MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Department of Physics

Course Code : PHT722

Course Name : Advanced Techniques for Materials Characterization

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : None

Course Contents

Module 1 [Lectures: 5, Tutorials: 0]
Introduction to surfaces, interfaces and bulk of solid materials, classification, distinction and overview of surface and bulk characterization techniques

Module 2 [Lectures: 14, Tutorials: 0]
Techniques for atomic structure and surface morphology determination: working principle and data analysis for X-ray Diffraction (XRD), transmission electron microscopy (TEM), low energy electron diffraction (LEED), scanning tunneling microscopy (STM) and atomic force microscopy (AFM).

Module 3 [Lectures: 8, Tutorials: 0]
Techniques for compositional analysis: working principle and data analysis for the techniques- electron probe micro analysis (EPMA) and energy dispersive analysis (EDAX), X-ray fluorescence (XRF)

Module 4 [Lectures: 12, Tutorials: 0]
Thermal analysis and other techniques: working principle and data analysis for the techniques- differential scanning calorimetry (DSC), differential thermal analysis (DTA) and thermo-gravimetric analysis (TGA), Measurements using Hall Effect, Four probe resistivity measurements set-up.

Recommended Readings

Reference books-

1. Surface Analysis Methods in Materials Science: D. J. O. Conner (Springer Verlag).
2. Surface and Interfaces of Solids: H. Lueth (Springer).
3. Advanced Techniques for Materials Characterization: A. K. Tyagi, M. Roy, S. K. Kulshrestha, S. Banerjee (Materials Science Foundations-Trans Tech Publications).
4. Vacuum Science and Technology: V. V. Rao, T. B. Ghosh, K. L. Chopra (Allied Publishers).
5. Instrumental Methods of Chemical Analyses: G.W. Ewing (McGraw Hill).
6. Characterization of Solid Surface: P.F. Kane (Plenum).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**
Course Code : **PHT 723**

Course Name : **Basics of Astronomy & Astrophysics**
Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Elective
Prerequisites : PHT-611, PHT-622

Course Contents

Coordinate Systems For Celestial Objects & Their Interrelations, Cardinal Points In The Sky, Time Measurements in Astronomy, Proper & Peculiar Motion of Stars, Astronomical Observations and Instruments, Parallaxes, Photometry, Magnitude System, Distance Modulus, Color Indices;
Stellar spectra and Structure, Ionization Equation & Elemental Abundances, H-R Diagram, Stellar Evolution, Nucleosynthesis and Formation of Elements, Variable Stars, Compact stars, Star clusters and Binary stars;
Galaxies & their Evolution and Origin, Classification of Galaxies, Hubble Law, Active Galaxies and Quasars, Big Bang Model (vs. Steady State), Early Universe and CMBR, Present Epoch & Future Evolution of the Universe.

Recommended Readings

Text Books:

1. An Introduction to Modern Astrophysics : by B. W. Carrol & D. A. Ostlie (Addison Wesley).
2. Textbook of Astronomy & Atrophysics with Elements of Cosmology : V. B. Bhatia (Narosa)
3. An Introduction to Astronomy & Astrophysics: Pankaj Jain (CRC press)
4. An Introduction to Astrophysics: B. Basu, T. Chattopadhyay & S. N. Biswas (PHI)

Reference Books:

1. Introduction to Astronomy & Cosmology: Ian Morrison (Wiley).
2. Astrophysics: Stars and Galaxies: K. D. Ghatak and S. Abhyankar (Universities Press).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 725**

Course Name : **General Theory of Relativity**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : Mathematical Physics, Classical Mechanics, Special Theory of Relativity

Course Contents

Why general relativity, Review of special theory of relativity: Inertial observers, Minkowski metric, spacetime diagrames, light cone, invariant hyperbolae, Lorentz transformations, vectors and vector spaces, Four-vector formulation of special relativity, Tensors and tensor manipulation, Energy and momentum in special relativity and energy-momentum tensor for perfect fluid.

Riemannian geometry: manifolds, curve on a manifold, functions on manifolds, vectors and vector fields on manifolds, tensors on manifolds, metric tensor and tensor densities, tensor calculus, Christoffel symbols and covariant derivative, parallel transport and geodesics, Riemann curvature tensor, general properties of Riemann tensor, Ricci tensor and scalar, Weyl tensor.

Equivalence principle, principle of general covariance, gravity as a curvature of spacetime, geodesics as trajectories under the influence of gravitational field, non-local lift experiment, geodesic deviation, Einstein's field equation.

Schwarzchild solutions of Einstein's field equation, construction of metric and its symmetries, motion of a particle in Schwarzchild metric, experimental tests of general relativity, precession of the perihelion, bending of light, gravitational redshift, singularities, horizons, black holes. FRW metric and Friedmann equation, Radiation and matter dominated universe, Cosmological Constant, Inflation and CMBR

Gravitational radiation, weak-field approximation, gauge transformations, plane gravitational waves, generation of gravitational waves, quadrupole radiation, detection of gravitational waves.

Recommended Readings

Text Books:

1. A First Course in General Relativity: Bernard Schutz (Cambridge University Press).
2. Spacetime and Geometry: An Introduction to General Relativity, Sean M. Carroll (Pearson Indian Education)
3. Gravity: An introduction to Einstein's General Relativity; J. B. Hartle (Pearson India Education).
4. Introducing Einstein's Relativity: Ray D'Inverno (Oxford University Press)

Reference Books:

1. General Relativity: R. M. Wald (University of Chicago Press).
2. Gravitation and Cosmology: S. Weinberg (Wiley India PVT. LTD).
3. Classical Theory of Fields: L. D. Landau and E. M. Lifshitz (CBSPD).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 726**

Course Name : **Introduction to MonteCarlo Simulation**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : none

Course Contents

Fundamentals of Monte Carlo approach to simulate the particle interactions with detector materials, random number generation, landau distribution of energy deposited, convolution with Poisson distribution, advantages of Monte Carlo method, basic Geant4 concepts, important features of Geant4, installation.

User classes: mandatory classes and action classes, detector construction, physics processes: electromagnetic, hadronic and decays, generation of primary particles through gun, action classes:run, event and tracking of particles in the experiment, Geant4 examples: basic, extended and advanced examples, design of simple geometry e.g. calorimeter to the real life experiment e.g. hadron therapy.

Hands on sessions on how to design the experiment, compile and run in geant4 simulation environment, analysis of simulated data from Geant4 using ROOT software: 1D, 2D and 3D histogram plotting, curve fitting, storing data in Tree and Ntuples, applications: computed tomography, 3D image reconstruction in medical physics, design optimization of any complex detector geometry in high energy physics experiments, radiation effects analysis in space science, application in solid state physics. .

Recommended Readings

Text books-

7. Statistics: R J Barlow (John Wiley and Sons)
8. A Practical Guide to Data Analysis for Physical Science Students –L. Lyons (Cambridge University Press)
9. Data analysis techniques for HEP, Fruhwirth et al (Cambridge University Press)
10. Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications: I. Kawrakow, in A. Kling et al (edts.) (Springer).
11. Techniques for Nuclear and Particle Physics Experiment: W. R. Leo (Springer).
12. Radiation Detection and Measurement: Glenn F. Knoll (Wiley).

13. Handbook of Radiotherapy Physics, Theory and Practice: P Mayles, A Nahum, J.C Rosenwald (Taylor & Francis).

Online resources-

1. Monte Carlo simulations, Geant4 User Guide: http://www.cern.ch/geant4
2. Data Analysis Software, ROOT User Guide: https://root.cern.ch/

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT727**

Course Name : **Introduction To Quantum Field Theory**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : Mathematical Physics, Quantum Mechanics

Course Contents

Introduction: basics of Special Relativity, Lorentz and Poincare group, problems with old relativistic quantum theory

Particles with no spin: classical theory of scalar fields, Klein-Gordon equation, Noether's Theorem, canonical quantisation of Klein-Gordon theory, propagators and Green's functions, discrete symmetries, Spin Statistics Theorem

Interacting scalar fields: path integrals, functional quantisation, cross sections and S-matrix, LSZ reduction formula, perturbation theory and Feynman diagrams, Kallen-Lehmann spectral representation

Renormalisation: renormalised perturbation theory using counterterms, spontaneous symmetry breaking, Wilson's approach to renormalisation

Particles with spin: Dirac Fields, brief introduction to Quantum Electrodynamics

Recommended Readings

Text Books:

14. An Introduction To Quantum Field Theory: Michael E. Peskin & Daniel V. Schroeder (CRC Press)
15. Quantum Field Theory: Mark Srednicki (Cambridge University Press)

Reference Books:

3. The Quantum Theory Of Fields, Volumes 1 and 2: Steven Weinberg (Cambridge University Press)
4. David Tong's lecture notes on QFT
5. Quantum Field Theory In A Nutshell: A. Zee (Princeton University Press)
6. Classical Theory Of Gauge Fields: Valerie Rubakov (Princeton University press)

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT730**

Course Name : **Nanostructured Materials and Applications**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : None

Course Contents

Overview of nanostructures, top-down and bottom-up approaches, size dependent properties of nanomaterials, zero, one- and two-dimensional nanostructures, physics of thin film deposition, superlattice structures, structural, optical, electrical, dielectric and magnetic properties of nanomaterials.

Synthesis of semiconductor and metal nanocrystals, carbon nanotubes, nanocomposites, nanocrystalline thin films, tuning the properties of nanomaterials, ion beam modification of nanostructures, analysis of nanostructured materials using XRD, Raman, Dynamic light scattering, TEM, SPM and SEM.

Applications of nanotechnology in energy, space, optics, medicine and electronics. Environmental, health and safety issues.

Recommended Readings

Text books:

16. Introduction to Nanotechnology: Charles P. Poole, Jr. and Frank J. Owens (Wiley-2013).
17. Nanostructures and Nanomaterials Synthesis, Properties and Applications: G. Cao (Imperial College Press-2006).
18. Introduction to Nanoscience and Nanotechnology, K K Chattopadhyay & A N Banerjee (PHI, EEE, October 2012)

Reference books:

7. Nano: The Essentials, T. Pradeep (McGraw Hill Education; 2017).
8. Nanotechnology: Basic Science & Emerging Technology: M. Wilson, K. Kannangara, G. Smith, M. Simmons and B. Raguse (Overseas Press-2005).
9. Nanotechnology: Principles and Practices, Sulabha K. Kulkarni (Springer)

Online resources-

- NPTEL lectures

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 731**

Course Name : **Nanotechnology for Energy Applications**

Credits : 3 **L -** 2 **T -** 1 **P -** 0
Course Type : Elective
Prerequisites : none; [preferred – understanding of basic nanotechnology]

Course Contents

Module 1 [Lectures: 6, Tutorials: 3]
Energy challenge in the 21st century, introduction of nanotechnology, synthesis and characterization of nanomaterials, nanomaterials and nano systems for energy applications, energy storage and energy harvesting technologies.

Module 2 [Lectures: 7, Tutorials: 4]
Renewable and non-renewable energy sources development and implementation of renewable energy technologies, energy transport, conversion and storage, challenges in photovoltaics, limits in conversion efficiency, solar cells and its merits/demerits, thermoelectric materials, thermoelectric properties on nanoscale, thermoelectric nanocomposites

Module 3 [Lectures: 6, Tutorials: 3]
Micro-fuel cell technologies, fuel cells, polymer membranes for fuel cells, PEM fuel cell. Acid/ alkaline fuel cells, design of fuel cells.

Module 4 [Lectures: 7, Tutorials: 3]
Methods for separation of hydrogen, membranes for gas separation, hydrogen storage methods, metal hydrides, hydrogen storage in carbon nanotubes, use of nanoscale catalysts to save energy, nanomaterials based rechargeable batteries.

Recommended Readings

Text books
Nanotechnology for the energy challenge: Javier Garcia-Martinez (WILEY- VCH)
Renewable energy resources: John Twidell, Anthony D. Weir (Taylor and Francis).
Physics of solar cells: Peter Würfel, John (Wiley & Sons).
Fuel cell technology handbook: Hoogers (CRC Press).
Hydrogen fuel: production, transport and storage, Gupta (CRC Press)

Reference books:
Nanoscale applications for information & energy systems: David J. Lockwood, A Korkin (Springer).
Energy efficiency and renewable energy through nanotechnology: Ling Zang (Springer).

Online resources
https://www.coursera.org/learn/renewable-energy-fundamentals#syllabus
https://onlinecourses.nptel.ac.in/noc19_me73/preview

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**
Course Code : **PHT736**

Course Name : Semiconductor Physics and Devices
Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Elective
Prerequisites : none;

Course Contents

Bipolar junction transistors, transistor as an amplifier and switch, field effect transistors, MOSFET devices, metal-semiconductors FET, hetero structure FET

Photonic devices, crystalline and amorphous solar cells, photo detectors, LEDs, semiconductor lasers, solid state microwave devices, techniques to measure properties of semiconductors, four probe method, hall effect, spreading resistance for diffusion measurements, measurement of mobility of carriers, semiconductor device

An overview of IC fabrication technology, epitaxial growth, diffusion, oxidation, wafer doping and etching, photolithographic processing, ion implantation, ultra purification.

Recommended Readings

19. **Text books**
    10. Solid State Electronic Devices: B. G. Streetman and Banerjee (Prentice Hall of India)
    11. Physics of Semiconductor Devices: S.M. Sze (John Wiley and Sons
20. **Reference books**
    - Principles of Electronic Materials : S.O.Kasap (McGraw Hill)
    - Principles of Semiconductor Devices: Sima Dimitrijev (Oxford University Press)
    - Physics of Semiconductor Devices: M. Schur (Prentice Hall of India)
    - Semiconductor Physics and Devices: S.S. Islam (Oxford University Press)
    - Electrical Characterization of Semiconductor Materials and Devices, (Chapter 20) Springer Handbook of Electronic and Photonic Materials, ISBN 978-0-387-26059-4, Springer-Verlag US

Online/E- resources

(i) Nptel Video - Electronic Materials, Devices & Fabrication, IIT Madras, Mod 1, Lec 20-31

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Department of Physics

Course Code : PHT738

Course Name : Solar Energy and Applications

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : none

Course Contents

Module 1 [Lectures: 12, Tutorials: 0]

Solar energy: origin, solar constant, spectral distribution of solar radiation, absorption of solar radiation in the atmosphere, global and diffused radiation, seasonal and daily variation of solar radiation, measurement of solar radiation, photo thermal conversion, types of solar energy collectors, concentrating/non-concentrating solar collectors, collector efficiency and its dependence on various parameters, solar fuels: electrolysis of water, photoelectrochemical splitting of water.

Module 2 [Lectures: 10, Tutorials: 0]

Fundamentals of solar cells: photo voltaic effect, *p-n* junction photodiodes, depletion region, electron and holes transports, absorption of photons, excitons and photoemission of electrons, band engineering, charge carrier generation, charge separation, recombination and other losses,

Module 3 [Lectures: 7, Tutorials: 0]

I-V characteristics, output power, efficiency, fill factor and optimization for maximum power, metal-semiconductor heterojunctions, surface structures for maximum light absorption, operating temperature vs conversion efficiency.

Module 4 [Lectures: 10, Tutorials: 0]

Device physics, device structures, device construction, solar cell properties and design, materials for solar cells, silicon based solar cells: single crystal, polycrystalline and amorphous silicon solar cells, organic solar cells, organic-inorganic hybrid solar cells, advanced concepts in photovoltaic research, nanotechnology applications.

Recommended Readings

21. **Text book-**
    1. Nelson, J. The Physics of Solar Cells. Imperial College Press, 2003. ISBN: 9781860943409.
    2. Solar Engineering of Thermal Process: Duffie and Beckman, John Wiley, 2013. ISBN: 9780470873663
    3. Solar Energy: S. P. Sukhatme, Tata McGraw Hill, 1996. ISBN: 1259081966, 9781259081965.
    4. Principles of Solar Engineering, D. Yogi Goswami, Taylor and Francis, 2015. ISBN: 9781138569478.

22. **Reference book-**

1. Wenham, S., M. Green, et al., eds. Applied Photovoltaics. 2nd Ed. Routledge, 2006. ISBN: 9781844074013.
2. Luque, A., and S. Hegedus, eds. Handbook of Photovoltaic Science and Engineering. John Wiley & Sons, Ltd, 2003. ISBN: 9780471491965
3. Green, M. A. Solar Cells: Operating Principles, Technology, and System Applications. Prentice Hall, 1981. ISBN: 9780138222703.

23. **Online resources-**

Kazmerski, L. "Solar Photovoltaics R&D at the Tipping Point: A 2005 Technology Overview." Journal of Electron Spectroscopy and Related Phenomena 150, no. 2-3 (2006): 105–35.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 999**

Course Name : **LabVIEW**

Credits : 3 **L -** 2 **T -** 0 **P -** 2

Course Type : **Elective**

Prerequisites : None

Course Contents

Theory: Basic of programming language, Types of Data in LabView, Controls, Indicators and Function Palettes, Structures, Loops, Math Script and Sequence, Shift Registers, Arrays: Introduction and Elements, Strings, Charts and Graph. File Handling: Input & Output Files, Curve Fitting, Basics of Data Acquisition, Different types of Signals and their sources, DAQ Card, RS232 and GPIB Interfaces, VISA Platform, LabVIEW Communication, Advanced topics in LabVIEW.

Labs: Programming in LabVIEW Environment, Creating New VIs: Front Panel and Block Diagram, Wiring and Run the Programme, Debugging the Problem and Help, Applications of Loops and Structures, LabVIEW programming using Charts and Graphs, Example of inbuild Programmes.
File Handling using LabVIEW Environment, Use of the Curve Fitting VIs, Simulate Signals and Analyse the input Signals, Connecting Instrument with LabVIEW and Data Acquisition, Hardware Installation and Configuration, Interfacing and Data Acquisition from Various Lab Instruments.

Recommended Readings

Text books-

24. Virtual instrumentation using LabVIEW: Sanjay Gupta, Joseph John (Tata McGraw-Hill)
25. LabVIEW for Everyone: Graphical Programming Made Easy and Fun: Jeffrey Travis, Jim Kring (Prentice Hall).
26. LabVIEW based Advanced Instrumentation Systems: LabVIEW based Advanced Instrumentation Systems: S. Sumathi and P. Surekha (Springer).
27. Analog Electronics with LabVIEW: Kenneth L. Ashley (Prentice Hall).

Reference books-

12. LabVIEW User Manual, National Instruments (NI)

Online resources-

NPTEL/Mooc Courses

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 999**

Course Name : **Membrane Technology for Energy Applications**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : Material Science

Course Contents

Types and uses of membranes; Isotropic Membranes, Anisotropic membranes, Ceramic, Metallic, and Liquid Membranes; Zeolite, Carbon, and Glass Membranes; Porous Membranes, Dense Membranes, Mixed-Matrix Membranes, Hollow-Fiber Membranes, Ion-exchange Membranes, Recent development in membranes; Solution-diffusion model, Pore-flow membranes; Types and uses of modules: Plate and frame module, Spiral wound module, Tubular module, Capillary module, Comparison of module configurations.

Concentration polarization in liquid separation processes, Gel layer model, Osmotic pressure model, Boundary layer resistance model, Concentration polarization in gas separation processes, Membrane fouling and fouling control; Reverse Osmosis, Ultrafiltration and Microfiltration and their applications; Dialysis and Electrodialysis and their applications.

Membrane reactors and membrane bioreactors; Prevaporation and its applications; Gas separation; Membrane Contactors; Introduction of synthetic membrane, Preparation of synthetic membranes, Phase inversion membranes, Preparation technique for composite membranes.

Membrane Applications: Fuel cell, Batteries, Hydrogen production, Membranes for coal and gas power plants; Membrane Characterization Techniques: Characterization of porous membranes, Characterization of ionic membranes, Characterization of non-porous membranes.

Recommended Readings

Text Books:

28. Baker, R. W. (2012), Membrane Technology and Applications, 3rd Ed., Wiley, UK.
29. Mulder, M. Mulder, J. (1996), Basic Principles of Membrane Technology, Kluwer Academic.

Reference Books:

13. W. S. W. Ho and K. K. Sirkar (1992), Membrane Handbook, Chapman & Hall, NY.
14. N.N. Li, A. G. Fane, W.S.W. Ho and T. Matsuura, (2008), Advanced Membrane Technology, Wiley.
15. M. Cheryan, (1998), Ultrafiltration and Microfiltration Handbook, CRC Press.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Department of Physics

Course Code : PHT 999

Course Name : Experimental Techniques in High Energy Physics

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : none;

Course Contents

Relativistic kinematics required to understand the experimental data in high energy physics (HEP), derivation of kinematic variables and their transformations, decay kinematics, rapidity, pseudo-rapidity, space like and time like, examples where relativistic kinematics play an important role for understanding data.

General concept of building a HEP experiment, interaction of high-energy particles with matter, specific applications related to the experimental high energy physics (EHEP), overview on various particle detectors used in EHEP: gaseous detectors, semiconductor detectors: silicon microstrip detectors, scintillators and cherenkov detectors, calorimeter and preshower detectors, basic principle of electromagnetic and hadronic shower generation

Detector simulation and data analysis, need of simulation, various techniques in Monte Carlo simulations and data analysis in HEP, general approach of data preselection and cleanup, calibration, track reconstruction, reconstruction of events, error analysis in EHEP, statistical and systematic error analysis.

Important highlights on physics analysis techniques: particle identification, Dalitz plot distributions, missing mass and invariant mass, overview on present and future HEP

experiments, Large Hadron Collider experiments, SuperLHC, Belle experiment at KEK, Japan, SuperKEKB, neutrino experiments, future collider experiment, ILC, applications of EHEP data analysis

Recommended Readings

Text books-

16. Relativistic Kinematics- A guide to the kinematic problems of High Energy Physics: R. Hagedorn (N.Y. W. A.Benjamin).
17. Techniques for Nuclear and Particle Physics experiments: W.R. Leo (Springer).
18. Radiation Detection and Measurement: Glenn F. Knoll (Wiley).
19. Evaluation of Silicon sensor technology in particle physics: Frank Hartmann (Springer).
20. Introduction to High Energy Physics: Donald H. Perkins (Cambridge University Press).
21. Statistics: R J Barlow (John Wiley and Sons)
22. A Practical Guide to Data Analysis for Physical Science Students –L. Lyons (Cambridge University Press)
23. Data analysis techniques for HEP, Fruhwirth et al (Cambridge University Press)
24. Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications: I. Kawrakow, in A. Kling et al (edts.) (Springer).
25. Introduction to High Energy Physics: Donald H. Perkins (Cambridge University Press).

Reference books-

30. The Experimental Foundations of Particle Physics: R. N. Cahn, G. Goldhaber (Cambridge University Press).
31. Experimental Techniques in High Energy Nuclear and Particle physics: T. Ferbel (World Scientific).
32. Introduction to Experimental Particle Physics: R.C. Fernow (Cambridge University Press, New York).
33. Data Reduction and Error analysis for the physical sciences: P. Bevington and D. K.Robinson (McGraw-Hill Higher Education).

Online resources-

34. High Energy Accelerator and Research Organization (KEK): https://www2.kek.jp/accl/eng/
35. Center for Nuclear Research, Europe (CERN): https://home.cern/

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code	:	**PHT 999**
Course Name	:	**Introduction to Machine Learning in Particle Physics**
Credits	:	3 **L -** 3 **T -** 0 **P -** 0
Course Type	:	Elective
Prerequisites	:	none

Course Contents

Machine learning software packages (open sources eg python) and their installation, Supervised and Unsupervised learning. Regression, Classification, Principal component analysis, Singular value decomposition, Support vector machines, Clustering, K-Nearest Neighbors, Decision trees, Neural Networks, Deep Learning. Application of machine learning in physics research, Preparation of mini projects in astrophysics, particle physics, space physics, medical physics, and solid state physics areas.

Recommended Readings

Text books-

26. Introduction to Machine Learning, 3rd ed., E. Alpaydin, MIT Press (2014)
27. Introduction to Machine Learning with Python, Andreas C. Müller & Sarah Guido
28. Python Machine Learning - Second Edition, Sebastian Raschka , Vahid Mirjalili
29. Statistics: R J Barlow (John Wiley and Sons)
30. A Practical Guide to Data Analysis for Physical Science Students –L. Lyons (Cambridge University Press)
31. Data analysis techniques for HEP, Fruhwirth et al (Cambridge University Press)
32. The Elements of Statistical Learning, 2nd ed., T. Hastie, R. Tibshirani, & J. Friedman, Springer (2016)
33. Handbook of Radiotherapy Physics, Theory and Practice: P Mayles, A Nahum, J.C Rosenwald (Taylor & Francis)
34. Hands-On Machine Learning : Concepts, Tools, and Techniques to Build Intelligent Systems 2nd Edition, Aurélien Géron

Online resources-

36. Data Analysis Software, ROOT User Guide: https://root.cern.ch/

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 999**

CourseName : **Advanced Quantum Mechanics**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Program Elective

Prerequisites : preferred – understanding of Quantum Mechanics

Course Contents

Time dependent perturbation theory, first order perturbative expression for the transition amplitude and probability, harmonic perturbations, transition probability under constant perturbation, Fermi's golden rule.

Interaction of radiation with matter, spontaneous emission, absorption, induced emission, dipole transitions, selection rules, identical particles, Pauli exclusion principle.

Non-relativistic scattering, solution of scattering problem by the method of Green's function, Born approximation and its validity for scattering problems, partial wave analysis, optical theorem.

Introduction to relativistic wave equations, Klein-Gordon equation, plane wave solution of Klein-Gordon equation, Dirac equation for a free particle, Dirac matrices, Dirac spinors, covariant form of Dirac equation, plane wave solutions of Dirac equation: energy spectrum, negative energy states, spin of the Dirac particle, Majorna equation

Recommended Readings

Text Books:

37. Quantum Mechanics – A Modern Approach: A. Das and A. C. Milissiones (CRC Press).
38. Quantum Mechanics: E. Merzbacher (Wiley).
39. Advanced Quantum Mechanics: J.J. Sakurai (Addison Wesley Publishing Co.)
40. Principles of Quantum Mechanics: R. Shankar.
41. Introduction to Quantum Mechanics: David J. Griffiths (Pearson Education).
42. Quantum Mechanics by Mathews and Venkatesan (McGraw Hill)
43. Quantum Mechanics by G.Arul das (PHI)

Reference Books:

35. Quantum Mechanics: L.I. Schiff, (McGraw Hill).
36. Quantum Mechanics, Theory and Applications: A.K. Ghatak and S. Loknathan, (McMillan India).

37. Quantum Mechanics: L. D. Landau and E. M. Liefshitz (Pergamon Press).
38. Quantum Mechanics- An Introduction: Walter Greiner (Springer).
39. Feynmann Lecturers: Vol I, II & III

Online resources:

NPTEL/Mooc Courses

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 999**

Course Name : **Physics at Low Dimensions**

Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Elective
Prerequisites : Preferred – Basic understanding of Solid State Physics

Course Contents
Module 1 [Lectures: 7, Tutorials: 0]
Brief overview of band structure and density of states function for 0D, 1D and 2D systems, schematics of making things smaller, limits to smallness, quantum nature of matter, realization of low-dimensional electron systems.

Module 2 [Lectures: 12, Tutorials: 0]
Band gap engineering and semiconductor heterostructures, infinite and finite square well potentials, the occupation of subbands, quantum wells in heterostructures, electronic transitions in a quantum well, multiple quantum wells, triangular potential well and its wave functions, two-dimensional electron gas (2DEG), Shubnikov de Haas oscillations, 2DEG at the high magnetic field and low temperature, edge states.

Module 3 [Lectures: 12, Tutorials: 0]
Quantum wires and nanowires, growth and fabrication of semiconductor quantum wires/nanowire, electronic transport in 1D structures, novel properties and applications of nanowires, interference of electronic waves, ballistic transport, resonant scattering, impurity scattering, Anderson localization, Anderson transition, scaling theory, various quantum transport phenomena, quantized conductance, coulomb blockade.

Module 4 [Lectures: 8, Tutorials: 0]
Device application of low dimensional systems: double heterostructure laser, high electron mobility transistors, 2D materials: graphene, topological insulators, WS_2 and their properties.

Recommended Readings

Text books-

44. The Physics of Low-dimensional Semiconductors, J. H. Davies, Cambridge University Press, 1998.
45. Transport in Nanostructures, D. K. Ferry, S. M. Goodnick, and J. Bird, Cambridge University Press, 2009.
46. Introduction to Mesoscopic Physics: Yoseph Imry, Oxford Univ. Press, 2008.
47. Electronic Transport in Mesoscopic Systems: Supriyo Datta, Cambridge Univ. Press, 1997.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**
Course Code : **PHT 999**

Course Name : **Spintronics: Physics and Technology**
Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Elective
Prerequisites : Preferred – Basic understanding of Solid State Physics

Course Contents

Module 1 [Lectures: 10, Tutorials: 0]
History and overview of spin electronics, classes of magnetic materials, quantum mechanics of spin, spin-orbit interaction, exchange bias, spin relaxation mechanisms, pure spin and charge currents.

Module 2 [Lectures: 12, Tutorials: 0]
Spin-Hall effect and inverse spin-Hall effect, spin Seebeck effect, magneto caloric effect, the spin galvanic effect, basic electron transport, spin-dependent electron transport, spin-dependent tunneling, the basic theory of Andreev reflection, ferromagnet/ superconductor/ ferromagnet double junctions. Semiclassical transport models, spin injection, spin accumulation, spin current.

Module 3 [Lectures: 12, Tutorials: 0]
Spin-transfer torque and its magnetic dynamics, current-driven switching of magnetization and domain wall motion, domain wall scattering and current-induced switching in ferromagnetic wires. basics of spin valve and magnetic tunnel junctions, tunnel magneto resistance, quantum mechanical model of coherent tunnelling and giant TMR, read heads, MRAMS, spin transistors, spintronic biosensors, and quantum computing with spins.

Module 4 [Lectures: 5, Tutorials: 0]
Materials for spin electronics, nanostructures for spin electronics, micro and nanofabrication techniques.

Recommended Readings

Text books-

48. Introduction to Spintronics, S. Bandyopadhyay, M. Cathay, CRC Press, 2008.
49. Magnetoelectronics, M. Johnson, Academic Press 2004.
50. Concepts in Spin Electronics, S. Maekawa, Oxford University Press, 2006.
51. Spintronic materials and technology, Y.B. Xu and S. M. Thompson, Taylor & Francis, 2006.
52. Magnetic Recording Technology, C.D. Mee and E.D. Daniel, McGraw-Hill Professional (1996).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 999**

Course Name : **Vacuum Science and Thin Film Technology**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : None

Course Contents

Basics of vacuum science, creation of vacuum: rotary, diffusion, getter ion, turbo molecular, and cryo-pumps, measurement of vacuum: Penning, Pirani, ionization gauges, Designing a typical vacuum system, vacuum leak detection: helium leak detector, residual gas analyzer.

Growth techniques of thin films: PVD & CVD methods, Thermal evaporation, E-beam evaporation, RF/DC sputtering, Pulsed Laser Deposition, Molecular Beam Epitaxy, Atomic Layer Deposition, spin & dip coating and Chemical vapour deposition. Film thickness measurement, properties of thin films: Structural, optical, electrical and mechanical properties.

Thin film analysis (with applications of techniques in solving research problems): ion beam sputtering, depth profiling, Study of inter diffusion in thin films using XPS, AES, SIMS and RBS. Diffraction studies on thin films using XRD and LEED. Thin film morphological studies by SEM, STM and AFM.

Recommended Readings

Text Books:

1. Materials Science of Thin Films: Deposition and Structure, 2nd Edition, M. Ohring, 2001
2. Thin Film Phenomena. K. L. Chopra (*McGraw-Hill*)
3. Introduction to Nanoscience and Nanotechnology: K. K. Chattopadhyay and A.N. Banerjee, (*PHI Learning Private Limited*)
4. Vacuum Technology: A. Roth (*North Holland*)

Reference Books:

- Encyclopedia of Materials Characterization: C Ricbard Brundle Charles A. Evans, Jr. Shaun Wilson, (Materials characterization series)

- Handbook of Thin Film Technology: Maissel and Glange (McGraw Hill)
- Basic Vacuum Technology: A. Chambers, R. K. Fitch, B. S. Halliday
- Elements of X-Ray Diffraction, B.D. Cullity & S.R. Stock

Online resources-

53. NPTEL lectures

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**

Course Code : **PHT 999**

Course Name : **Surface Science**

Credits : 3 **L -** 3 **T -** 0 **P -** 0

Course Type : Elective

Prerequisites : Bachelors in Physics/Chemistry/Materials Science

Course Contents

Basics of surface science, surfaces and interfaces and their importance, surface thermodynamics, from solid to surface, Morphology and Structure of Surfaces, Interfaces and Thin films, Surface geometry: truncated bulk, relaxation, reconstruction, defects and super-structures, Surface Creation; Surface cleaning
Adsorption (chemisorption, physisorption) and Desorption, Mechanisms of Adsorption/Diffusion/Desorption
Surface Reactions: Catalysis, Crystal Growth, Chemical Reactions & Nucleation, Thermodynamics and kinetics of thin film growth, thin film deposition mechanism
An overview of ultra high vacuum (UHV) for applied Surface Science, basic principles of UHV, importance of UHV
Auger Electron Spectroscopy (AES): Principle, Instrumentation, Chemical Analysis
X-ray Photoelectron Spectroscopy (XPS): Basics of XPS, Instrumentation; Vacuum Systems, X-ray Sources, Analyzer, Chemical Analysis, Depth Profiling
Secondary Ion Mass spectroscopy (SIMS): Basics, Instrumentation, Depth profiling
Vibrational Spectroscopy from Surfaces: Infrared Spectroscopy from Surfaces, Raman Spectroscopy from surfaces, Electron Energy Loss Spectroscopy (EELS)

Recommended Readings

54. Text book- Physics at Surfaces, Andrew Zangwill (Cambridge University Press) Physics of Surfaces and Interfaces, Haralad Ibach (Springer) Surface Analysis: The Principal Techniques, John C. Vickerman, Ian S. Gilmore (Wiley)
55. Reference book- Lecture Notes on Surface Science, Philip Hofmann. Solid Surfaces, Interfaces and Thin Films, Hans Luth (Springer). Surface Science- An Introduction, K Oura (Springer). Fundamentals of Molecular Spectroscopy, C N Banwell (Mc Graw Hill)
56. Online resources- https://onlinecourses.nptel.ac.in/noc21_cy45/course

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**
Course Code : **PHT 999**

CourseName : **Materials Science and Engineering**
Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Program Elective
Prerequisites : preferred – basic understanding of concepts of solid state physics

Course Contents

Module 1 [Lectures: 9]
Defects-types of defects, motion and properties of dislocation, diffusion in solids, Fick's laws of diffusion, solutions to Fick's second law, atomic theory of diffusion, mechanism of diffusion

Module 2 [Lectures: 15]
Phase transformations in solids- solid solutions, phase rule, binary phase diagrams, binary isomorphous systems, binary eutectic systems, types of transformations, homogeneous and heterogeneous transformation, thermodynamics of transformation, nucleation and growth kinetics, overall kinetics, recovery, recrystallization and grain growth.

Module 3 [Lectures: 15]
Properties of materials- mechanical properties of materials-elastic and plastic deformation, hardness, dislocations and strengthening mechanisms, failure-fatigue and creep, corrosion and degradation of materials- corrosion rates, forms of corrosion

Recommended Readings

Text Books:

1. Materials Science and Engineering, An Introduction by W.D.Callister, Wiley Publications.
2. Materials Science and Engineering by V.Raghvan, PHI
3. Solid State Phase Transformations by V.Raghvan, PHI

Reference Books:

1. Essential Materials- Science and Engineering by Askeland and Phule, CENGAGE Learning
2. Basics of Materials Science and Engineering by W F Smith, Mc Graw Hill

Online resources:

NPTEL/Mooc Courses

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : **Department of Physics**
Course Code : **PHT 999**

Course Name : **Plasma Physics**
Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Elective
Prerequisites : PHT-621

Course Contents

Basic properties, occurrence of plasma, criteria for plasma behavior, plasma oscillations, quasineutrality, Debye shielding, plasma parameters

Charged particle motion and drifts, guiding center motion of charged particles, motion in uniform electric and magnetic fields, motion in non-uniform magnetic field, principle of magnetic mirror, loss cone, motion in non-uniform electric field for small Larmor radius, time varying electric field, time varying magnetic field, adiabatic invariance of magnetic moment

Brief discussion of methods of plasma production, DC discharge, RF discharge, Photo ionization, plasma diagnostics, Langmuir probe. Plasma as fluids, equation of motion, convective derivative, Waves in plasma, Electrostatic waves, Electromagnetic waves, Instabilities, two stream instability. Collision and diffusion parameters, Fick's Law. Fusion energy, Lawson criterion, Controlled fusion schemes (Tokamak, ITER). Principle of MHD power generation.

Recommended Readings

Text Books:

1. Introduction to Plasma Physics and Controlled Fusion: Francis F. Chen (Springer).
2. Principles of Plasma Physics for Engineers and Scientists: Umran Inan and Marek Golkowski (Cambridge University Press).
3. Fundamentals of Plasma Physics: Paul M. Bellan (Cambridge University Press)).
4. Introduction to plasma Physics: R. J. Goldston & P. H.Rutherford (IoP Publication).

Reference Books:

1. Plasma Physics: An introduction to the theory of astrophysical, geophysical, and laboiatory plasmas, Peter A. Sturrock (Cambridge University Press)).
2. Fundamentals of Plasma Physics: J.A. Bittencourt (Pergamons Press).
3. Basic Plasma Physics: B. Ghosh (Narosa Publishing House).
4. Plasma: The first state of matter: V. Krishan (Cambridge University Press).
5. Plasma Physics in Theory and Applications: W.B. Kunkel (McGraw Hill).
6. Methods in Non-linear Plasma theory: R.C. Davidson (Academic Press).

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Department of Physics
Course Code : PHT 999

Course Name : Soft Materials

Credits : 3 **L -** 2 **T -** 1 **P -** 0
Course Type : Elective
Prerequisites : none; [preferred – understanding of basic material science]

Course Contents

Module 1 [Lectures: 7, Tutorials: 4]
Introduction to soft materials and soft matter, generic aspects of soft materials, classification in terms of their thermal, mechanical and often unusual physical properties. examples of soft systems: polymers, foams, granular media, colloids, liquid crystals, micelles, vesicles and biological membranes.

Module 2 [Lectures: 6, Tutorials: 3]
From hard to soft building blocks, synthesis of hard and soft colloids, hard systems, softer systems and their characterization, dispersion forces, polymers in solution, gels, emulsions and foams

Module 3 [Lectures: 7, Tutorials: 3]
Shape and directional interaction, crystal structure, effect on maximum packing density, anisotropic and directionally interacting colloids, complex shape particles, deforming and stretching, soft lithography and micro molding.

Module 4 [Lectures: 6, Tutorials: 3]
Building blocks for self-assembled soft materials, learning from small molecules, block copolymers, phase diagram, crystallization, micellization, experimental methods for study of block copolymers.

Recommended Readings

Text books

Fundamentals of soft matter science: Linda S. Hirst (CRC).
Introduction to soft matter: Ian W. Hamle (Wiley).
Polymer surfaces and interfaces: M Stamm (Springer).
Soft condensed matter: R.A.L. Jones (Oxford)

Reference books:

Soft materials: structure and dynamics: John R. Dutcher, A. G. Marangoni (CRC).

Online resources

https://digitalcommons.uri.edu/soft_matter_physics/
https://nptel.ac.in/courses/112/108/112108289/