering, Magnetron sputtering, Ion beam sputtering.<br>**Chemical Methods:** Chemical vapor deposition system (CVD)**,** Chemical bath deposition: Ionic and solubility products, Preparation of binary semiconductors, Electrochemical deposition: Deposition mechanism and Preparation of compound thin films, Spray pyrolysis: Deposition mechanism and preparation of compound thin films. | |
| **Credit – 1UNIT III** | **Properties of Thin Films**: | **(15)** |
| | Mechanical properties: Stresses and strain in thin films, Mechanical constants of thin films, Electrical and magnetic properties: Electrical conduction in thin metallic discontinuous and continuous films, Optical properties: Optical constants of thin films, Experimental methods as | |

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|---|---|---|
| | Reflection, Interferometry and Critical angle method | |
| **Credit – 1UNIT IV** | **Methods for Characterizations of Thin Films:** | **(15)** |
| | Thickness Measurement Methods: Weight Difference Method, Stylus Method, Ellipsometry, Characterization Methods: X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and Energy dispersive analysis of X-rays (EDAX)**,** UV-VIS spectroscopy, X-ray photoelectron spectroscopy (XPS), Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM). | |

**Learning Outcomes:**Students should able to

1. understand technological applications of thin Films, mechanism of thin film formation, Crystallographic structure of films.
2. differentiate physical and chemical method of thin film preparation.
3. understand the mechanical, electrical, optical and magnetic properties of thin film.
4. analyze various characterization techniques, thickness measurement methods.

**Reference books**


1. K. L Chopra,1979,Thin Film Phenomena,McGraw -Hill Book Company, NY(Unit I, II, III, IV)Sulabha K. Kulkarni , 2007, Nanotechnology principle and practice,Springer International Publishing(Unit II, IV)

2. Joy George, 1992, Preperation of Thin Films, New York ; Basel ; Hong Kong : Marcel Dekker(Unit I,II, III)

3. C. D. Lokhande,1991, Chemical deposition of metal chalcogenide thin films,, Materials Chemistry and PhysicsVolume 27, Issue 1, January, Pages 1-43. (Unit II)

4. P .S. Patil,1999, Review:Versatility of chemical spray pyrolysis technique,Materials Chemistry and physics 59 (3), 185-198. (Unit II)

5.R. K. Pandey, S.N. Sahu, S. Chandra.,1996, Handbook of semiconductor electrodeposition, New York : Marcel Dekker, cop. (Unit II)


## MPT 403: SOLID STATE PHYSICS-IV
## (Energy Conversion and Storage Devices)

**Learning Objectives:**Students will able to

1. understand solar cell and its characteristics.
2. study generations of Solar cell and types of solar cells.
3. study battery parameters, Ni/Cd batteries, Lithium batteries and Supercapacitors.
4. understand the importance of Hydrogen as a future fuel.

| Credits=4 | **SEMESTER-IV**<br>**MPT 403: SOLID STATE PHYSICS-IV**<br>**(Energy Conversion and Storage Devices)** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I UNIT I** | **Photovoltaics** | **(15)** |
| | P-N junction under illumination, Light generated current, I-V equation, Characteristics, Upper limits of cell parameters, Losses in solar cells, Equivalent circuit, Effects of various parameters on efficiency, Solar cell design, Design for high Isc, Anti-Reflective coating (ARC), Design for highVoc and fill factor, Analytical techniques; Solar simulator, Quantum efficiency, Minority carrier lifetime and Diffusion length measurement. | |
| **Credit –1 UNIT II** | **Types of solar cells** | **(15)** |
| | Generations of Solar cells, Trends of η of solar cell, Dye sensitized solar cells, Advantages and disadvantages, Quantum dot sensitized solar cells, Perovskite solar cells, Photo electrochemical (PEC) Solar cells, Tandem solar cells, Polymer solar cells. | |
| **Credit – 1UNIT III** | **Batteries and Supercapacitors** | **(15)** |
| | Basics of electrochemical cell, Primary batteries, Rechargeable batteries, Battery parameters(Battery capacity, Battery voltage, Battery life cycle, Discharge/charge rate), Ni/Cd batteries charging methods and techniques, Characteristic curves, Lithium batteries, Chemistry and Physics of lithium batteries, Anode and cathode materials, Applications.<br>**Supercapacitors:** Similarities and differences between supercapacitors and batteries, Energetics, Double layer electrostatic capacitor, Pseudocapacitance, Origin, Kinetic theory, Regon plot, Electrolyte factor, Energy density and Power density, Impedance of a pseudo capacitance, Technology development, Various oxides as pseudo capacitors. | |
| **Credit – 1UNIT IV** | **UNIT IV: Hydrogen Energy** | **(15)** |
| | Hydrogen Fuel: Importance of Hydrogen as a future fuel, Sources of Hydrogen, Fuel of vehicles. Hydrogen production: Production of Hydrogen by various methods, Solar water splitting, Direct electrolysis of water, Direct thermal decomposition of water Hydrogen storage: Gaseous, Cryogenic and Metal hydride. Utilization of hydrogen: Fuel cell – Principle, construction and applications. | |

**Learning Outcomes:**Students should able to

1.understand solar cell fabrication techniques and its characteristics.

2.differentiategenerations and types of solar cell.

3.analyze Ni/Cd batteries and Lithium batteries and supercapacitors.

4.understand methods of Hydrogen production and principle of Fuel cell.

**References:**


1. Chetan Singh Solanki, Solar Photovoltaics, Fundamentals, Technologies and Applications (Delhi, PHI Learning Private Limited, 3rd Edition, 2015) 5-302.(Unit I, II, III)
2. Frederik C. Krebs, Polymer Photovoltaics: A Practical Approach (Washington USA, Spie Press Bellingham, 2008)48-245.(Unit II)
3. Kamal K. Kar, Handbook of Nanocomposite Supercapacitor Materials II (Switzerland, Springer Series in Materials Science, 2020 ) 2-85. (Unit III)
4. H. A. Kiehne, Battery Technology Handbook (Germany, Expert Verlag, Renningen-Malsheim, 2003)1.1-19.2.5.(Unit III)
5. B. E. Conway, Electrochemical Supercapacitors, Scientific Fundamentals and Technological Applications (Kluwer Academic/ Plenum Publishers, 1999) 12-385. (Unit III)
6. S.A. Sherif, D. Yogi Goswami, E.K. (Lee) Stefanakos, Aldo Steinfeld, Handbook of Hydrogen Energy (CRC Press, 2014) 3-78. (Unit IV)


## MPT 404A: ELECTRONIC DEVICES

**Learning Objectives:**Students will able to

1. understand BJT, MOSFET and microwave devices.
2. study thyristors and unijunctiontransistors.
3. understand photonic devices
4. understand memory devices.

| **Credits=4** | **SEMESTER-IV**<br>**ELECTRONIC DEVICES** | **No. of hours per unit/ credits** |
|---|---|---|
| **Credit –I**<br>**UNIT I** | **Bipolar Transistors and Microwave Devices:** | **(15)** |
| | Revision of bipolar junction transistor (BJT), transistor as switch, MOSFET: Si-$SiO_2$ systems, types, characteristics. CMOS and BiCMOS Microwave Devices: Basic Microwave Technology, Tunnel diode, IMPATT diode, Transferred Electronic devices (TED). | |
| **Credit –1**<br>**UNIT II** | **Thyristors and Unijunction Transistor** | **(15)** |

| | | |
|---|---|---|
| | Silicon Controlled Rectifier (SCR): Characteristics and Parameters, SCR Controlled Circuit, Traic and Diac.<br>Other four layer devices: Four layer diode (Schottky diode), bilateral four layer diode,<br>Unijunction Transistor (UJT): Characteristics, Parameters, application of UJT as relaxation oscillator, programmable unijunction transistor. | |
| **Credit – 1UNIT III** | **Photonic Devices:** | **(15)** |
| | Radiative transitions and optical absorption , Light Emitted Diode: Visible LED, Organic LED, Infrared diode, Semiconductor lasers, Laser operation, Population inversion, Heterojunction Laser, Laser diode materials. | |
| **Credit – 1UNIT IV** | **Memory Devices** | **(15)** |
| | Semiconducting memories, memory organization and operation, Read and Write operation, Expanding memory size, Classification and characteristics of memories, Static and dynamic RAM, SRAM and DRAM, Charge couple memory (CCD) Devices. | |

**Learning Outcomes:**Students should able to

1. understand Bipolar Junction Transistor, MOSFET and different microwave devices.
2. understandThyristors, Programmable unijuction Transistor, Silicon Controlled Rectifier and Four layer diode.
3. differentiate Light emitting Diodes, Organic LED and Laser operation.
4. analyze Semiconducting memories, memory organization and operation and CCD.

**Reference Books:**

1. S.M.Sze, 2008,Semiconductor devices - Physics and Technology,2nd edi.Wiley India Pvt. Ltd.(Unit I, III)
2. David Bell, 2008, Electronic devices & circuits, 3rd ed., Prentice Hall Publication.(Unit II)
3.M. S. Tyagi, 2008, Introduction to Semiconductor devices, Wiley.(Unit I,II)
4. R. P. Jain , 2009, Modern Digital Electronics,4th ed., McGraw Hill Education. (Unit IV)

## MPT 404B: Optoelectronics and Photonics

**Learning Objectives:** Students will able to

1. understand concepts of light emitting materials.
2. study different modulators and electro-optic devices.
3. understand the principle of optical fibers and their types.
4. understand second, third order nonlinear optical media and concepts of optical digital computer.

| Credits=4 | SEMESTER-III<br>MPT 404B: Optoelectronics and Photonics | No. of hours per unit/ credits |
|---|---|---|
| **Credit –I UNIT I** | **Optoelectronic devices** | **(15)** |
| | Photoconductivity, Light dependent resistor, photodiode, phototransistor, solar cell, metal semiconductor detector, Liquid crystal display, charged coupled devices, light emitting diode Laser diode: Spontaneous and stimulated emission, laser structures, time response of lasers, advanced semiconductor laser structures, temperature dependence of laser output. PIN photodiode, Avalanche photodiode, Heterojunction photodiode, Organic light emitting diodes (OLED) , way to perceive colors, conventional, transparent, inverted and flexible OLEDs, Organic thin films transistors (OTFT), OTFT based display technology; Organic laser-Lasing process, optically pumped lasing structures, applications; Organic multilayer, photodetectors; organic photovoltaic cells. | |
| **Credit –1 UNIT II** | **Optoelectronic modulators** | **(15)** |
| | Polarization of Light, Elliptical polarization, Optics of anisotropic media: The index ellipsoid, Birefringence, Optical activity, Electro-optic effect, Electro-optic modulators, Acousto-optic modulators, use of optoelectronic modulator, Kerr modulator- Kerr effect, Magneto-optic modulator – Faraday effect, Acousto-optic effect, Electro-optic Devices: Wave retarders, rotators and optical isolators, Intensity Modulators, Phase Modulators, Traveling Wave Modulator, Acousto-optic Devices: Raman-Nath acousto-optic modulator, Acousto-optic deflector, parametric oscillation. | |
| **Credit –1 UNIT III** | **Fiber optics** | **(15)** |
| | Basic characteristics and ray propagation in an optical fibers, Step –index and graded-index fibers, Multipath dispersion, pulse dispersion, material dispersion, combined effect of multipath and maerial dispersion, rms | |

| | | |
|---|---|---|
| | pulse width. Modes In planar waveguides – TE modes of a symmetric step-index planar waveguide, power distribution and confinement factor, wave propagation in a cylindrical wave guide, single mode fiber and its characteristic parameters, dispersion and attenuation in SMF, Optical fiber cable and connections, Dispersion compensation mechanism, Dispersion-tailored and dispersion compensating fibers, Birefringent fibers and polarization mode dispersion, Fiber bandwidth. fiber material and its fabrication, Erbium-doped fiber amplifiers, Fiber Bragg gratings. Photonic Crystal and Holey fibers. Fiber optic communications: Analog and digital fiber optic communication system, System architectures, Nonlinear effects in fiber optic: Stimulated Raman Scattering, Stimulated Brillouin Scattering, Self Phase Modulation, Cross Phase Modulation, Four wave mixing, Optical Solitons optical amplifiers : semiconductor optical amplifier, Fiber raman amplifier. | |
| **Credit –1 UNIT IV** | **Non-linear Optics** | **(15)** |
| | Non-linear optical media, second order non-linear optics- SHG, Three wave mixing. Third order non-linear optics, THG and self-phase modulation, Coupled wave theory of three-wave mixing. Four wave mixing and Optical Phase conju- gation. Frequency conversion, Parametric Ampli_cation and Oscillation. Self focusing of light. Optical Bistability**Concept Optical digital computer** - Optical components for binary digital computer, Optical Switches- SEED , Photonic logic gates. | |
| | | |
| | | |

**Learning Outcomes:**Students should able to

1. understand concepts of photodiodes, LEDs, OLEDs based displays.
2. understand electro-optic and magneto-optic phenomenons and devices based on it.
3. analyze principle of optical fibers, analog and digital fiber optic communication system.
4. differentiate second, third order non linear optical media and concepts of optical digital computer, optical switches etc.

**References:**


1) J. Wilson ,J. F. B. Hawkes,1889,Optoelectronics: An Introduction,2nd ed.,Prentice-Hall.
2) A. Ghatak , K.Thyagarajan,1989,Optical Electronics ,Cambridge University Press.
3) A. Ghatak ,K.Thyagarajan ,Introduction to Fiber Optics -
4) Optical Properties of Solids – Frederick Wooten
5) Quantum Electronics - Amnon Yariv, John Wiley & Sons,

**M.Sc. II (Physics Practical) Semester IV**

**MPP 405 LAB-III: (**Practical III+ Project)

**Learning Objectives:**Students will able to

1. study the measurement of the resistivity of films by four probe method.
2. study I-V characteristics and spectral response of solar cell.
3. study characteristics of LDR, phototransistor and SCR.
4. Understand to interpret data using Origin 8 software.

| **Credits=4** | **SEMESTER-III**<br>**MPP 405 LAB-III: (**Practical III+ Project) | **No. of hours per unit (60) credits** |
|---|---|---|
| | **MPP 405 LAB-III: (**Practical III+ Project) | |
| | Measurement of resistivity of film by four probe method.<br>To study BJT as a switch<br>Study of supercapacitor properties.<br>Photocatalytic dye degradation<br>I-V characteristics of solar cell.<br>Spectral response studies of solar cell.<br>Flat band potential of Si wafer.<br>To study characteristics of LDR.<br>To study characteristics of photodiode.<br>. Bistablemultivibrator | |
| | **MPP 406 LAB-IV: (**Practical IV + Project) | |
| | Photoluminescence<br>Analysis of Raman spectrum<br>Cyclic –Voltammetry<br>Analysis of FTIR spectrum<br>Gas sensitivity<br>TGA-DTA<br>Measurement of film thickness by optical method.<br>Interpretation of data using Origin 8 software.<br>XPS<br>Chronoamperometry | |

**Learning Outcomes:** Students should able to

1. understand I-V characteristics and spectral response of solar cell.
2. differentiate characteristics of LDR, phototransistor and SCR.
3. analyze data using Origin 8 software.
4. understand the Photoluminescence, Raman, IR, XPS,TGA-DTA spectra.

**References:**


1. Chetan Singh Solanki,2015,Solar photovoltaics, Fundamentals, Technologies and Applications,3rd edition,PHI Learning Private Limited, Delhi-110092
2. B.E.Conway,2009,Electrochemicalsupercapacitors:scientific fundamentals and technological applications,Kluwer Academic/ Plenum Publishers, New York,Boston, Dordrencht, London, Moscow
3. Robert B. Braun,2019,Introduction to Instrumental Analysis,BSP BOOKS
4. A. Skoog, F.James Holler, Stanley R. Crouch ,2006,Principles of Instrumental Analysis,6th edition, Cengage Learning.