"Education for Knowledge, Science, and Culture"
- Shikshanmaharshi Dr. Bapuji Salunkhe

Shri Swami Vivekanand Shikshan Sanstha's

Vivekanand College, Kolhapur (Autonomous)

KOLHAPUR (AUTONOMOUS)

Department of Physics (2019-20)

M.Sc. (Physics) (Part-II)

CORE PAPER (COMPULSORY)-(CP) CHOICE BASED PAPER-(CBP)

M.Sc. (Physics) Part -II Semester-III (Total Credits = 24)		
Paper Code	**Paper Title**	**Credits**
CP-1112C	Nuclear and Particle Physics (Compulsory)	4
CBP-1113C	(Thin film deposition and other techniques)	4
CP-1114C	SOLID STATE PHYSICS- I (Thin film deposition techniques-Magnetic and Electric properties)	4
CP-1115C	SOLID STATE PHYSICS- II (Semiconductor Physics)	4
CPPR-1116C (Practical Lab-I)	Laboratory/ Practical Course-I SOLID STATE PHYSICS LAB –I	4
CPPR-1117C (Practical Lab-II)	Seminar +Tutorials on practical Course-I	4
M.Sc. (Physics) Part -II Semester-IV (Total Credits = 24)		
Paper Code	**Paper Title**	**Credits**
CP-1118D	EXPERIMENTAL TECHNIQUES	4
CBP-1119D	Electronic Devices and applications	4
CP-1120D	SOLID STATE PHYSICS- III (Physical properties of solid)	4
CP-1121D	SOLID STATE PHYSICS-IV (Energy Conversion and Storage Devices)	4
CPPR-1122D(Practical Lab-III)	Laboratory/ Practical Course-II SOLID STATE PHYSICS LAB –II	4
CPPR-1123D(Practical Lab-IV)	Seminar +Tutorials on practical Course-II	4

M.Sc. (Physics) (Semester-III and IV)

Paper title: Nuclear and Particle Physics

Course Outcomes:

CO-1) Acquire basic knowledge about Nucleon-Nucleon interaction, deuteron problem, n-p ,p-p and N-N scattering , nuclear forces etc.

CO-2) Understand the Elementary ideas of alpha, beta and gamma decays, nuclear fission and fusion reactions mechanism.

CO-3) Develop the understanding of cosmic rays and elementary particles and their properties.

CO-4) Learn about the concept of particle physics classification like charge, spin, parity, isospin, strangeness etc

Paper title: Thin film deposition and other techniques

Course Outcomes:

CO-1) Gain basic knowledge of deposition techniques like Chemical Vapor, Spray and other like, electro spray, electroplating, Spin coating, SILAR .

CO-2) To clarify the concepts of Solid solutions like substitutional, disordered, ordered, interstitial hardening, Age hardening, dispersion hardening, phase transformation hardening principles of hot and cold working of metals and their effects on mechanical properties .

CO-3) To impart knowledge of Raman Scattering rotational and vibrational spectra, Raman Electron Spin Resonance(ESR Hyperfine structure, ESR of Transition metals

CO-4) To develop the understanding of Heat treatment furnaces like Oil and Gas fired furnaces, Electric furnaces, Batch furnace and their types, Semi continuous and continuous furnace, Air convection furnace, salt bath furnace

Paper title: Solid State Physics- I (Thin film deposition techniques- Magnetic and Electric properties)

Course Outcomes:

CO-1) Provide a critical and systematic understanding on advanced Physical methods of thin film deposition like vacuum, evaporation, Chemical vapor deposition, sputtering, etc

CO-2) Provide a critical and systematic understanding on advanced chemical methods of thin film deposition like Chemical bath deposition, electro deposition, Spray pyrolysis , (SILAR), Sol-gel, hydrothermal deposition techniques etc.

CO-3) Learn the basics of the Magnetic behavior of various materials and their types

CO-4) Understanding of electrical properties in solids, Wiedermann-Franz law, Hall Effect, magneto resistance, thermionic emission

Paper title: SOLID STATE PHYSICS- II (Semiconductor Physics)

Course Outcomes:

CO-1) A critical and systematic understanding of energy bands and charge carriers in Semiconductors.

CO-2) Learn the basics of excess carriers in semiconductors, Optical absorption, Luminescence, diffusion and drift of carriers.

CO-3) Provide a broad view of fabrication of p-n junctions and current flow through at a junction, Capacitance of p-n junctions, heterojunction.

CO-4) Provide a broad view of current flow mechanism across p-n junction.

Paper title: EXPERIMENTAL TECHNIQUES

Course Outcomes:

CO-1) Provide a critical and systematic understanding on vacuum techniques like rotary, diffusion, and sputter ion pumps

CO-2) Provide a critical and systematic understanding on measurement of low pressure and simple methods of LD, palladium barrier and halogen leak detectors.

CO-3) Learn the basics of the Atomic Absorption Spectrometry and Low Temperature and Microscopy Techniques like Optical microscopy, scanning electron microscopy, electron microprobe analysis, low energy electron diffraction.

CO-4) Impart the knowledge about X-Ray Fluorescence Spectrometry and Mössbauer Spectroscopy

Paper title: Electronic Devices and applications

Course Outcomes:

CO-1)Understand the working ,structure and operation and functions of (BJT), (JFET), MOSFET, MESFET, and diodes.

CO-2] Identify the problems and applications of Magneto-optic and acousto-optic , Piezoelectric, Electrostrictive and magnetostrictive effects.

CO-3] Acquire basic knowledge about Light emitting Diodes, OLED, Infrared LED, Photodetector, Photoconductor, Photodiode, p-n junction Solar cells, ,Semiconductor Lasers

CO-4] Learn the techniques of Thermistor, and sensors.

Paper title: SOLID STATE PHYSICS- III (Physical properties of solid)

Course Outcomes:

CO-1) Understand the matter interaction Electronic Structure of Crystals

CO-2] Identify the problems and applications of Transport Properties of Metals.

CO-3] Acquire basic knowledge about Phonons, Plasmons, Polaritons, and Polarons

CO-4] Impart the knowledge about the Defects in crystals

Paper title: SOLID STATE PHYSICS-IV (Energy Conversion and Storage Devices)

Course Outcomes:

CO-1) Understand the concept and applications of Solar Photovoltaics

CO-2] Identify the problems and applications of Dye and Quantum Dot Sensitized Solar Cell.

CO-3] Acquire basic knowledge of Perovskite and Organic Solar cell.

CO-4] Impart the knowledge and provide a broad view about the Supercapacitors and Batteries.

M.Sc. (Physics) (Semester-III)
Paper Code: CP-1112C
Total Credits: 4-credits
Paper title: Nuclear and Particle Physics

Unit-I Nucleon-Nucleon Interaction: (15)

Nature of the nuclear forces, form 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 (cross-section, experiment , and results) ; exchange forces, tensor forces; high energy N-N scattering (qualitative discussion only of n-p and p-p scatterings), charge-independence and charge-symmetry of nuclear forces.

Unit-II Nuclear Reactions: (15)

Elementary ideas of alpha, beta and gamma decays and their classifications, characteristics, selection rules and basic theoretical understanding. Nuclear reactions, reaction mechanism, Compound nucleus reaction (origin of the compound nucleus hypothesis, discrete resonances, continuum states), optical model of particle-induced nuclear reaction and direct reactions (experimental characteristics, direct inelastic scattering and transfer reactions). Fission and fusion, Fission and heavy ion reactions.

Unit-III Cosmic rays and elementary particles (15)

Concept of cosmic rays and their properties, secondary radiations Cosmic ray stars, Electronic showers-geomagnetic, latitude, longitude and azimuth effects, Elementary particles and their properties.

Unit-IV Particle Physics: (15)

Classification of fundamental forces. Classification of Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, CPT invariance. Application of symmetry arguments to particle ,reactions, Parity non-conservation in weak interaction, Relativistic kinematics.

Reference Books:

1. Nuclear and Particle Physics- W.E. Burcham and M.Jobes, (Addison Wesley, Longman, England, 1995).
2. Introduction to Particle Physics- M.P. Khanna (Prentice Hall, India, 1999).
3. Concept of Nuclear Physics, B.L. Cohen, (Tata McGraw-Hill, 2005)
4. Nuclear Physics Principles and Applications, John Lilley, (John Wiley and Sons (Asia) 2001)
5. Nuclear physics – D. C. Tayal. (Himalaya Publishing House,1997)
6. Nuclear Physics- Iriving Kaplan (Narosa, Madras, 1989).
7. Introduction to High Energy Physics- Donald H.Perkins (Addison Wesley, Massachusetts, 1982).
8. Fundamentals of Nuclear Physics- Srivastava, Rastogi publications

M.Sc. (Physics) (Semester-III)
Paper Code: CBP-1113C
Total Credits: 4-credits
Paper title: (Thin film deposition and other techniques)

Unit I:Chemical Vapor, Spray and other deposition techniques : (15)

Introduction, reaction types, thermodynamics of CVD, gas transport and growth kinetics, CVD process and basic systems; Low-Pressure CVD (LPCVD),Spray deposition Introduction, basic instrumentation, different type of spray techniques; spray pyrolysis technique, electrospray deposition technique, advantages and disadvantages of spry deposition techniques. Electroplating, Spin coating, SILAR technique.

Unit II:Solid solutions and strengthening of metals (15)

Types of solid solutions, substitutional, disordered, ordered, interstitial solid solution, intermediate phases ,Hume Rothery's rules, concept of solidification of metals-nucleation, homogeneous and heterogeneous nucleation, growth its new phase and phase change kinetics, solid solution hardening, Age hardening, dispersion hardening, phase transformation hardening principles of hot and cold working of metals and their effects on mechanical properties .

Unit III:**Raman and ESR Techniques (15)**

Raman Scattering-introduction theory , Rotational and Vibrational spectra, Raman spectrometer Fourier transform Raman spectrometer, Structure determination using IR and Raman - Electron Spin Resonance(ESR)-Principle, construction and working ,Total Hamiltonian, Hyperfine structure, ESR of Transition metals

Unit IV: **Heat treatment furnaces (15)**

Definition and concept of furnace, types of heat treatment furnaces : Oil and Gas fired furnaces, Electric furnaces, Batch furnace and their types, Semi continuous and continuous furnace, Air convection furnace, salt bath furnace-advantages and limitations, Furnace atmosphere and temperature control.

References:

1. "The Material Science of thin films" by MiltonOhring.
2. "Coatings on Glass" (volume 6) by H. K.Pulker.
3. "Langmuir Blodgett films" (volume 3) by C. W. Pitt, G. G.Roberts.
4. "Handbook of thin film Technology" by Frey, Hartmut, Khan and HamidR.
5. "Thin film Technology and Application" by K. L. Chopra & L. K.Malhotra.
6. "Deposition Technology for films and coatings" by Rointan F.Bunshah.
7. "High vacuum techniques" J.Yarwood (Chapman & Hall)1967.
8. "Vacuum technology" A.Roth (North-Holland Publishing Company, Amsterdam) 1982
9. Molecular structure and Spectroscopy-G.Aruldhas
10. A text book of material science and Metallurgy O.P.Khanna Dhanapt Rai publications

M.Sc. (Physics) (Semester-III)
Paper Code: **CP-1114C**
Total Credits: 4-credits

Paper title: SOLID STATE PHYSICS- I (Thin film deposition techniques- Magnetic and Electric properties)

Unit 1: Physical methods of thin film deposition (15)

Vacuum deposition apparatus: Vacuum systems, substrate deposition technology, substrate materials, substrate cleaning, masks and connections, multiple film deposition, Thermal Evaporation methods: Resistive heating, Flash evaporation, Arc evaporation, laser evaporation, electron bombardment heating, Sputtering: Introduction to sputtering process andsputtering variants, glow discharge sputtering, Magnetic field assisted (Triode) sputtering, RFSputtering, Ion beam sputtering, sputtering of multicomponent materials

Unit II: Chemical methods (15)

Chemical vapor deposition: Common CVD reactions, Methods of film preparation, laser CVD, Photochemical CVD, Plasma enhanced CVD, Chemical bath deposition: ionic and solubility products, preparation of binary semiconductors, Electrodeposition: Deposition mechanism and preparation of compound thin film Spray pyrolysis : Deposition mechanism and preparation of compound thin films, Chemical bath deposition, successive ionic layer adsorption reaction method (SILAR) method, Sol-gel method, Hydrothermal method

Unit III: Magnetism in solids (15)

Types of magnetism: Langevin's classical and quantum theory in diamagnetism, paramagnetism, ferromagnetism- Magnetostriction, Weiss theory and molecular field concept of domains, Antiferomagnetism, Ferimagnetism

Unit IV: Electrical Properties in solids (15)

Classical theory of electric conduction and its temperature dependence , Wiedermann-Franz law, Electron scattering and sources of resistance in metals, variation of resistivity with temperature, resistivity of alloys, mechanical effects on electrical resistance, conductivity at high frequencies, effect of the magnetic fields- hall effect and magnetorésistance, thermionic emission

Reference Books:

1. Thin Film Phenomena by K L Chopra McGraw -Hill Book Company, NY 1969
2. The Materials Science of Thin Films by Milton Ohring, Academic Press, (1992) (unit4)
3. Properties of Thin Films by Joy George, Marcel and Decker, (1992)
4. Physics of Thin Films by LudmilaEckertová, Springer (1986)
5. Thin Film Technology by O S Heavens, Methuen young books (1970) (1970)
6. Solid state Physics-R.K.Puri, V.K.Bubber(1999)

M.Sc. (Physics) (Semester-III)
Paper Code: **CP-1115C**
Total Credits: 4-credits

Paper title: SOLID STATE PHYSICS- II (Semiconductor Physics)

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, space charge neutrality, conductivity and mobility, Drift and resistance, effects of temperature and doping on mobility, High field effects.

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.

UNIT III: Junctions-I (15)

Fabrication of p-n junctions; Thermal oxidation, diffusion, Rapid thermal processing, Ion implantation, CVD, Photolithography, etching, metallization, The contact potential, Space charge at a junction, qualitative description of current flow at a junction, reverse-bias breakdown, Zener and Avalanche breakdown.

UNIT IV: Junctions-II (15)

Capacitance of p-n junctions, the Varactor diode, recombination and generation in the transition region, ohmic losses, graded junctions, schottky barriers, rectifying contacts, ohmic contacts, heterojunctions, AlGaAs-GaAs heterojunction.

References:

1. Solid state electronic devices by B. G. Streetman.
2. Physics of semiconductor devices by S. M. Sze.
3. Solid State and Semiconductor Physics by McKelvey.
4. Principles of Elecronic Materials and Devices by S.O. Kasap

M.Sc. (Physics) (Semester-IV)
Paper Code: CP-1118D
Total Credits: 4-credits
Paper title: EXPERIMENTAL TECHNIQUES

Unit I Vacuum Techniques (15)

Production of low pressures: rotary, diffusion, and sputter ion pumps; measurement of low pressure: McLeod, Pirani, thermocouple & Penning gauges; leak detection : simple methods of LD, palladium barrier and halogen leak detectors.

Unit II Low Temperature and Microscopy Techniques (15)

Production of low temperatures: Adiabatic cooling, the Joule-Kelvin expansion, adiabatic demagnetization, 3He cryostat, the dilution refrigerator, principle of Pomerunchuk cooling,principle of nuclear demagnetization; measurement of low temperatures. Optical microscopy,scanning electron microscopy, electron microprobe analysis, low energy electron diffraction.

Unit III Atomic Absorption Spectrometry (15)

Fundamentals : principle, basic equipment, operation, monochromator action, modulation;apparatus : double beam instrument, radiation sources, aspiration and atomization;interferences, control of AAS parameters, reciprocal sensitivity and detection limit techniques of measurement : routine procedure, matrix matching method, and method of additions.

Unit IV X-Ray Fluorescence Spectrometry and Mössbauer Spectroscopy (15)

Introduction to wavelength-dispersive X-ray fluorescence spectrometry (WDXRF) and energy-dispersive X-ray fluorescence spectrometry (EDXRF), dispersive systems, detectors ,instruments, matrix effects, XRF with synchrotron radiation. Elementary theory of recoil free emission and resonant absorption of gamma rays, Mössbauer experiment, hyperfine, interactions: chemical isomer shift, magnetic dipole hf splitting, and electric quadrupole hf splitting; line broadening.

Reference Books:

1. High vacuum techniques- J.Yarwood (Chapman & Hall) 1967
2. Vacuum technology- A.Roth (North-Holland Publishing Company, Amsterdam) 1982
3. Experimental techniques in low temperature physics – G.K.White (Oxford) 1968
4. Low temperature physics – L.C. Jackson
5. Experimental principles & methods below 1K – O.V .Lounasmaa (Academic press, New York) 1974
6. Modern metallography - R.E.Smallman & K.H.G.Ashbee(Peramon press, Oxford)
7. Microscopy of materials - D.K.Bowen & C.R.Hall (the MacMillan press Ltd. (London) 1975; Chap.1-3.
8. Electron optical applications in materials science- L.E. Murr, (McGraw Hill, New York) 1970.
9. Atomic absorption spectroscopy - B.Welz (Verlag Chemie, New York) 1976.

10. Atomic absorption spectroscopy- R.J. Reynolds,K.Aldous & K.C. Thompson (CharlesGriffin and company Ltd. London) 1970.
11. Modern methods for trace element determination- C.Vandecasteele & C.B.Block (John Wiley & Sons, New York) 1993.
12. Principles of instrumental analysis- D.A. Skoog & J.J.Leary (Saunders College publishing) 1992.
13. Mössbauer spectroscopy- N.N.Greenwood & T.C. Gi bb (Chapman & Hall,London) 1971.
14. Spectroscopy, vol.1 – Straughan & Walker (Chapm an& Hall, London) 1976; Chap.5.
15. Mössbauer effect: principles and applications- G.K.Wertheim (Academicpress,New York) 1964.
16. An introduction to Mössbauer spectroscopy - Leo pold May, Edr. (Plenumpress,New York) 1971.

M.Sc. (Physics) (Semester-IV)
Paper Code: CBP-1119D
Total Credits: 4-credits
Paper title: Electronic Devices and applications

Unit 1 Transistors and Microwave Devices: (15)

Bipolar junction transistor (BJT), frequency response and switching of BJT, Field effect transistor (JFET), MOSFET and related devices, MESFET device structure and its operation,Tunnel diode, Transferred electron devices and Gunn diode, Avalanche transit time diode and IMPATT diode.

Unit 2 Photonic Devices: (15)

Radiative transitions and optical absorption, Light emitting Diodes, OLED, Infrared LED,Photodetector, Photoconductor, Photodiode, p-n junction Solar cells, Conversion efficiency,Semiconductor Lasers, Laser operation, population inversion, carrier and optical confinement, optical cavity.

Unit 3 Other electronic Devices: (15)

Magneto-optic and acousto-optic effects, Material's properties related to get these effects, Piezoelectric, Electrostrictive and magnetostrictive effects, important materials, exhibiting these properties and their applications in sensors and actuator devices.

Unit 4 Sensors: (15)

Thermal sensors-Thermistor, transistor thermal sensor, nonsemiconductor sensors, thermocouple, Mechanical sensors- strain gauge , Magnetic sensors-capacitive sensor-Hall plate, Magnetoresistor,Magnetotransistor, Chemical Sensors- Metal- Oxide Sensors, Bio sensors

Reference Books:

1. Semiconductor devices: Physics and Technology 2nd Edition, S. M. Sze
2. Modern Digital Electronics, R. P. Jain
3. Introduction to Semiconductor devices by M. S. Tyagi
4. Optical electronics by Ajoy Ghatak and K. Thyagrajan, Cambridge University Press.

M.Sc. (Physics) (Semester-IV)
Paper Code: CP-1120D
Total Credits: 4-credits
Paper title: SOLID STATE PHYSICS- III (Physical properties of solid)

Unit 1: Electronic Structure of Crystals (15)

Basic assumptions of Model, Collision or relaxation times, DC electrical conductivity,Failures of the free electron model, The tight-binding method, Linear combinations of atomicorbitals, Application to bands from s-Levels, General features of Tight-binding levels,Wannier functions, Other methods for calculating band structure,Independent electronapproximation, general features of valence band wave functions,Cellular method, Muffin Tin potentials, Augmented plane wave (APW) method,Green's function (KKR) method, Orthogonalized Plane Wave (OPW) method Pseudopotentials

Unit 2:Transport Properties of Metals (15)

Drift velocity and relaxation time, The Boltzmann transport relation, The Sommerfeld theoryof metals of electrical conductivity, The mean free path in metals, Thermal scattering, The electrical conductivity at low temperature, The thermal conductivity of metals, DielectricProperties of insulators, Macroscopic electrostatic Maxwell equations, Theory of Local Field, Theory of polarizability, Clausius- Mossotti relation, Long- wavelength optical modes inIonic crystals.

Unit 3: Phonons, Plasmons, Polaritons, and Polarons (15)

Vibrations of monatomic lattices: first Brillion zone, group velocity, Long wavelength limit,Lattice with two atoms per primitive cell. Quantization of lattice vibrations, Phonon momentum Dielectric function of the electron gas, Plasma optics, Dispersion relation for Electromagnetic waves, Transverse optical modes in a plasma, Longitudinal Plasma oscillations, Plasmons, Polaritons, LST relations, Electron- electron interaction, Electron phonon interaction: Polarons,

Unit 4: Defects in crystals (15)

Thermodynamics of point defects, Schottky and Frenkel defects, annealing, electrical conductivity of ionic crystals, color centers, Polarons and exciton, dislocations, strength of crystals, crystal growth, stacking faults and grain boundaries

Reference Books:

1. Solid State Physics by N W Ashcroft and N D Mermin, HRW, International editions (1996) (Units 1, 2 and 3)
2. Introduction to Solid State Physics by C Kittle (4th edition) John Willey Publication (1979) (Units 3)
3. Solid State Physics by A J Dekker ((1986) Macmillan India Ltd

M.Sc. (Physics) (Semester-IV)
Paper Code: CP-1121D
Total Credits: 4-credits
Paper title: SOLID STATE PHYSICS-IV (Energy Conversion and Storage Devices)

UNIT I: Solar 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, Antireflective coating (ARC), Design for high Voc and fill factor, Analytical techniques; solar simulator, Quantum efficiency, Minority carrier life time and diffusion length measurement. Thin film solar cells: Advantages, materials, a-Si, CdTe, CIGS

UNIT II: Dye and Quantum Dot Sensitized Solar Cell (15)

Dye sensitized solar cells: - Operation, Materials and their properties, Advantages and Disadvantages Quantum dot sensitized solar cells: - What is quantum dot? Tuning the electronic properties of Quantum dot, Operation, Materials and their properties, Advantages and Disadvantages

UNIT III: Perovskite and Organic Solar cell (15)

Pervoskite sensitized solar cells: - Crystal Structure and Related Properties, Opto-electronic Properties, Device Structures, operation and Performances Organic Photovoltaic Materials: - Organic Photovoltaic Materials properties, Principles of Operation and Device Concepts, Stability and Performance

UNIT IV: Supercapacitors and Batteries:- (15)

Supercapacitor:Comparison between capacitor, supercapacitor and battery; Capacitor principle, Types of capacitors; Electrochemical capacitor: Introduction,Ragone plot, Charge-discharge of supercapacitor and battery; Electric double layer capacitor: electrode-electrolyte interfaces (models), construction, advantages and disadvantages; pseudocapacitor: electrochemical pseudocapacitor of electrode-electrolyte interface; electrochemistry of pseudocapacitor: underpotential, Redox, Intercalation; Electrode material, Ruthenium oxide. Introduction to Li-Ion battery, Introduction to fuel cell.

References:

1. Solar photovoltaics, Fundamentals, Technologies and Applications by Chetan Singh Solanki, PHI Learning Private Limited, Delhi-110092.
2. Dye Sensitized Solar Cells by K. Kalyansundaram, EPFL Press, A Swiss academic publisher distributed by CRC press.
3. Quantum dot solar cells. Semiconductor nanocrystals as light harvesters, PV Kamat, The Journal of Physical Chemistry C 112 (48), 18737-18753
4. Photovoltaic Solar Energy: From Fundamentals to Applications by Editors(s):AngèleReinders, Pierre Verlinden, Wilfried van Sark, Alexandre Freundlich, John Wiley & Sons, Ltd
5. Clean Electricity from Photovoltaics: Second Edition by Mary D Archer, Martin GreenImperial College Press Syllabus for M. Sc (Physics) Choice Base Credit System

6. Advanced Concepts in Photovoltaics by Arthur J Nozik, Gavin Conibeer and Matthew C Beard, RSC Energy and Environment Series
7. Practical Handbook of Photovoltaics: Fundamentals and Applications by AugustinMcEvoy, Tom Markvart and Luis Castaner. Academic Press
8. Electrochemicalsupercapacitors forenergy storageand deliveryfundamentals and applications by Aipingyu, victor Chabot and jiujunzhang.
9. Electrochemical Supercapacitors, Scientific fundamentals and Technological Applications by B. E. Conway, Kluwer Academic/ Plenum Publishers, New York, Boston, Dordrencht, London, Moscow
10. https://batteryuniversity.com/learn/article/lithium_based_batteries BU-204
11. Battery reference book 3rd edition by T. R. Crompton
12. Battery Technology Handbook by H. A. Kiehne , Marcel Dekker, Inc. , New York, Basel.
13. Fuel cell handbook &th edition by E G and G technical services.Inc.