Vidyasagar University

Curriculum for B.Sc. (Honours) in Physics [Choice Based Credit System]

Semester-V

Course	Course Code	Name of the Subjects	Course Type/ Nature	Teaching Scheme in hour per week			Credit	Marks
				L	T	P		
CC- 11		C11T: Quantum Mechanics and applications	Core Course-11	4	0	0	6	75
		- Lab		0	0	4		
CC- 12		C12T: Solid State Physics	Core Course-12	4	0	0	6	75
		- Lab		0	0	4		
DSE-1		**DSE1T**: TBD	Discipline Specific Electives -1	5/4	1/0	0/4	6	75
DSE-2		**DSE2T:** TBD	Discipline Specific Electives -2	5/4	1/0	0/4	6	75
Semester Total							**24**	**300**

L= Lecture, **T=** Tutorial, **P =** Practical, **CC -** Core Course, **TBD -** To be decided, **DSE:** Discipline Specific Elective.

Semester-V

List of Core Course (CC)

CC-11: Quantum Mechanics and Applications

CC-12: Solid State Physics

Discipline Specific Electives (DSE)

DSE-1: Advanced Mathematical Physics - I
Or
DSE-1: Classical Dynamics
Or
DSE-1: Applied Dynamics
Or
DSE-1: Atmospheric Physics

DSE-2:Nuclear and Particle Physics
Or
DSE-2: Astronomy and Astrophysics
Or
DSE-2: Physics of Earth
Or
DSE-2: Advanced Mathematical Physics - II

SEMESTER –V

Core Courses (CC)

CC-11: Quantum Mechanics and Applications Credits 06

C11T: Quantum Mechanics and Applications Credits 04

Course Contents :

Schrodinger equation:

Time dependent Schrodinger equation and dynamical evolution of a quantumstate; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energyoperators; commutator of position and momentum operators; Expectation values of position and momentum.Wave Function of a Free Particle.

Time independent Schrodinger equation-Hamiltonian, stationary states and energy eigenvalues; expansion of anarbitrary wave function as a linear combination of energy eigen functions; General solution of the time dependent Schrodinger equation interms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wave function; Position-momentum uncertainty principle.

General discussion of bound states in an arbitrary potential

Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermitepolynomials; ground state, zero point energy & uncertainty principle.

Quantum theory of hydrogen-like atoms:

Time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angularmomentum operator & quantum numbers; Radial wave functions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angula rmomentum quantum numbers l and m;s,p,d,..shells.

Atoms in Electric & Magnetic Fields:

Electron angular momentum. Space quantization. Electron Spinand Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton.

Atoms in External Magnetic Fields:-Normal and Anomalous ZeemanEffect. Paschen Back and Stark Effect (QualitativeDiscussiononly).

Many electron atoms:

Pauli's Exclusion Principle. Symmetric & Antisymmetric WaveFunctions. Periodictable. Finestructure. Spinorbit coupling. Spectral Notations for Atomic States. Total angular momentum.Vector Model. Spin-orbit coupling in atoms - L- S and J-J couplings. Hund'sRule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.).

Suggested Readings :

1. ATextbook ofQuantum Mechanics, P.M. Mathews and K.Venkatesan, 2nd Ed.,2010, Mc Graw Hill

2. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn.,2002,Wiley.

3. Quantum Mechanics, LeonardI. Schiff, 3rd Edn. 2010,TataMcGrawHill.

4. Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHILearningofIndia.

5. Quantum Mechanics, Bruce Cameron Reed, 2008, JonesandBartlettLearning.

6. Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993,Springer

7. Quantum Mechanics for Scientists & Engineers, D.A.B.Miller, 2008, Cambridge University Press

Additional Books for Reference

1. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.

2. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed.2005,Pearson Education

3. Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer

C11P: Quantum Mechanics and Applications Lab Credits 02

List of Practicals

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{h^2}[V(r) - E] \text{ where } V(r) = -\frac{e^2}{r}$$

S wave Schrodinger equation for tnhe ground state and the first excited state of the hydrogen atom : Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 (eVÅ)1/2 , ħc = 1973 (eVÅ) and m = 0.511x10 eV/c2 .

2. Solve the s-wave radial Schrodinger equation for an atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{h^2}[V(r) - E]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential

$$V(r) = \frac{e^2}{r}e^{-r/a}$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 (eVÅ)1/2 , m = 0.511x106 eV/c2 , and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{h^2}[V(r) - E]$$

For the anharmonic oscillator potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2 , k = 100 MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3}In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

4. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{h^2}[V(r) - E]$$

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D(e^{-2\alpha r'} - e^{-\alpha r'}), r' = \frac{r - r_0}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take m= 940 x 10^6eV/C^2, D=0.755501eV, α=1.44, r_0=0.131349 Å

Laboratory based experiments:

5. Study of Electron spin resonance- determine magnetic field as a function of the resonance frequency
6. Study of Zeeman effect: with external magnetic field; Hyperfine splitting
7. To show the tunneling effect in tunnel diode using I-V characteristics.
8. Quantum efficiency of CCDs

Suggested Readings :

1. Schaum's outline of Programming with C++. J. Hubbard, 2000, Mc Graw-Hill Publication
2. Numerical Recipes in C: The Art of Scientific Computing, W.H. Press et al., 3rd Edn., 2007, Cambridge University Press.
3. An introduction to computational Physics, T. Pang, 2nd Edn.,2006, Cambridge Univ. Press
4. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific & Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández.2014 Springer.
5. Scilab (A Free Software to Matlab) : H. Ramchandran, A.S. Nair. 2011 S. Chand & Co.
6. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
7. Scilab Image Processing: L.M.Surhone.2010 Beta script Publishing

CC-12: Solid State Physics — Credits 06

C12T: Solid State Physics — Credits 04

Course Contents :

Crystal Structure:

Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis– Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor.

Elementary Lattice Dynamics:

Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrumin Solids. Dulong and Petit'sLaw, Einstein and Debye theories of specific heat of solids.T^3 law

MagneticPropertiesofMatter:

Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia − and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie′s law, Weiss′s Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.

Dielectric Properties of Materials:

Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes.

Ferro electric Properties of Materials:

Structural phase transition, Classification of crystals, Piezo electric effect, Pyro electric effect, Ferro electric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

Elementary band theory: Kronig Penny model. Band Gap. Conductor, Semiconductor (PandNtype) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (04 probe method) & Hall coefficient.

Superconductivity: Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type Iand type II Superconductors, London′s Equation and Penetration Depth. Isotopeeffect. Idea of BCS theory (Noderivation)

Suggested Readings:

1. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
3. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
5. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
6. Solid State Physics, Rita John, 2014, McGraw Hill
7. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
8. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

C12P: Solid State Physics Lab Credits 02

List of Practicals

1. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency
5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
6. To determine the refractive index of a dielectric layer using SPR
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
9. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 ^{o} C) and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.

Suggested Readings :

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.

2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.

3. A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal

4. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.

Department Specific Electives (DSE)

DSE-1: Advanced Mathematical Physics - I Credits 06
DSE1T: Advanced Mathematical Physics - I Credits 04

Course Contents:

Laplace Transform

Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2nd order Differential

Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1st order. Solution of heat flow along infinite bar using Laplace transform.

Linear Vector Spaces

Abstract Systems. Binary Operations and Relations. Introduction to Groups and Fields. Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformations. Algebra of Linear Transformations. Non-singular Transformations. Representation of Linear Transformations by Matrices.

Inner products. Gram-Schmidt orthogonalization. Orthogonal and unitary transformations and their matrix representations.

Cartesian Tensors

Transformation of Co-ordinates. Einstein's Summation Convention. Relation between Direction Cosines. Tensors. Algebra of Tensors. Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti- symmetric Tensors. Invariant Tensors: Kronecker and Alternating Tensors. Association of Antisymmetric Tensor of Order Two and Vectors. Vector Algebra and Calculus using Cartesian Tensors: Scalar and Vector Products, Scalar and Vector Triple Products. Differentiation. Gradient, Divergence and Curl of Tensor Fields. Vector Identities. Tensorial Formulation of Analytical Solid Geometry: Equation of a Line. Angle Between Lines. Projection of a Line on another Line. Condition for Two Lines to be Coplanar. Foot of the Perpendicular from a Point on a Line. Rotation Tensor (No Derivation). Isotropic Tensors. Tensorial Character of Physical Quantities. Moment of Inertia Tensor. Stress and Strain Tensors: Symmetric Nature. Elasticity Tensor. Generalized Hooke's Law.

General Tensors

Transformation of Co-ordinates. Minkowski Space. Contravariant & Covariant Vectors. Contravariant, Covariant and Mixed Tensors. Kronecker Delta and Permutation Tensors. Algebra of Tensors. Sum, Difference & Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Metric Tensor.

Suggested Readings:

1. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications
2. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, and F.E. Harris, 1970, Elsevier.
3. Modern Mathematical Methods for Physicists and Engineers, C.D. Cantrell, 2011, Cambridge University Press
4. Introduction to Matrices and Linear Transformations, D.T. Finkbeiner, 1978, Dover Pub.

5. Linear Algebra, W. Cheney, E.W.Cheney & D.R.Kincaid, 2012, Jones & Bartlett Learning
6. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole
7. Mathematical Methods for Physicis & Engineers, K.F.Riley, M.P.Hobson, S.J.Bence, 3rd Ed., 2006, Cambridge University Press

DSE1P: Advanced Mathematical Physics - I Lab **Credits 02**

List of Practical

1. Linear algebra:

a) Multiplication of two 3 x 3 matrices.

b) Eigenvalue and eigenvectors of

$$\begin{matrix} 2 & 1 & 1 \\ 1 & 3 & 2 \\ 3 & 1 & 4 \end{matrix} \; ; \quad \begin{matrix} 1 & -i & 3+4i \\ +i & 2 & 4 \\ 3-4i & 4 & 3 \end{matrix} \; ; \quad \begin{matrix} 2 & -i & 2i \\ +i & 4 & 3 \\ -2i & 3 & 5 \end{matrix}$$

2. Orthogonal polynomials as eigen functions of Hermitian differential operators.

3. Determination of the principal axes of moment of inertia through diagonalization.

4. Vector space of wave functions in Quantum Mechanics: Position and momentum differential operators and their commutator, wave functions for stationary states as eigen functions of Hermitian differential operator.

5. Lagrangian formulation in Classical Mechanics with constraints.

6. Study of geodesics in Euclidean and other spaces (surface of a sphere, etc).

7. Estimation of ground state energy and wave function of a quantum system.

Suggested Readings:

1. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer

2. Scilab by example: M. Affouf, 2012,

3. Scilab Image Processing: L.M.Surhone. 2010, Betascript Pub.,

Or

DSE-1: Classical Dynamics **Credits 06**

DSE1T: Classical Dynamics

Course Contents:

Classical Mechanics of Point Particles
Review of Newtonian Mechanics; Application to the motion of a charge particle in external electric and magnetic fields- motion in uniform electric field, magnetic field- gyroradius and gyrofrequency, motion in crossed electric and magnetic fields. Generalized coordinates and velocities,
Recap of Lagrangian and Hamiltonian mechanics. Applications: Hamiltonian for a harmonic oscillator, solution of Hamilton's equation for Simple Harmonic Oscillations; particle in a central force field- conservation of angular momentum and energy. Effective potential. The Laplace-Runge-Lenz vector.

Small Amplitude Oscillations
Minima of potential energy and points of stable equilibrium, expansion of the potential energy around a minimum, small amplitude oscillations about the minimum, normal modes of oscillations example of N identical masses connected in a linear fashion to (N -1) - identical springs.

Special Theory of Relativity
Postulates of Special Theory of Relativity. Lorentz Transformations. Minkowski space. The invariant interval, light cone and world lines. Space-time diagrams. Time-dilation, length contraction and twin paradox. Four-vectors: space-like, time-like and light-like. Four-velocity and acceleration. Metric and alternating tensors. Four-momentum and energy-momentum relation. Doppler effect from a four-vector perspective. Concept of four-force. Conservation of four-momentum. Relativistic kinematics. Application to two-body decay of an unstable particle.

Fluid Dynamics
Density ρ and pressure P in a fluid, an element of fluid and its velocity, continuity equation and mass conservation, stream-lined motion, laminar flow, Poiseuille's equation for flow of a liquid through a pipe, Navier-Stokes equation, qualitative description of turbulence, Reynolds number.

Suggested Readings:

1. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002, Pearson Education.
2. Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
3. Classical Electrodynamics, J.D. Jackson, 3rd Edn., 1998, Wiley.
4. The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn., 2003, Elsevier.
5. Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
6. Classical Mechanics, P.S. Joag, N.C. Rana, 1st Edn., McGraw Hall.
7. Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.

8. Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
9. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press

Or

DSE-1: Applied Dynamics **Credits 06**

DSE1T: Applied Dynamics **Credits 04**

Course Contents:

Introduction to Dynamical systems:

Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Simple mechanical systems as first order dynamical systems: the free particle, particle under uniform gravity, simple and damped harmonic oscillator. Sketching flows and trajectories in phase space; sketching variables as functions of time, relating the equations and pictures to the underlying physical intuition.

Other examples of dynamical systems –
In Biology: Population models e.g. exponential growth and decay, logistic growth, species competition, predator-prey dynamics, simple genetic circuits.

In Chemistry: Rate equations for chemical reactions e.g. auto catalysis, bistability In Economics: Examples from game theory.

Illustrative examples from other disciplines.

Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems, with applications to the above examples.

Computing and visualizing trajectories on the computer using software packages. Discrete dynamical systems. The logistic map as an example.

Introduction to Chaos and Fractals:

Examples of 2-dimensional billiard, Projection of the trajectory on momentum space. Sinai Billiard and its variants. Computational visualization of trajectories in the Sinai Billiard. Randomization and ergodicity in the divergence of nearby phase space trajectories, and dependence of time scale of divergence on the size of obstacle. Electron motion in mesoscopic conductors as a chaotic billiard problem. Other examples of chaotic systems; visualization of their trajectories on the computer.

Self-similarity and fractal geometry: Fractals in nature – trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure. Fractals in dynamics – Serpinski gasket and DLA. Chaos in nonlinear finitedifference equations- Logistic map: Dynamics from time series. Parameter dependence- steady, periodic and chaos states. Cobweb iteration. Fixed points. Defining chaos- aperiodic, bounded, deterministic and sensitive dependence on initial conditions. Period- Doubling route to chaos.

Nonlinear time series analysis and chaos characterization: Detecting chaos from return map. Power spectrum, autocorrelation, Lyapunov exponent, correlation dimension.

Elementary Fluid Dynamics:

Importance of fluids: Fluids in the pure sciences, fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational fluid dynamics. Basic physics of fluids: The continuum hypothesis- concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform & non-uniform flows, viscous & inviscid flows, incompressible & compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated & unseparated flows. Flow visualization - streamlines, pathlines, Streaklines.

Suggested Readings:

1. Nonlinear Dynamics and Chaos, S.H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
4. Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

DSE1P: Applied Dynamics Lab **Credits 02**

Laboratory/Computing and visualizing trajectories using software such as Maple, Octave, XPPAUT based on Applied Dynamics problems like:

1. To determine the coupling coefficient of coupled pendulums.
2. To determine the coupling coefficient of coupled oscillators.
3. To determine the coupling and damping coefficient of damped coupled oscillator.
4. To study population models e.g. exponential growth and decay, logistic growth, species competition, predator-prey dynamics, simple genetic circuits.
5. To study rate equations for chemical reactions e.g. auto catalysis, bistability.
6. To study examples from game theory.
7. Computational visualization of trajectories in the Sinai Billiard.
8. Computational visualization of trajectories Electron motion in mesoscopic conductors as a chaotic billiard problem.
9. Computational visualization of fractal formations of Deterministic fractal.
10. Computational visualization of fractal formations of self-similar fractal.
11. Computational visualization of fractal formations of Fractals in nature – trees, coastlines, earthquakes.
12. Computational Flow visualization - streamlines, pathlines, Streaklines

Suggested Readings:

1. Nonlinear Dynamics and Chaos, Steven H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
4. Fluid Mechanics, 2nd Edn, L.D.Landau & E.M. Lifshitz, Pergamon Press, Oxford, 1987
5. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer

Or

DSE-1: Atmospheric Physics — Credits 06

DSE1T: Atmospheric Physics — Credits 04

Course Contents:

General features of Earth's atmosphere:
Thermal structure of the Earth's Atmosphere, Ionosphere, Composition of atmosphere, Hydrostatic equation, Potential temperature, Atmospheric Thermodynamics, Greenhouse effect and effective temperature of Earth, Local winds, monsoons, fogs, clouds, precipitation, Atmospheric boundary layer, Sea breeze and land breeze. Instruments for meteorological observations, including RS/RW, meteorological processes and different systems, fronts, Cyclones and anticyclones, thunderstorms.

Atmospheric Dynamics:
Scale analysis, Fundamental forces, Basic conservation laws, The Vectorial form of the momentum equation in rotating coordinate system, scale analysis of equation of motion, Applications of the basic equations, Circulations and vorticity, Atmospheric oscillations, Quasi biennial oscillation, annual and semi-annual oscillations, Mesoscale circulations, The general circulations, Tropical dynamics.

Atmospheric Waves:
Surface water waves, wave dispersion, acoustic waves, buoyancy waves, propagation of atmospheric gravity waves (AGWs) in a nonhomogeneous medium, Lamb wave, Rossby waves and its propagation in three dimensions and in sheared flow, wave absorption, non-linear consideration

Atmospheric Radar and Lidar:
Radar equation and return signal, Signal processing and detection, Various type of atmospheric radars, Application of radars to study atmospheric phenomena, Lidar and its applications, Application of Lidar to study atmospheric phenomenon. Data analysis tools and techniques.

Atmospheric Aerosols:

Spectral distribution of the solar radiation, Classification and properties of aerosols, Production and removal mechanisms, Concentrations and size distribution, Radiative and health effects, Observational techniques for aerosols, Absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Bouguert-Lambert law, Principles of radiometry, Optical phenomena in atmosphere, Aerosol studies using Lidars.

Suggested Readings:

1. Fundamental of Atmospheric Physics – Murry L Salby; Academic Press, Vol 61, 1996
2. The Physics of Atmosphere – John T. Houghton; Cambridge University press; 3rd edn. 2002.
3. An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
4. Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014

DSE1P: Atmospheric Physics Lab **Credits 02**

C++ based simulations experiments based on Atmospheric Physics problems like

1. Numerical Simulation for atmospheric waves using dispersion relations
   a. Atmospheric gravity waves (AGW)
   b. Kelvin waves
   c. Rossby waves, and mountain waves
2. Offline and online processing of radar data
   a. VHF radar,
   b. X-band radar, and
   c. UHF radar
3. Offline and online processing of LIDAR data
4. Radiosonde data and its interpretation in terms of atmospheric parameters using vertical profiles in different regions of the globe.
5. Handling of satellite data and plotting of atmospheric parameters using radio occultation technique
6. Time series analysis of temperature using long term data over metropolitan cities in India – an approach to understand the climate change

Suggested Readings:

1. Fundamental of Atmospheric Physics – Murry L Salby; Academic Press, Vol 61, 1996
2. The Physics of Atmosphere – J.T. Houghton; Cambridge Univ. Press; 3rd edn. 2002.
3. An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
4. Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014

DSE-2:Nuclear and Particle Physics Credits 06

DSE2T:Nuclear and Particle Physics

Course Contents :

General Properties of Nuclei :

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.

Nuclear Models :

Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

Radioactivity decay :

(a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.

Nuclear Reactions :

Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

Interaction of Nuclear Radiation with matter :

Energy loss due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.

Detector for Nuclear Radiations :

Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

Particle Accelerators :

Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons.

Particle physics :

Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons.

Suggested Readings :

1. Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
2. Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
3. Introduction to the physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004).
4. Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
5. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
6. Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
7. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP- Institute of Physics Publishing, 2004).
8. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
9. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
10. Theoretical Nuclear Physics, J.M. Blatt & V.F.Weisskopf (Dover Pub.Inc., 1991).

Or

DSE-2: Astronomy and Astrophysics Credits 06

DSE2T: Astronomy and Astrophysics

Course Contents :

Astronomical Scales :

Astronomical Distance, Mass and Time, Scales, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. Basic concepts of positional astronomy: Celestial Sphere, Geometry of a Sphere, Spherical Triangle,Astronomical Coordinate Systems, Geographical Coordinate Systems, Horizon System, Equatorial System, Diurnal Motion of the Stars, Conversion of

Coordinates. Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar. Basic Parameters of Stars: Determination of Distance by Parallax Method; Brightness, Radiant Flux and Luminosity, Apparent and Absolute magnitude scale, Distance Modulus; Determination of Temperature and Radius of a star; Determination of Masses from Binary orbits; Stellar Spectral Classification, Hertzsprung-Russell Diagram.

Astronomical techniques :

Basic Optical Definitions for Astronomy (Magnification Light Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Detectors and Their Use with Telescopes (Types of Detectors, detection Limits with Telescopes).

Physical principles :

Gravitation in Astrophysics (Virial Theorem, Newton versus Einstein), Systems in Thermodynamic Equilibrium.

The sun and solar family :

The sun (Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Basics of Solar Magneto-hydrodynamics. Helioseismology). The solar family (Solar System: Facts and Figures, Origin of the Solar System: The Nebular Model, Tidal Forces and Planetary Rings, Extra-Solar Planets.

Stellar spectra and classification Structure (Atomic Spectra Revisited, Stellar Spectra, Spectral Types and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification).

The milky way :

Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus.

Galaxies :

Galaxy Morphology, Hubble's Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms.

Large scale structure & expanding universe :

Cosmic Distance Ladder (An Example from Terrestrial Physics, Distance Measurement using Cepheid Variables), Hubble's Law (Distance- Velocity Relation), Clusters of Galaxies (Virial theorem and Dark Matter).

Suggested Readings :

1. Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
2. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory,4th Edition, Saunders College Publishing.
3. The physical universe: An introduction to astronomy, F.Shu, Mill Valley: University Science Books.
4. Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
5. Astro Physics a modern perspective, K.S. Krishnasamy, Reprint, New Age International (p) Ltd, New Delhi,2002.
6. An introduction to Astro physics, Baidyanath Basu, Second printing, Prentice -Hall of India Private limited, New Delhi, 2001.
7. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.

Or

DSE-2: Physics of Earth **Credits 06**

DSE2T: Physics of Earth

Course Contents:

The Earth and the Universe
Origin of universe, creation of elements and earth. A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography. Introduction to various branches of Earth Sciences.
General characteristics and origin of the Universe. The Milky Way galaxy, solar system, Earth's orbit and spin, the Moon's orbit and spin. The terrestrial and Jovian planets. Meteorites & Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age.
Energy and particle fluxes incident on the Earth.
The Cosmic Microwave Background.

Structure
The Solid Earth: Mass, dimensions, shape and topography, internal structure, magnetic field, geothermal energy. How do we learn about Earth's interior?
The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.
The Atmosphere: variation of temperature, density and composition with altitude, clouds.
The Cryosphere: Polar caps and ice sheets. Mountain glaciers.
The Biosphere: Plants and animals. Chemical composition, mass. Marine and land organisms.

Dynamical Processes

The Solid Earth: Origin of the magnetic field. Source of geothermal energy. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations. Concept of plate tectonics; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes: types products and distribution.
The Hydrosphere: Ocean circulations. Oceanic current system and effect of coriolis forces. Concepts of eustasy, tend– air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.
The Atmosphere: Atmospheric circulation. Weather and climatic changes. Earth's heat budget. Cyclones.
Climate: Earth's temperature and greenhouse effect. Paleoclimate and recent climate changes. The Indian monsoon system.
Biosphere: Water cycle, Carbon cycle, Nitrogen cycle, Phosphorous cycle. The role of cycles in maintaining a steady state.

Evolution
Nature of stratigraphic records, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Introduction to geochronological methods in their application in geological studies. History of development in concepts of uniformitarianism, catastrophism and neptunism. Law of superposition and faunal succession. Introduction to the geology and geomorphology of Indian subcontinent.
Time line of major geological and biological events.
Origin of life on Earth.
Role of the biosphere in shaping the environment.
Future of evolution of the Earth and solar system: Death of the Earth.

Disturbing the Earth - Contemporary dilemmas

1. Human population growth.
2. Atmosphere: Greenhouse gas emissions, climate change, air pollution.
3. Hydrosphere: Fresh water depletion.
4. Geosphere: Chemical effluents, nuclear waste.
5. Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems.

Suggested Readings:

1. Planetary Surface Processes, H. Jay Melosh, Cambridge University Press, 2011.
2. Consider a Spherical Cow: A course in environmental problem solving, John Harte. University Science Books
3. Holme's Principles of Physical Geology. 1992. Chapman & Hall.
4. Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.

Or

DSE-2: Advanced Mathematical Physics - II **Credits 06**

DSE2T: Advanced Mathematical Physics - II

Course Contents:

Calculus of Variations:

Variational Calculus: Recapitulation of the Variational Principle, Euler-Lagrange's Equations of Motion Euler angles, spherical top and symmetric top. Symmetry and conservation laws. Canonical Pair of Variables. Definition of Generalized Force: Definition of Hamiltonian (Legendre Transformation). Hamilton's Principle. Poisson Brackets and their properties. Canonical transformations. Action-angle variables for simple systems.

Group Theory

Review of sets, Mapping and Binary Operations, Relation, Types of Relations.

Groups: Elementary properties of groups, uniqueness of solution, Subgroup, Centre of a group, Co-sets of a subgroup, cyclic group, Permutation/Transformation. Homomorphism and Isomorphism of group. Normal and conjugate subgroups, Completeness and Kernel.

Some special groups with operators. Matrix Representations: Reducible and Irreducible representations. Schur's lemma. Orthogonality theorems. Character tables and their uses. Application to small vibrations.

Advanced Probability Theory:

Fundamental Probability Theorems. Conditional Probability, Bayes' Theorem, Repeated Trials, Binomial and Multinomial expansions. Random Variables and probability distributions, Expectation and Variance, Special Probability distributions: The binomial distribution, The poisson distribution, Continuous distribution: The Gaussian (or normal) distribution, The principle of least squares.

Suggested Readings:

1. Mathematical Methods for Physicists: Weber and Arfken, 2005, Academic Press.
2. Mathematical Methods for Physicists: A Concise Introduction: Tai L. Chow, 2000, Cambridge Univ. Press.
3. Elements of Group Theory for Physicists by A. W. Joshi, 1997, John Wiley.
4. Group Theory and its Applications to Physical Problems by Morton Hamermesh, 1989, Dover

5. Introduction to Mathematical Physics: Methods & Concepts: Chun Wa Wong, 2012, Oxford University Press
6. Introduction to Mathematical Probability, J. V. Uspensky, 1937, Mc Graw-Hill.