Cooch Behar Panchanan Barma University

Syllabus for Physics

UNDER NEP 2020

Cooch Behar Panchanan Barma University

Cooch Behar, West Bengal

Preamble

University Grants Commission (UGC) introduced, in 2018, a major reform in the higher education sector in India. Accordingly, Learning Outcomes-based Curriculum Framework (LOCF) took the centre-stage to make the curriculum student-centric, interactive and outcome-oriented with well-defined aims and objectives. The Physics Undergraduate Board of Studies of Cooch Behar Panchanan Barma University took the initiative to implement the reforms and frame the syllabus so as to increase the spirit of enquiry, analytical ability and comprehension skills among the students.

Credit Scheme

1^{st} SEM	Cr
Major 1	6
Minor 1	6
SEC 1	3
MDC 1	3
AEC 1	4
	22

2^{nd} SEM	Cr
Major 2	6
Minor 2	6
SEC 2	3
VAC 1	3
INTRN	4
	22

CERTIFICATE 44

3^{rd} SEM	Cr
Major 3	6
Major 4	6
Minor 3	6
SEC 3	3
MDC 2	3
	24

4^{th} SEM	Cr
Major 5	6
Major 6	6
Minor 4	6
AEC 2	4
	22

DIPLOMA 90

5^{th} SEM	Cr
Major 7	6
Major 8	6
Major 9	6
MDC 3	3
	21

6^{th} SEM	Cr
Major 10	6
Major 11	6
Major 12	6
VAC 2	3
	21

DEGREE 132

Paper	Distribution of marks				
	Theory	Lab	Project/ Seminar/ Assignment	Continuous Evaluation	Attendance
Major	50	25	10	10	5
Minor	50	25	10	10	5
SEC		35		10	5
MDC	35			10	5
AEC	35			10	5
VAC	35			10	5

w/o RESEARCH

7^{th} SEM	Cr	8^{th} SEM	Cr
Major 13*	6	Major 17	6
Major 14	6	Major 18	6
Minor 5	6	Minor 6	6
Major 15†	6		
Major 16	6	Major 19	6
	30		24

DEGREE (HONOURS) 186

w/ RESEARCH

7^{th} SEM	Cr	8^{th} SEM	Cr
Major 13*	6	Major 17	6
Major 14‡	6	Major 18‡	6
Minor 5	6	Minor 6	6
Major 15†	6		
Major 16#	6	Major 19#	6
	30		24

DEGREE (RESEARCH) 186

* Research Methodology & Ethics
† Seminar based paper
‡ Elective paper
\# Dissertation

SCHEME FOR NATIONAL CURRICULUM AND CREDIT FRAMEWORK (NCCF) IN B.Sc (Physics)

	MAJOR COURSE (19)	MINOR COURSE (6)	Skill Enhancement Course (3)	Multi-disciplinary Course (3)	Ability Enhancement Course (2)	Value Added Course (2)	Internship (1)
				Odd Semester			
I	• Mechanics and General Properties of Matter	• Mechanics and General Properties of Matter	• Computational Physics 1	• Physics I	• AEC 1		
III	• Waves and Optics • Analog Electronics	• Mechanics and General Properties of Matter	• Computational Physics 3	• Physics II			
V	• Electromagnetic Theory • Classical Dynamics • Modern Physics and Quantum Mechanics			• Physics III			
VII	• Research Methodology & Ethics • Advanced Mathematical Methods • Advanced Quantum Mechanics • Advanced Classical Dynamics/ Research Project	• Electronics					
				Even Semester			
II	• Electricity and Magnetism	• Electricity and Magnetism	• Computational Physics 2			• VAC 1	• INTRN
IV	• Heat and Thermodynamics • Digital Electronics	• Electricity and Magnetism			• AEC 2		
VI	• Solid State Physics • Statistical Mechanics • Nuclear and Particle Physics					• VAC 2	
VIII	• Advanced Solid State Physics • Atomic and Molecular Physics • Advanced Statistical Mechanics/ Research Project	• Electronics					

SEM	PAPER OPTED	PAPER NAME	Credits	Periods per week
I	Major 1	Mechanics and General Properties of Matter	4	4
	Major 1 Practical	Mechanics and General Properties of Matter Lab	2	4
	Minor 1	Mechanics and General Properties of Matter	4	4
	Minor 1 Practical	Mechanics and General Properties of Matter Lab	2	4
	Skill Enhancement Course 1	Computational Physics 1	3	6
	Multidisciplinary Course 1	Physics	3	3
	Ability Enhancement Course 1	Bengali or Hindi or Sanskrit or Alternative English	4	4
III	Major 3	Waves and Optics	4	4
	Major 3 Practical	Waves and Optics Lab	2	4
	Major 4	Analog Electronics	4	4
	Major 4 Practical	Analog Electronics Lab	2	4
	Minor 3	Mechanics and General Properties of Matter	4	4
	Minor 3 Practical	Mechanics and General Properties of Matter Lab	2	4
	Skill Enhancement Course 3	Computational Physics 3	3	6
	Multidisciplinary Course 2	Physics II	3	3
V	Major 7	Electromagnetic Theory	4	4
	Major 7 Practical	Electromagnetic Theory Lab	2	4
	Major 8	Classical Dynamics	5	5
	Major 8 Tutorial	Classical Dynamics Tut	1	1
	Major 9	Modern Physics and Quantum Mechanics	5	5
	Major 9 Tutorial	Modern Physics and Quantum Mechanics Tut	1	1
	Multidisciplinary Course 3	Physics III	3	3
VII	Major 13	Research Methodology & Ethics	4	4
	Major 13 Practical	Research Methodology Lab	2	2
	Major 14	Advanced Mathematical Methods	5	5
	Major 14 Tutorial	Advanced Mathematical Methods Tut	1	1
	Major 15	Advanced Quantum Mechanics	4	4
	Major 15 Seminar	Seminar	2	2
	Major 16 [w/o RESEARCH]	Advanced Classical Dynamics	5	5
	Major 16 Tutorial [w/o RESEARCH]	Advanced Classical Dynamics Tut	1	1
	Major 16 [w/ RESEARCH]	Research Project	6	6
	Minor 5	Electronics	4	4
	Minor 5 Practical	Electronics Lab	2	4

SEM	PAPER OPTED	PAPER NAME	Credits	Periods per week
II	Major 2	Electricity and Magnetism	4	4
	Major 2 Practical	Electricity and Magnetism Lab	2	4
	Minor 2	Electricity and Magnetism	4	4
	Minor 2 Practical	Electricity and Magnetism Lab	2	4
	Skill Enhancement Course 2	Computational Physics 2	3	6
	Value Added Course 1	Environmental Studies	3	3
	Internship		4	4
IV	Major 5	Heat and Thermodynamics	4	4
	Major 5 Practical	Heat and Thermodynamics Lab	2	4
	Major 6	Digital Electronics	4	4
	Major 6 Practical	Digital Electronics Lab	2	4
	Minor 4	Electricity and Magnetism	4	4
	Minor 4 Practical	Electricity and Magnetism Lab	2	4
	Ability Enhancement Course 2	Basics in English	4	4
VI	Major 10	Solid State Physics	4	4
	Major 10 Practical	Solid State Physics Lab	2	4
	Major 11	Statistical Mechanics	5	5
	Major 11 Tutorial	Statistical Mechanics Tut	1	1
	Major 12	Nuclear and Particle Physics	5	5
	Major 12 Tutorial	Nuclear and Particle Physics Tut	1	1
	Value Added Course 2	Constitution of India and Health & Wellness	3	3
VIII	Major 17	Advanced Solid State Physics	4	4
	Major 17 Practical	Advanced Solid State Physics Lab	2	2
	Major 18	Atomic and Molecular Physics	5	5
	Major 18 Tutorial	Atomic and Molecular Physics Tut	1	1
	Major 19 [w/o RESEARCH]	Advanced Statistical Mechanics	5	5
	Major 19 Tutorial [w/o RESEARCH]	Advanced Statistical Mechanics Tut	1	1
	Major 19 [w/ RESEARCH]	Research Project	6	6
	Minor 6	Electronics	4	4
	Minor 6 Practical	Electronics Lab	2	4

MAJOR COURSES (PHYSICS)

Semester I

Physics - Major 1 : Mechanics and General Properties of Matter
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Vector Calculus Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and Curl of a vector field. Del and Laplacian operators. Vector identities.

Vector Integration: Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes' Theorems and their applications (no rigorous proofs).

Orthogonal Curvilinear Coordinates: Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. *8 Lectures*

Fundamentals of Dynamics Reference frames. Inertial frames; Galilean transformations. Review of Newton's Laws of Motion. Projectile motion, Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum, Impulse. Momentum of variable-mass system: motion of rocket. Components of Velocity and Acceleration in plane polar, Cylindrical and Spherical Coordinate Systems.

Laws of physics in rotating coordinate systems, Centrifugal force. Coriolis force and its applications. *11 Lectures*

Work and Energy Work and Kinetic Energy Theorem. Conservative and non- conservative forces. Potential Energy. Stable and unstable equilibrium. Force as gradient of potential energy. Work done by non-conservative forces. Law of conservation of Energy. Elastic and inelastic collisions. Centre of Mass frame and Laboratory frame. *7 Lectures*

Rotational Dynamics Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Moment of Inertia, parallel and perpendicular axes theorem, moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation. *8 Lectures*

Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS). Physiological effects on astronauts. *8 Lectures*

Elasticity Hook's Law, Relation between Elastic constants. Poisons ratio, Strain energy in a stretched wire, Twisting torque on a Cylinder or Wire. *5 Lectures*

Fluid Motion Surface Tension: Surface Energy, Phenomena involving surface tension, Angle of Contact, Capillary rise.

Viscosity: Streamline flow, Turbulent motion, Stokes Law, Reynold's Number, Equation of Continuity, Bernoulli's Theorem, Poiseuille's equation for flow of a liquid through a Capillary Tube. *7 Lectures*

Special Theory of Relativity Michelson-Morley Experiment. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic addition of velocities. Variation of mass with velocity. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum. *6 Lectures*

Reference Books

[1] R. Sengupta and H. Chatterjee, A Treatise on General Properties of Matter, New Central Agency.
[2] D.S. Mathur, Elements of Properties of Matter, S. Chand.
[3] R.P. Feynman, R.B. Leighton and M. Sands, The Feynman Lectures in Physics, vol.1, B I Publications.
[4] L. Pachuau and L. Sailo, A Textbook of Properties of Matter, Oscillations and Acoustics, PUC and GSC.

Physics - Major 1 Lab : Mechanics and General Properties of Matter 60 Lectures

Student should study the measurements of length (or diameter) using Vernier caliper, screw gauge and travelling microscope.

Experiments

1. To determine the height of a building using a Sextant.
2. To study the motion of Spring and calculate (a) Spring constant; (b) Acceleration due to Gravity.
3. To determine the Modulus of Rigidity of material of a cylindrical wire by Statical Method.
4. To determine the Modulus of Rigidity of material of a cylindrical wire by Dynamical Method.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine the Moment of Inertia of a cylindrical/rectangular bar.
7. To determine the value of g and velocity for a freely falling body using Digital Timing Technique.
8. To determine the Coefficient of Viscosity of a viscous liquid using Stokes' Law.
9. To determine Coefficient of Viscosity of water by Poiseuille's flow Method.
10. To determine the Young's Modulus of a Bar by Flexure Method.
11. To determine the Young's Modulus of a Wire by Optical Lever Method.
12. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
13. To determine the Young's Modulus of a wire by Searle's method.
14. To determine the value of g using Bar Pendulum.
15. To determine the value of g using Kater's Pendulum.
16. To determine the surface tension of water by Jaeger's Method.

Reference Books

[1] B.L. Flint and H.T. Worsnop, Advanced Practical Physics for Students, Asia Publishing House, 1971.
[2] Michael Nelson and Jon M. Ogborn, Advanced Level Physics Practicals (4ed), Heinemann, 1985.
[3] I. Prakash and Ramakrishna, A Text Book of Practical Physics (11ed), Kitab Mahal, 2011.
[4] G.L. Squires, Practical Physics (4ed), Cambridge, 2015.

Semester II

Physics - Major 2 : Electricity and Magnetism
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Electric Field and Electric Potential Coulomb's Law, Electric field: Electric field lines. Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Conservative nature of Electrostatic Field and Potential. Potential energy of system of charges, Electrostatic energy of a charged sphere, Laplace's and Poisson equations. The Uniqueness Theorem. Electrostatic force on a charged particle. Electric dipole, Electric Potential and Field due to a dipole. Force, torque on a dipole, potential energy of a dipole. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere. *14 Lectures*

Electric field in Conductor and Dielectric material Electric Field in conductor, Dielectric Polarisation ($\boldsymbol{P}$), Polarisation Charges. Electrical Susceptibility and Dielectric Constant. Displacement vector ($\boldsymbol{D}$). Relations between $\boldsymbol{E}$, $\boldsymbol{P}$ and $\boldsymbol{D}$. Gauss' Law in dielectrics. *7 Lectures*

Capacitance Capacitance of a conductor, Charging, discharging of a capacitor, Capacitance of parallel plate, spherical, cylindrical capacitor, combination of capacitors. *5 Lectures*

Magnetic Field Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to straight wire, Solenoid and Toroid. Properties of $\boldsymbol{B}$: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire. Torque on a current loop in a uniform Magnetic Field, Ballistic Galvanometer: Current and Charge Sensitivity, Electromagnetic damping, Logarithmic damping, CDR. *11 Lectures*

Magnetic Properties of Matter Magnetisation vector ($\boldsymbol{M}$). Magnetic Intensity ($\boldsymbol{H}$). Magnetic Susceptibility and Permeability. Relation between $\boldsymbol{B}$, $\boldsymbol{H}$ and $\boldsymbol{M}$. Dia-, Para- and Ferromagnetism. $\boldsymbol{B}$-$\boldsymbol{H}$ curve and hysteresis. *4 Lectures*

Electromagnetic Induction Faraday's Law. Lenz's Law. Motional emf, eddy current, Self-Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. *7 Lectures*

Electrical Circuits DC Circuits: Transient phenomena, growth and decay of currents in LR, CR and LCR circuits. AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit. LC oscillations, transformer. *8 Lectures*

Network theorems Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin's theorem, Norton's theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. *4 Lectures*

Reference Books

[1] H.K. Malik and A.K. Singh, Engineering Physics, McGraw Hill, 2018.
[2] D.J. Griffiths, Introduction to Electrodynamics (3ed), Prentice-Hall, 2002.
[3] E. M. Purcell, Electricity and Magnetism: Berkeley Physics Course vol. 2, McGraw Hill, 2017.
[4] D.C. Tayal, Electricity and Magnetism (4ed), Himalaya Publishing, 2019.
[5] D. Chattopadhyay and P.C. Rakshit, Electricity and Magnetism, Central Book Agency, 2005.

Physics - Major 2 Lab : Electricity and Magnetism
60 Lectures

Student should study the use a Multimeter for measuring (a) Resistances; (b) AC and DC Voltages; (c) Direct Current; (d) Capacitances; and (e) Checking electrical fuses.

Experiments

1. To determine an unknown Low Resistance using Potentiometer/fall of potential method.
2. To determine an unknown Resistance using Carey Foster's Bridge.
3. To compare capacitances using De'Sauty's bridge.
4. Measurement of field strength B and its variation in a solenoid (determine dB/dx).
5. To verify the Thevenin's and Norton's theorems.
6. To verify the Superposition, and Maximum power transfer theorems.
7. To determine self inductance of a coil by Anderson's bridge.
8. To study the ac characteristics of a series CR Circuit.
9. To study the ac characteristics of a series LR Circuit.
10. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency; (b) Impedance at resonance (c) Quality factor Q and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti resonance frequency; and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
13. Determine a high resistance by leakage method using Ballistic Galvanometer.
14. To determine self-inductance of a coil by Rayleigh's method.
15. To determine the self-inductance of two coils separately by using Anderson's Bridge and the total equivalent inductance when they are connected in series and hence estimate the coefficient of coupling between the two coils.
16. To determine the mutual inductance of two coaxial coils at different orientations using Ballistic Galvanometer.
17. To determine the horizontal component of the Earth's magnetic field and the magnetic moment of a magnet using a deflection and oscillation magnetometer.

Reference Books

[1] D. Chattopadhyay and P.C. Rakshit, Electricity and Magnetism, Central Book Agency, 2005.
[2] B. Ghosh, K.G. Mazumdar, Advanced Practical Physics, vol. 1, Sreedhar Publications, 2013.

Semester III

Physics - Major 3 : Waves and Optics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Mathematical Preliminaries Ordinary differential equation: Series solution of ordinary linear second order differential equation (outlines of methods of series solution without going in to proof), Legendre and Hermite polynomials and elementary properties of Legendre and Hermite polynomials (orthogonality and recurrence relation).

Partial differential Equations : Solution by the method of separation of variables, Laplace's equation and its solution in cartesian, spherical polar and cylindrical coordinates

Fourier series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Fourier Series: Periodic functions. Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. *10 Lectures*

Simple Harmonic Motion Differential equation of simple harmonic oscillator, its solution and characteristics, energy in simple harmonic motion, linearity and superposition principle. Lissajous Figures with equal and unequal frequencies, effect of variation of phase. *6 Lectures*

Damped and Forced Oscillations Damped Oscillations: Equation of motion, dead beat motion, critically damped system, lightly damped system: relaxation time, logarithmic decrement, quality factor Forced Oscillations: Equation of motion, complete solution, steady state solution, resonance, sharpness of resonance, power dissipation, quality factor. *8 Lectures*

Wave Motion One dimensional plane wave, classical wave equation, Travelling wave solution. Standing (Stationary) Waves in a String: Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves. Newton's Formula for Velocity of Sound. Laplace's Correction. *12 Lectures*

Geometrical Optics Fermat's Principle. Cardinal point, Aberration, Dispersion. Optical instruments. *5 Lectures*

Wave nature of light Electromagnetic nature of light, Huygen's principle – derivation of laws of reflection and refraction. Temporal and Spatial Coherence. *5 Lectures*

Interference Division of amplitude and division of wavefront; Young's double slit experiment: width and shape of fringes; Fresnel's biprism; Lloyd's mirror; Phase change on reflection: Stokes' treatment; Interference in thin films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau Fringes); Newton's rings: Measurement of wavelength and refractive index. *8 Lectures*

Diffraction Fraunhofer diffraction: Single slit, double slit, diffraction grating Fresnel diffraction: Fresnel's assumptions. Fresnel's half-period zones for plane wave. Explanation of rectilinear propagation of light; Fresnel's diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis. *6 Lectures*

Reference Books

[1] A.P. French, Vibrations And Waves, CBS, 2003.
[2] N.K. Bajaj, The Physics of Waves and Oscillations, Tata McGraw Hill, 1998.
[3] K. Uno Ingard, Fundamentals of Waves and Oscillations, Cambridge University Press, 1988.
[4] D. Kleppner and R. Kolenkow, An Introduction to Mechanics, Cambridge University Press, 2021.
[5] F. Crawford, Waves: Berkeley Physics Course, Vol 3, Tata McGraw-Hill, 2007.
[6] P.A. Dourmashkin, Classical Mechanics, Wiley, 2014.
[7] Resnick, Halliday and Walker, Physics (9ed), Wiley, 2010.
[8] R.P. Feynman, R.B. Leighton and M. Sands, Feynman Lectures, Vol 1, Pearson Education, 2008.
[9] H.D. Young and R.A. Freedman, University Physics (14ed), Pearson Education, 2017.
[10] G.B. Arfken, H.J. Weber, F.E. Harris, Mathematical Methods for Physicists (7ed), Elsevier, 2012.
[11] M.R. Spiegel, Fourier Analysis, Tata McGraw-Hill, 2004.
[12] A.K. Ghatak, I.C. Goyal and S.J. Chua, Mathematical Physics, Laxmi Publications, 2017.
[13] P.K. Chattopadhyay, Mathematical Physics (3ed), New Academic Science Ltd, 2008.

Physics - Major 3 Lab : Waves and Optics
60 Lectures

Experiments

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify $\lambda^2 - T$ law.
2. To investigate the motion of coupled oscillators.
3. To study Lissajous Figures to find out the ratios of frequencies and phase determinations.
4. Familiarisation with: Schuster's focusing; determination of angle of prism.
5. To determine refractive index of the Material of a prism using sodium source.
6. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
7. To determine the wavelength of sodium source using Michelson's interferometer.
8. To determine wavelength of sodium light using Fresnel Biprism.
9. To determine wavelength of sodium light using Newton's Rings.
10. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
11. To determine the wavelength of a monochromatic source using diffraction of single slit.
12. To determine the wavelength of a monochromatic source using diffraction of double slits.
13. To determine wavelength of a monochromatic source using plane diffraction grating.
14. To determine angular spread of He-Ne laser using plane diffraction grating.
15. To determine dispersive power and resolving power of a plane diffraction grating.

Reference Books

[1] B.L. Flint and H.T. Worsnop, Advanced Practical Physics for Students, Asia Publishing House, 1971.
[2] Michael Nelson and Jon M. Ogborn, Advanced Level Physics Practicals (4ed), Heinemann Educational Publishers, 1985.
[3] Indu Prakash and Ramakrishna, A Text Book of Practical Physics (11ed), Kitab Mahal, 2011.
[4] D.P. Khandelwal, A Laboratory Manual of Physics for Undergraduate Classes, Vani Pub, 1985.

Physics - Major 4 : Analog Electronics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Semiconductor Diodes: P and N type semiconductors. Energy Level Diagram of Semiconductors. Conductivity and Mobility. Concept of Drift & Diffusion current. Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. *6 Lectures*

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half- wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, Diode Clipping and Clamping circuits (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LED (2) Photodiode and (3) Solar Cell, (4) Tunnel Diode. *8 Lectures*

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff and Saturation Regions. *8 Lectures*

Regulated Power Supply: Basic idea of Series and Shunt voltage regulation. *2 Lectures*

Field Effect Transistors: Characteristics and structure of JFET. *4 Lectures*

Amplifiers: Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model , Input and Output Impedance, Current, Voltage and Power Gains. Basic idea of Class A, Class B , Class C & Class AB Amplifiers. *9 Lectures*

Coupled Amplifier: Two stage RC-coupled amplifier and its frequency response. *3 Lectures*

Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. *4 Lectures*

Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, Hartley oscillator & Colpitts oscillator, determination of Frequency. *5 Lectures*

Operational Amplifiers (Black Box approach): Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground. *5 Lectures*

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder (3)Subtractor (4) Differentiator (5) Integrator (6) Log amplifier (7) Zero crossing detector (8) Wien bridge oscillator. *6 Lectures*

Conversion: Resistive network (Weighted and R-2R Ladder), Accuracy and Resolution. A/D Conversion (successive approximation) *3 Lectures*

Analog Modulation: Amplitude Modulation, modulation index and frequency spectrum. Amplitude Demodulation (diode detector). Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM. *7 Lectures*

Reference Books

[1] J. Millman and C.C. Halkias, Integrated Electronics, Tata McGraw Hill, 1991.
[2] J.D. Ryder, Electronics: Fundamentals and Applications, Prentice-Hall, 2004.
[3] B.G. Streetman and S.K. Banerjee, Solid State Electronic Devices (6ed), PHI Learning, 2009.
[4] S. Salivahanan and N.S. Kumar, Electronic Devices and Circuits (3ed), Tata Mc-Graw Hill, 2012.
[5] A.S. Sedra, K.C. Smith, A.N. Chandorkar, Microelectronic Circuits (6ed), Oxford University Press, 2014.

[6] U.Tietze and C.Schenk, Electronic Circuits: Handbook of Design and Applications, Springer, 2008.
[7] S.M. Sze, Semiconductor Devices: Physics and Technology (2ed), Wiley India, 2002.
[8] M.H. Rashid, Microelectronic Circuits (2ed), Cengage Learning.
[9] Thomas L. Floyd, Electronic Devices (7ed), Pearson India, 2008.

Physics - Major 4 Lab : Analog Electronics
60 Lectures

Experiments

1. To study V-I characteristics of PN junction diode or Light emitting diode.
2. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
3. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
4. To study the various biasing configurations of BJT for normal class A operation.
5. To design a CE (CC) transistor amplifier of a given gain (mid-gain) using voltage divider bias.
6. To study the frequency response and voltage gain of a RC-coupled transistor amplifier.
7. To design a Wien bridge oscillator for given frequency using an OP-AMP.
8. To design a phase shift oscillator of given specifications using BJT.
9. To study the Colpitt's oscillator.
10. To design an inverting amplifier using Op-amp (741,351) for DC voltage of given gain.
11. To design inverting amplifier using Op-amp(741,351) and study its frequency response
12. To design non-inverting amplifier using Op-amp (741,351).
13. To add two DC voltages using OP-AMP in inverting and non-inverting mode
14. To design a precision Differential amplifier of given I/O specification using Op-amp.
15. To investigate the use of an OP-AMP as an Integrator.
16. To investigate the use of an OP-AMP as a Differentiator.
17. To design a circuit to simulate the solution of a 1st/2nd order differential equation.
18. To design an Amplitude Modulator and Demodulator using Transistor.
19. To study FM - Generator and Detector circuit.

Reference Books

[1] P.B. Zbar, A.P. Malvino, M.A. Miller, Basic Electronics: A Text Lab Manual, McGraw Hill, 1994.
[2] R.A. Gayakwad, OP-Amps and Linear Integrated Circuit (4ed), Prentice Hall, 2000.
[3] Albert Malvino, Electronic Principle, Tata McGraw Hill, 2008.
[4] R.L. Boylestad and L.D. Nashelsky, Electronic Devices And Circuit Theory, Pearson, 2009.

Semester IV

Physics - Major 5 : Heat and Thermodynamics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Mathematical preliminaries Some Special Integrals: Beta and Gamma functions and relations between them. Expansion and integrals in terms of Gamma functions. Error function.

Introduction to probability. Independent random variables: Sample space and probability distribution functions. Binomial, Gaussian and Poisson distribution with examples. Random walk in 1D.

5 Lectures

Kinetic Theory of Gases: Distribution of Velocities; Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. *7 Lectures*

Molecular Collisions: Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and Diffusion. purpleian Motion and its Significance. *5 Lectures*

Conduction of Heat: Thermal and thermometric conductivity, diffusivity, Fourier's equation for heat propagation and its solutions, periodic flow of heat, Measurement of thermal conductivity. Wiedemann-Franz law. *5 Lectures*

Real Gases: Behaviour of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. p-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling. *8 Lectures*

Zeroth and First Law of Thermodynamics: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics and Concept of Temperature, Concept of Work and Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law and various processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient. *6 Lectures*

Second Law of Thermodynamics: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine and efficiency. Refrigerator and coefficient of performance, Second Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale. *6 Lectures*

Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero. *6 Lectures*

Thermodynamic Potentials: Extensive and Intensive Thermodynamic Variables. Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetisation, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations. *6 Lectures*

Maxwell's Thermodynamic Relations: Derivations and applications of Maxwell's Relations, Maxwell's Relations: (1) Clausius Clapeyron equation, (2) Values of CP-CV, (3) Tds Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process. *6 Lectures*

Reference Books

[1] M.W. Zemansky, Richard Dittman, Heat and Thermodynamics, McGraw Hill, 1981.
[2] Meghnad Saha, and B.N. Srivastava, A Treatise on Heat, Indian Press, 1958.
[3] S. Garg, R. Bansal and Ghosh, Thermal Physics (2ed), Tata McGraw Hill, 1993.
[4] Carl S. Helrich, Modern Thermodynamics with Statistical Mechanics, Springer, 2009.
[5] Francis W. Sears and Gerhard L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Narosa, 1986.
[6] S.J. Blundell and K.M. Blundell, Concepts in Thermal Physics (2ed), Oxford University Press, 2012.
[7] A. Kumar and S.P. Taneja, Thermal Physics, R. Chand Publications, 2014.

Physics - Major 5 Lab : Heat and Thermodynamics
60 Lectures

Experiments

1. Determination of linear expansion coefficient of a solid by Optical Lever method.
2. Determination of the thermal conductivity of Glass in the form of tube.
3. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
4. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
5. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
6. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
7. To determine the Temperature Coefficient of Resistance of a copper coil/Platinum Resistance Thermometer.
8. To study the variation of Thermo-Emf of a Thermocouple with Difference of Tem perature of its Two Junctions.
9. To calibrate a thermocouple to measure temperature in a specified Range using (a) Null Method; and (b) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

Reference Books

[1] B.L. Flint and H.T. Worsnop, Advanced Practical Physics for Students, Asia Publishing House, 1971.
[2] Michael Nelson and Jon M. Ogborn, Advanced Level Physics Practicals (4ed), Heinemann Educational Publishers, 1985.
[3] Indu Prakash and Ramakrishna, A Text Book of Practical Physics (11ed), Kitab Mahal, 2011.
[4] D.P. Khandelwal, A Laboratory Manual of Physics for Undergraduate Classes, Vani Pub, 1985.

Physics - Major 6 : Digital Electronics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Introduction to CRO Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: Study of Waveform, Measurement of Voltage, Current, Frequency, and Phase Difference. *3 Lectures*

Integrated Circuits (Qualitative treatment only) Active & Passive components. Discrete components. Wafer, Chip. Advantages and drawbacks of ICs, basic idea of Monolithic IC. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital ICs. *2 Lectures*

Digital Circuits Advantage, Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. *8 Lectures*

Boolean algebra De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map (up to four variable). *7 Lectures*

Data processing circuits Basic idea of Multiplexers, De-Multiplexers, Decoders, Encoders, Seven segment display and Digital Comparators. *4 Lectures*

Arithmetic Circuits Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor. *5 Lectures*

Sequential Circuits SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip- Flop. Master-Slave JK Flip-Flop. *7 Lectures*

Timers IC 555: Block diagram and Applications: Astable multivibrator and Monostable multivibrator. *3 Lectures*

Shift registers Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits). *3 Lectures*

Counters (4 bits) Ring Counter. Asynchronous Counters, Decade Counter. Synchronous Counter, Applications. *4 Lectures*

Computer Organisation Input/Output Devices. Data storage (idea of RAM and ROM). Computer memory. Memory organization & addressing. Memory Interfacing. Memory Map. *4 Lectures*

Intel 8085 Microprocessor Architecture Main features of 8085. Block diagram. Components. Pin-out diagram, Buses. Registers, ALU, Memory, Stack memory. Timing & Control circuitry. Timing states. Instruction cycle, Timing diagram of MOV and MVI. *6 Lectures*

Introduction to Assembly Language 1 byte, 2 byte and 3 byte instructions. *2 Lectures*

Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation, Digital Carrier Modulation Techniques, Sampling, Quantizing and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Binary Phase Shift Keying (BPSK). *2 Lectures*

Reference Books

[1] A.P. Malvino, D.P. Leach and Saha, Digital Principles and Applications (7ed), Tata McGraw Hill, 2011.
[2] Anand Kumar, Fundamentals of Digital Circuits, PHI Learning, 2009.
[3] Venugopal, Digital Circuits and Systems, Tata McGraw Hill, 2011.
[4] G.K. Kharate, Digital Electronics, Oxford University Press, 2010.
[5] R.J. Tocci and N.S. Widmer, Digital Systems: Principles and Applications, PHI Learning, 2001.
[6] Shimon P. Vingron, Logic Circuit Design, Springer, 2012.
[7] Subrata Ghoshal, Digital Electronics, Cengage Learning, 2012.
[8] S.K. Mandal, Digital Electronics, McGraw Hill, 2010.
[9] R.S. Goankar, Microprocessor Architecture Programming and Applications with 8085, Prentice Hall, 2002.

Physics - Major 6 Lab : Digital Electronics
60 Lectures

Experiments

1. To design a switch (NOT gate) using a transistor.
2. To verify and design AND, OR, NOT and XOR gates using NAND gates.
3. To design a combinational logic system for a specified Truth Table.
4. To convert a Boolean expression into logic circuit and design it using logic gate ICs.
5. To minimize a given logic circuit.
6. Half Adder, Full Adder and 4-bit binary Adder.
7. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder IC.
8. To design a digital to analog converter (DAC) of given specifications.
9. To study the analog to digital convertor (ADC) using ICs.
10. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
11. To build JK Master-slave flip-flop using Flip-Flop ICs.
12. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
13. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
14. To design an astable multivibrator of given specifications using 555 Timer.
15. To design a monostable multivibrator of given specifications using 555 Timer.
16. To study ASK, PSK and FSK modulators.
17. Write the following programs using 8085 Microprocessor
    (a) Addition and subtraction of numbers using direct addressing mode.
    (b) Addition and subtraction of numbers using indirect addressing mode.
    (c) Multiplication by repeated addition.
    (d) Division by repeated subtraction.
    (e) Handling of 16-bit Numbers.
    (f) Use of CALL and RETURN Instruction.
    (g) Block data handling.
    (h) Other programs (e.g. Parity Check, using interrupts, etc.).

Reference Books

[1] R.P. Jain, Modern Digital Electronics (4ed), Tata McGraw Hill, 2010.
[2] P.B. Zbar, A.P. Malvino, M.A. Miller, Basic Electronics: A Text Lab Manual, McGraw Hill, 1994.
[3] A. Wadhwa, Microprocessor 8085: Architecture, Programming and Interfacing, PHI Learning, 2010.

Semester V

Physics - Major 7 : Electromagnetic Theory
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Maxwell's Equations Review of the Gauss' law and Faraday's law. Ampére's law beyond magnetostatics and its rectification by Maxwell. Concept of Displacement Current Density. Maxwell's Equations. Poynting Theorem and Poynting Vector. Derivation of Electromagnetic Field Energy Density, Momentum Density, Intensity of EM Wave and Radiation Pressure. *10 Lectures*

EM Wave Propagation in unbounded media Wave equations for and fields in free space and dielectric media. Solution of the EM wave equations: Monochromatic plane wave. Transverse nature of the plane EM wave. Derivation of the relation connecting field, field and propagation vector. Plane EM waves through isotropic dielectric medium, Refractive index and Dielectric constant. Propagation through conducting media, Relaxation time, Skin Depth and ratio of amplitudes of and fields. Wave Guides, TE waves, TEM waves. TE waves in Rectangular Wave Guide: Cutoff frequency, Propagation speed of EM wave down the Wave Guide. *16 Lectures*

EM Wave Propagation in bounded media Boundary conditions for the EM wave at a plane interface between two media. Reflection and Refraction of plane waves at plane interface between two dielectric media. Derivations of the Laws of Reflection and Refraction. Fresnel's formulae for perpendicular and parallel polarization cases, Derivations of reflection and transmission coefficients, Brewster's law. Total internal reflection, evanescent waves. Mathematical description of Metallic reflection (for Normal Incidence). *14 Lectures*

Polarization Polarization by dichroic crystals, birefringence, Nicol prism, retardation plates and Babinet's compensator. Analysis of polarized light. Optical Rotation - Fresnel's explanation of optical rotation and Half Shade & Biquartz polarimeters. *10 Lectures*

Dispersion Equation of motion of an electron in a radiation field, Lorentz theory of dispersion- normal and anomalous. Cauchy's formulae. *6 Lectures*

Scattering Scattering of radiation by a bound charge, Rayleigh scattering, blue of the sky; absorption. *4 Lectures*

Reference Books

[1] D.J. Griffiths, Introduction to Electrodynamics, Pearson Education, 2012.
[2] M.N.O. Sadiku, Elements of Electromagnetics, Oxford University Press, 2001.
[3] T.L. Chow, Introduction to Electromagnetic Theory, Jones & Bartlett Learning, 2006.
[4] M.A.W. Miah, Fundamentals of Electromagnetics, Tata McGraw Hill, 1982.
[5] R.S. Kshetrimayun, Electromagnetic Field Theory, Cengage Learning, 2012.
[6] Willian H. Hayt, Engineering Electromagnetics (8ed), McGraw Hill, 2012.
[7] G. Lehner, Electromagnetic Field Theory for Engineers and Physicists, Springer, 2010.
[8] P. Lorrain and D. Corson, Electromagnetic Fields and Waves, W.H.Freeman & Co.
[9] J.A. Edminster, Electromagnetics, Tata McGraw Hill, 2006.
[10] B. Guru and H. Hiziroglu, Electromagnetic Field Theory Fundamentals, Cambridge University Press, 2004.

Physics - Major 7 Lab : Electromagnetic Theory
60 Lectures

Experiments

1. To verify the law of Malus for plane polarised light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyse elliptically polarised Light by using a Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection, refraction of microwaves.
7. To study Polarisation and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarisation of light by reflection and determine the polarising angle for air-glass interface.
11. To verify the Stefan's law of radiation.
12. To determine the Boltzmann constant using V-I characteristics of PN junction diode.
13. Measurement of Planck's constant using black body radiation and photo-detector.
14. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
15. To determine work function of material of filament of directly heated vacuum diode.
16. To determine the Planck's constant using LEDs of at least 4 different colours.
17. To determine the wavelength of H-alpha emission line of Hydrogen atom.
18. To determine the ionisation potential of mercury.
19. To determine the value of e/m by (a) Magnetic focusing; or (b) Bar magnet.

Reference Books

[1] B.L. Flint and H.T. Worsnop, Advanced Practical Physics for Students, Asia Publishing House, 1971.
[2] Michael Nelson and Jon M. Ogborn, Advanced Level Physics Practicals (4ed), Heinemann Educational Publishers, 1985.
[3] Indu Prakash and Ramakrishna, A Text Book of Practical Physics (11ed), Kitab Mahal, 2011.
[4] G. Lehner, Electromagnetic Field Theory for Engineers and Physicists, Springer, 2010.

Physics - Major 8 : Classical Dynamics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Mathematical Preliminaries Matrices: Basic properties of matrices. Real symmetric, Hermitian, orthogonal and unitary matrices. Eigenvalue and Eigenvectors (degenerate and non-degenerate cases). Caley-Hamilton theorem. Diagonalisation of matrices. *10 Lectures*

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. Generalised coordinates and velocities. Calculus of variations: Hamilton's principle, Lagrangian and the Euler-Lagrange equations, one-dimensional examples of the Euler-Lagrange equations- one-dimensional Simple Harmonic Oscillations and falling body in uniform gravity; applications to simple systems such as coupled oscillators Canonical momenta and Hamiltonian. Hamilton's equations of motion.

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.

35 Lectures

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. *15 Lectures*

Relativistic mechanics 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. *15 Lectures*

Reference Books

[1] H. Goldstein, C.P. Poole and J.L. Safko, Classical Mechanics (3ed), Pearson Education, 2002.
[2] L.D. Landau and E.M. Lifshitz, Mechanics, Pergamon, 1976.
[3] J.D. Jackson, Classical Electrodynamics (3ed), Wiley, 1998.
[4] L.D. Landau and E.M. Lifshitz, The Classical Theory of Fields (4ed), Elsevier, 2003.
[5] D.J. Griffiths, Introduction to Electrodynamics, Pearson Education, 2012.
[6] P.S. Joag and N.C. Rana, Classical Mechanics, McGraw Hall.
[7] R. Douglas Gregory, Classical Mechanics, Cambridge University Press, 2015.
[8] Dieter Strauch, Classical Mechanics: An Introduction, Springer, 2009.
[9] O.L. Delange and J. Pierrus, Solved Problems in Classical Mechanics, Oxford University Press, 2010.

Physics - Major 9 : Modern Physics and Quantum Mechanics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Empirical application to quantum ideas Planck's quantum hypothesis, Planck's constant and light as a collection of photons; Blackbody Radiation: Quantum theory of Light. Photo-electric effect: Particle nature of radiation, photons. Compton scattering: Scattering of radiation as particles. Diffraction of matter particles: De Broglie wavelength and wave-particle duality. Experimental verification of de Broglie hypothesis: Davisson-Germer and G.P. Thompson's experiment.

Atomic spectra: Ritz combination principle, Balmer and other series, Rutherford model. Bohr atomic model: Quantization of angular momentum, Bohr energies.

Atoms in Electric and Magnetic Fields: Space quantisation. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Normal and Anomalous Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Paschen Back and Stark Effect (Qualitative Discussion only).

Many electron atoms: Pauli's Exclusion Principle. Symmetric and Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms- L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.). *22 Lectures*

Elements of quantum mechanics Particles as wave packets. Group and Phase velocities. Double split thought experiment with electrons. Probability. Wave amplitude and wave functions.

Position measurement - gamma ray microscope thought experiment; Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Impossibility of a particle following a trajectory from wave packets; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle: application to virtual particles and range of an interaction.
10 Lectures

Time dependent Schrödinger equation Time dependent Schrödinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalisation. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle. *11 Lectures*

Time independent Schrödinger equation Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrödinger equation in terms 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 wavefunction; Position-momentum uncertainty principle. *10 Lectures*

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; Hermite polynomials; ground state, zero point energy and uncertainty principle.
11 Lectures

Quantum theory of hydrogen-like atoms Time independent Schrödinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator and quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground and first excited states; Orbital angular momentum quantum numbers l and m; s, p, d, ...shells. *11 Lectures*

Reference Books

[1] P.M. Mathews and K. Venkatesan, Text Book of Quantum Mechanics (2ed), McGraw Hill, 2010.
[2] Robert Eisberg and Robert Resnick, Quantum Mechanics (2ed), Wiley, 2002.
[3] Leonard I. Schiff, Quantum Mechanics (3ed), Tata McGraw Hill, 2010.
[4] G. Aruldhas, Quantum Mechanics (2ed), Prentice-Hall, 2002.
[5] Bruce Cameron Reed, Quantum Mechanics, Jones and Bartlett Learning, 2008.
[6] Arno Bohm, Quantum Mechanics: Foundations and Applications (3ed), Springer, 1993.
[7] D.A.B. Miller, Quantum Mechanics for Scientists and Engineers, Cambridge University Press, 2008.
[8] Eugen Merzbacher, Quantum Mechanics, John Wiley & Sons, 2004.
[9] D.J. Griffiths, Introduction to Quantum Mechanics (2ed), Pearson Education, 2005.
[10] Walter Greiner, Quantum Mechanics (4ed), Springer, 2001.

Semester VI

Physics - Major 10 : Solid State Physics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

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. *10 Lectures*

Elementary Lattice Dynamics Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law. *8 Lectures*

Magnetic Properties of Matter Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia and para magnetic 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. *8 Lectures*

Dielectric Properties of Materials Polarisation. Local Electric Field at an Atom. Depolarisation Field. Electric Susceptibility. Polarisability. Clausius Mosotti Equation. Classical Theory of Electric Polarisability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes. *8 Lectures*

Ferroelectric Properties of Materials Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop. *5 Lectures*

Structure of Solids Different types of bondings, Free electron theory of metals, effective mass, drift current, Widemann Franz law. *7 Lectures*

Elementary band theory Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (4 probe method) and Hall coefficient. *9 Lectures*

Superconductivity Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation). *5 Lectures*

Reference Books

[1] Charles Kittel, Introduction to Solid State Physics (8ed), Wiley India Pvt. Ltd, 2004.
[2] J.P. Srivastava, Elements of Solid State Physics (2ed), Prentice-Hall, 2006.
[3] Leonid V. Azaroff, Introduction to Solids, Tata Mc-Graw Hill, 2004.
[4] N.W. Ashcroft and N.D. Mermin, Solid State Physics, Cengage Learning, 1976.
[5] H. Ibach and H. Luth, Solid State Physics, Springer, 2009.
[6] Rita John, Solid State Physics, McGraw Hill, 2014.
[7] M. Ali Omar, Elementary Solid State Physics, Pearson India, 1999.
[8] M.A. Wahab, Solid State Physics, Narosa Publications, 2011.

Physics - Major 10 Lab : Solid State Physics
60 Lectures

Experiments

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 static dielectric constant of two dielectric materials.
5. To measure the Dielectric Constant of a dielectric Materials with frequency.
6. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR).
7. To determine the refractive index of a dielectric layer using SPR.
8. To study the PE Hysteresis loop of a Ferroelectric Crystal.
9. To draw the BH curve of Fe and determine energy loss from Hysteresis.
10. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 °C) and to determine its band gap.
11. To determine the Hall coefficient of a semiconductor sample.
12. To study the dynamics of lattice vibrations via electrical simulation.

Reference Books

[1] B.L. Flint and H.T. Worsnop, Advanced Practical Physics for Students, Asia Publishing House, 1971.
[2] Michael Nelson and Jon M. Ogborn, Advanced Level Physics Practicals (4ed), Heinemann Educational Publishers, 1985.
[3] Indu Prakash and Ramakrishna, A Text Book of Practical Physics (11ed), Kitab Mahal, 2011.
[4] J.P. Srivastava, Elements of Solid State Physics (2ed), Prentice-Hall, 2006.

Physics - Major 11 : Statistical Mechanics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Classical Statistics Statistical descriptions of system of particles, Macrostate and Microstate, Elementary Concept of Ensemble, Phase Space. Distribution of energy between macroscopic systems. Microcanonical ensemble, Postulate of Equal a-priori probabilities, Entropy and Thermodynamic Probability. Canonical ensemble, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox. Equivalence of microcanonical and canonical ensemble. Grand canonical ensemble. Application of ideal gas using grand canonical ensemble. Concept of chemical potential. Sackur Tetrode equation, Law of Equipartition of Energy (with proof), Applications to Specific Heat and its Limitations. Thermodynamic Functions of a Two-Energy Level System. Negative Temperature. *28 Lectures*

Systems of Identical particles Collection of non-interacting identical particles. Classical approach and quantum approach: distinguishability and indistinguishability, Occupation number and MB distribution, Emergence of Boltzmann factor, Composite system postulate and symmetry postulate of quantum mechanics (for a pair of particles only), Bosons and Fermions. Symmetric and Antisymmetric wave functions, State counting for Bosons and Fermions. *8 Lectures*

Application of Statistical Mechanics in thermodynamics

Conduction Conductivity, Diffusivity, Fourier equation for heat conduction. *3 Lectures*

Convection Importance in Atmospheric Science Adiabatic lapse rate. *2 Lectures*

Classical Theory of Radiation Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Newton's laws of cooling, Wien's Displacement law. Wien's Distribution Law. Saha's Ionisation Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe. *8 Lectures*

Quantum Theory of Radiation Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law. *8 Lectures*

Quantum Statistics

Bose-Einstein Statistics B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. *9 Lectures*

Fermi-Dirac Statistics Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. Richardson Dushman equation. Dependence of Fermi Level with temperature. *9 Lectures*

Reference Books

[1] R.K. Pathria, Statistical Mechanics (2ed), Oxford University Press, 1996.
[2] F. Reif, Statistical Physics - Berkeley Physics Course, Tata McGraw-Hill, 2008.
[3] S. Lokanathan and R.S. Gambhir, Statistical and Thermal Physics, Prentice Hall, 1991.
[4] Francis W. Sears and Gerhard L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Narosa, 1986.
[5] Carl S. Helrich, Modern Thermodynamics with Statistical Mechanics, Springer, 2009.
[6] R.H. Swendsen, An Introduction to Statistical Mechanics and Thermodynamics, Oxford University Press, 2002.

Physics - Major 12 : Nuclear and Particle Physics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

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. *8 Lectures*

Nuclear Models Liquid drop model approach, semi empirical mass formula and significance of its various terms, α and β nuclear stability from semi empirical mass formula, 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. *13 Lectures*

Radioactivity decay (a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) Beta decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission and kinematics, internal conversion. *12 Lectures*

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). *10 Lectures*

Interaction of Nuclear Radiation with matter Energy loss due to ionisation (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter. *9 Lectures*

Detector for Nuclear Radiations Gas detectors: estimation of electric field, mobility of particle, for ionisation 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. *8 Lectures*

Particle Accelerators Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons. *5 Lectures*

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. *10 Lectures*

Reference Books

[1] Kenneth S. Krane, Introductory Nuclear Physics, Wiley India Pvt. Ltd., 2008.
[2] Bernard L. Cohen, Concepts of Nuclear Physics, Tata Mcgraw Hill, 1998.
[3] R.A. Dunlap, Introduction to the Physics of Nuclei and Particles, Thomson Asia, 2004.
[4] D.H. Perkins, Introduction to High Energy Physics, Cambridge Univ. Press.
[5] D.J. Griffith, Introduction to Elementary Particles, John Wiley & Sons.
[6] F. Halzen and A.D. Martin, Quarks and Leptons, Wiley India.
[7] K. Heyde, Basic Ideas and Concepts in Nuclear Physics – An Introductory Approach, IOP, 2004.
[8] G.F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, 2000.
[9] Syed Naeem Ahmed, Physics and Engineering of Radiation Detection, Academic Press, 2007.
[10] J.M. Blatt and V.F. Weisskopf, Theoretical Nuclear Physics, Dover, 1991.

Semester VII

Physics - Major 13 : Research Methodology & Ethics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

Research in Physics Nature and scope of research in physics. Inductive and deductive reasoning. The character of physical laws: universality, falsifiability and reproducibility. Scientific models, idealisation and approximation. Pseudoscience and misuse of scientific language. Role of symmetry, conservation laws and invariance principles in physics. Examples of paradigm shifts in physics as case studies.

7 Lectures

Types of Research and Research Design Theoretical, experimental, computational and phenomenological research. Fundamental and applied research. Interdisciplinary research involving physics, biology, materials science, data science and artificial intelligence. Selection of a research problem, formulation of research questions, objectives and hypotheses. Research plan, research proposal and feasibility of a research problem. Responsible use and misuse of AI tools in research. *8 Lectures*

Literature Survey and Information Retrieval Structure of a research paper. Research articles, review articles, preprints, conference proceedings, theses and books. Literature survey and identification of research gaps. Use of research databases and repositories: arXiv, INSPIRE-HEP, NASA ADS, Web of Science, Scopus and Google Scholar as discipline-specific examples. Citation tracking, impact factor, h-index and their limitations. Reference management tools. *8 Lectures*

Logic, Argument and Proof in Physics Need for logical reasoning in scientific work. Statements and truth values, negation, implication, equivalence, contradiction and quantifiers. Basic rules of inference. Methods of proof: direct proof, proof by contradiction, proof by contrapositive and proof by induction. Use of examples and counterexamples in physics and mathematics. *6 Lectures*

Scientific Data Analysis and Numerical Methods Data collection in theoretical, experimental and computational physics. Errors and uncertainties, significant figures, propagation of errors, graphical representation of data. Population and sample, sampling methods. Estimation of mean, variance and median. Least-squares fitting, weighted least-squares fitting and parameter estimation. Introductory numerical methods relevant to data analysis: interpolation, numerical differentiation, numerical integration, root-finding and simple numerical solution of ordinary differential equations. Monte Carlo sampling and simulation. Goodness of fit using χ^2. *15 Lectures*

Scientific Writing and Communication Writing a research proposal. Structure of a dissertation or thesis. Writing abstracts, introductions, literature reviews, methodology, results, discussion and conclusion. Figures, tables and captions. Citation styles and bibliography preparation for scientific writing. Oral presentation, poster presentation and preparation of slides using PowerPoint, Beamer or similar tools. Defending results, handling questions and communicating physics to non-experts. *10 Lectures*

Research Ethics and Professional Conduct Ethics in research. Academic honesty and integrity. Plagiarism, self-plagiarism, data fabrication, data falsification, selective reporting, image manipulation and misuse of data. Authorship and collaboration ethics. Conflict of interest. Peer review process. Open access and subscription journals. Predatory journals and conferences. Retractions and corrections. Gender bias, discrimination and responsible research culture. Research environment, pressure to publish, mentoring, collaboration and well-being of researchers. Intellectual property rights. *6 Lectures*

Reference Books

[1] C. R. Kothari and Gaurav Garg, *Research Methodology: Methods and Techniques*, New Age International Publishers.
[2] Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners*, SAGE Publications.
[3] D. B. Resnik, *The Ethics of Science: An Introduction*, Routledge/Taylor and Francis.
[4] K. Muralidhar, A. Ghosh and A. K. Singhvi, eds., *Ethics in Science Education, Research and Governance*, Indian National Science Academy.
[5] J. R. Taylor, *An Introduction to Error Analysis*, University Science Books.
[6] Philip R. Bevington and D. Keith Robinson, *Data Reduction and Error Analysis for the Physical Sciences*, McGraw-Hill.
[7] Glen Cowan, *Statistical Data Analysis*, Oxford University Press.
[8] Particle Data Group, *Review of Particle Physics*, section on Statistics.
[9] Nicholas J. Higham, *Handbook of Writing for the Mathematical Sciences*, SIAM.
[10] Jeffrey Beall, "Predatory publishers are corrupting open access," *Nature* **489**, 179, 2012.
[11] N. K. Acharya, *Textbook on Intellectual Property Rights*, Asia Law House.

Physics - Major 13 Lab : Research Methodology
60 Lectures

The practicals should be based on Python/Scilab/Octave/Matlab or any suitable computational platform. The emphasis shall be on scientific data analysis, uncertainty estimation, curve fitting, elementary numerical methods, simulation, reproducibility and scientific reporting.

Sample Practicals: Scientific Data Analysis and Numerical Methods

1. **Statistical analysis of repeated measurements.**
   The time period T of a pendulum was measured ten times and the following values were obtained in seconds:

   $$1.921,\ 1.934,\ 1.928,\ 1.936,\ 1.930,\ 1.925,\ 1.932,\ 1.927,\ 1.935,\ 1.929.$$

   Calculate the mean, variance, standard deviation and standard error of the mean. If the length of the pendulum is

   $$L = (0.920 \pm 0.002)\,\text{m},$$

   calculate

   $$g = \frac{4\pi^2 L}{T^2}$$

   and estimate the uncertainty in g using propagation of errors. Present the result in the form $g \pm \Delta g$, with correct units and significant figures.
2. **Linear least-squares fitting: Ohm's law.**
   The current through a resistor and the corresponding potential difference are measured as follows:

I (mA)	5	10	15	20	25	30
V (V)	0.51	1.02	1.48	2.01	2.49	3.03

   Fit the data to

   $$V = RI + V_0.$$

   Find the best-fit values of R and V_0. Plot the data points and the best-fit straight line. Interpret the physical meaning of the slope and intercept.

3. **Weighted least-squares fitting: spring constant.**
A spring is loaded with different masses and the extension x is measured:

m (g)	50	100	150	200	250
x (cm)	1.21	2.38	3.62	4.83	6.01
σ_x (cm)	0.05	0.05	0.06	0.06	0.07

Using
$$mg = kx,$$
perform a weighted least-squares fit and determine the spring constant k. Use $g = 9.81\,\mathrm{m\,s^{-2}}$. Estimate the uncertainty in k and compare the result with an unweighted fit.

4. **Nonlinear curve fitting and goodness of fit: exponential decay.**
The voltage across a discharging capacitor is measured as:

t (s)	0	1	2	3	4	5	6	7	8
V (V)	5.02	3.69	2.70	2.02	1.49	1.09	0.82	0.60	0.45

Fit the data to
$$V(t) = V_0 e^{-t/\tau}.$$
Estimate V_0 and τ. Repeat the fit by plotting $\ln V$ versus t, and compare the two methods. Assuming
$$\sigma_V = 0.05\,\mathrm{V},$$
calculate χ^2 and reduced χ^2, and comment on the quality of the fit.

5. **Interpolation of calibration data.**
The thermo-emf E of a thermocouple was measured at different temperatures:

T (°C)	0	20	40	60	80	100
E (mV)	0.00	0.79	1.61	2.43	3.26	4.10

Using linear interpolation, estimate the temperature corresponding to
$$E = 2.75\,\mathrm{mV}.$$
Then use a quadratic interpolation based on three nearby points and compare the result.

6. **Numerical differentiation of experimental data.**
The position x of a particle moving along a straight line is measured at equal time intervals:

t (s)	0	1	2	3	4	5
x (m)	0.00	1.10	4.05	8.95	16.10	25.20

Use finite-difference formulae to estimate the velocity and acceleration at interior points. Compare the result with the expected behaviour for nearly uniform acceleration.

7. **Numerical integration: work done by a variable force.**
A force $F(x)$ is measured at different positions:

x (m)	0	0.5	1.0	1.5	2.0	2.5	3.0
F (N)	0.0	1.2	2.1	2.8	3.2	3.5	3.6

Estimate the work done,

$$W = \int_0^3 F(x)\,dx,$$

using the trapezoidal rule and Simpson's rule. Compare the two results and comment on the numerical accuracy.

8. **Root finding: Wien's displacement equation.**
   The dimensionless equation for the maximum of Planck's spectral distribution can be written as

   $$5(1 - e^{-x}) = x.$$

   Use the bisection method and Newton-Raphson method to find the non-zero root in the interval

   $$4 < x < 6.$$

   Compare the number of iterations required by the two methods.

9. **Numerical solution of an ordinary differential equation.**
   A body falling through a resistive medium obeys

   $$\frac{dv}{dt} = g - \gamma v,$$

   where

   $$g = 9.81\,\mathrm{m\,s^{-2}}, \qquad \gamma = 0.40\,\mathrm{s^{-1}}.$$

   Starting from $v(0) = 0$, solve the equation numerically using Euler/RK2/RK4 method for

   $$0 \le t \le 10\,\mathrm{s}$$

   with step sizes

   $$h = 0.5\,\mathrm{s}, \quad 0.1\,\mathrm{s}, \quad 0.01\,\mathrm{s}.$$

   Compare the numerical result with the exact solution

   $$v(t) = \frac{g}{\gamma}\left(1 - e^{-\gamma t}\right).$$

10. **Euler-Cromer method for the simple harmonic oscillator.**
    Solve the equation

    $$\frac{d^2x}{dt^2} = -\omega^2 x$$

    using the Euler/RK2/RK4/Euler-Cromer method with

    $$\omega = 2.0\,\mathrm{s^{-1}}, \qquad x(0) = 1.0, \qquad v(0) = 0.$$

    Take

    $$h = 0.05\,\mathrm{s}, \qquad 0 \le t \le 20\,\mathrm{s}.$$

    Plot $x(t)$, $v(t)$, and the total energy

    $$E = \frac{1}{2}v^2 + \frac{1}{2}\omega^2 x^2.$$

    Comment on energy conservation.

11. **Monte Carlo estimation of π and Monte Carlo integration.**
Generate random points uniformly in the square

$$-1 \leq x \leq 1, \qquad -1 \leq y \leq 1.$$

Estimate π using the fraction of points falling inside the unit circle for

$$N = 10^2,\ 10^3,\ 10^4,\ 10^5.$$

Then evaluate

$$I = \int_0^1 e^{-x^2}\, dx$$

using crude Monte Carlo integration and compare the result with Simpson's rule using 1000 subintervals.

12. **Random walk and diffusion-like behaviour.**
Simulate a one-dimensional random walk in which each step is $+1$ or -1 with equal probability. Use

$$N_{\text{walkers}} = 5000$$

and number of steps

$$n = 10,\ 50,\ 100,\ 500,\ 1000.$$

Compute

$$\langle x \rangle, \qquad \langle x^2 \rangle$$

as functions of n. Verify that

$$\langle x \rangle \approx 0, \qquad \langle x^2 \rangle \propto n.$$

13. **Gaussian and Poisson distributed data.**
Generate 10^4 random numbers from a Gaussian distribution with

$$\mu = 50, \qquad \sigma = 5.$$

Plot the histogram and estimate the mean and standard deviation from the generated data. Generate 10^4 random numbers from a Poisson distribution with

$$\lambda = 4.$$

Plot the histogram and verify that the mean and variance are approximately equal.

Physics - Major 14 : Advanced Mathematical Methods
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

Complex Analysis Brief revision of complex numbers and their graphical representation, Euler's formula, De Moivre's theorem and roots of complex numbers. Functions of a complex variable, analytic functions, Cauchy-Riemann conditions and examples of analytic functions. Cauchy's theorem and Cauchy's integral formula. Simply connected regions. Singularities: removable singularities, poles and branch points; order of poles and branch cuts. Taylor and Laurent series. Residue theorem and evaluation of real definite integrals using contour integration. *15 Lectures*

Integral Transforms and Dirac Delta Function Fourier integral theorem, Fourier transform, Fourier sine and cosine transforms, inverse Fourier transform. Fourier transforms of elementary functions: single pulse, trigonometric, exponential and Gaussian functions. Fourier transform of derivatives, convolution theorem and properties of Fourier transforms: translation, change of scale and complex conjugation. Applications to ordinary and partial differential equations, including the one-dimensional wave equation and elementary applications in physics.

Laplace transform of elementary functions. Properties of Laplace transforms: change of scale theorem, shifting theorem, Laplace transforms of derivatives and integrals, Laplace transform of unit step function. Convolution theorem and inverse Laplace transform. Applications of Laplace transforms to second-order differential equations with simple physical examples.

Dirac delta function: definition and properties, representation as a Fourier integral, Fourier transform of the Dirac delta function. *17 Lectures*

Linear Vector Spaces and Operators Vector spaces and subspaces, linear combination of vectors, use of ket notation $|\alpha\rangle$, linear independence and linear dependence, basis and dimension of a vector space, change of basis. Linear mappings, rank and nullity, range space and kernel. Linear transformations and algebra of linear transformations. Non-singular transformations and matrix representation of linear transformations.

Inner product spaces, inner product $\langle\alpha|\beta\rangle$, norm of a vector, Euclidean and unitary spaces, Cauchy-Schwarz inequality, concept of length and distance, Hilbert space as an infinite-dimensional inner product space. Orthogonality of vectors, orthonormal basis and Gram-Schmidt orthogonalisation procedure. Linear operators, inverse of an operator, adjoint operators, projection operators and matrix representation of linear operators. *16 Lectures*

Cartesian Tensors and Metric Methods in Curvilinear Coordinates Transformation of coordinates and direction cosines. Einstein summation convention. Scalars, vectors and second-rank Cartesian tensors. Kronecker delta and Levi-Civita symbol. Tensor notation for scalar product, vector product and simple vector identities. Symmetric and antisymmetric tensors.

Tensorial character of physical quantities. Moment of inertia tensor: principal axes and principal moments of inertia. Stress and strain tensors: physical meaning and symmetry. Elementary idea of the stress-energy tensor as an example of a tensorial physical quantity.

Curvilinear coordinates in Euclidean space. Line element and metric tensor,

$$ds^2 = g_{ij}\, dq^i dq^j.$$

Inverse metric g^{ij}, metric determinant $g = \det(g_{ij})$, and volume element $\sqrt{g}\, dq^1 dq^2 dq^3$. Metric forms of gradient, divergence, curl and Laplacian:

$$(\nabla f)^i = g^{ij}\partial_j f,$$

$$\nabla \cdot \boldsymbol{A} = \frac{1}{\sqrt{g}}\partial_i\big(\sqrt{g}\, A^i\big),$$

$$(\nabla \times \boldsymbol{A})^i = \frac{1}{\sqrt{g}}\varepsilon^{ijk}\partial_j A_k,$$

where $A_k = g_{kl}A^l$, and

$$\nabla^2 f = \frac{1}{\sqrt{g}}\partial_i\big(\sqrt{g}\, g^{ij}\partial_j f\big).$$

Reduction of these formulae to cylindrical and spherical polar coordinates. Comparison with the usual scale-factor formulae in orthogonal curvilinear coordinates. *12 Lectures*

Group Theory Symmetry transformations in physics and the need for group theory. Definition of a group, elementary properties of groups, subgroups, cyclic groups and permutation groups. Physical examples from $SO(2)$, $SO(3)$, $SU(2)$. *15 Lectures*

Reference Books

[1] G. B. Arfken, H. J. Weber and F. E. Harris, *Mathematical Methods for Physicists*, Academic Press.
[2] Tulsi Dass and S. K. Sharma, *Mathematical Methods in Classical and Quantum Physics*, Universities Press.
[3] J. Mathews and R. L. Walker, *Mathematical Methods of Physics*, Pearson.
[4] M. L. Boas, *Mathematical Methods in the Physical Sciences*, Wiley.
[5] K. F. Riley, M. P. Hobson and S. J. Bence, *Mathematical Methods for Physics and Engineering*, Cambridge University Press.
[6] R. V. Churchill and J. W. Brown, *Complex Variables and Applications*, McGraw-Hill.
[7] M. R. Spiegel, *Schaum's Outline of Complex Variables*, McGraw-Hill.
[8] Seymour Lipschutz and Marc Lipson, *Linear Algebra*, Schaum's Outline Series, McGraw-Hill.
[9] A. W. Joshi, *Matrices and Tensors in Physics*, New Age International.
[10] A. W. Joshi, *Elements of Group Theory for Physicists*, New Age International.
[11] M. Hamermesh, *Group Theory and Its Application to Physical Problems*, Dover.
[12] I. M. Gelfand and S. V. Fomin, *Calculus of Variations*, Dover.
[13] G. F. Roach, *Green's Functions*, Cambridge University Press.
[14] H. K. Dass, *Mathematical Physics*, S. Chand.
[15] W. W. Bell, *Special Functions for Scientists and Engineers*, Dover.

Physics - Major 15 : Advanced Quantum Mechanics
(Credits: Theory-04, Seminar-02)
Theory: 60 Lectures

Recapitulation of Basic Concepts Basic postulates, observables and operators, measurements in quantum mechanics. Schrödinger equation and time evolution of a quantum mechanical system, normalisation, linearity and superposition principles. Wave packets, Fourier transforms and momentum-space wavefunction, Gaussian wave packet as a representative example, wave packets and uncertainty relations, time evolution of wave packets, Parseval's theorem. *6 Lectures*

Mathematical Formulation of Quantum Mechanics One-particle wavefunction space $\mathscr{F}$, $\mathscr{F}$ as a linear vector space, scalar product, linear operators; discrete orthonormal bases in $\mathscr{F}$, closure relation and orthonormality condition; continuous orthonormal bases. State space: Dirac notation, ket vectors and bra vectors, correspondence between kets and bras, scalar product in Dirac notation, linear operators acting on kets, Hermitian conjugation: action of a linear operator on a bra, adjoint operators of linear operators, Expansion of kets and bras in discrete and continuous bases. Matrix representation of kets, bras, and operators. Hermitian operators, eigenvalues and eigenvectors of Hermitian operators, compatible and incompatible observables, uncertainty relation between two operators. Change of bases and unitary transformations. Projector operators, parity operators, infinitesimal and finite unitary transformations: time evolution, translation and rotation. Position and momentum representations, position-space wavefunction, momentum operator in the position basis, momentum-space wavefunction. *14 Lectures*

Linear Harmonic Oscillator [Algebraic Method] Creation and annihilation operators, commutation relation between creation and annihilation operators, expression of the Hamiltonian using creation and annihilation operators, action of creation and annihilation operators on energy eigenkets and determination of energy eigenvalues. Ground-state wavefunction and first excited-state wavefunction. *6 Lectures*

Algebra of Angular Momentum Fundamental orbital angular momentum commutation relations, generalisation to total angular momentum operators, raising and lowering operators, simultaneous eigenstates of J^2 and J_z, or L^2 and L_z, action of raising and lowering operators on them, determination of the eigenvalues of J^2 and J_z. Matrix representation of angular momentum operators in the basis of simultaneous eigenstates of J^2 and J_z for simple cases. Pauli spin matrices and their properties. Addition of angular momentum for two spin-$\frac{1}{2}$ particles. *12 Lectures*

Variational Methods Calculus of Variations in Quantum Mechanics: trial wave function and minimisation of ground state energy. *4 Lectures*

Time-Independent Perturbation Theory Non-degenerate and degenerate perturbation theory, first- and second-order corrections to energy eigenvalues, and first-order corrections to energy eigenfunctions. Applications of perturbation theory. *10 Lectures*

Scattering Theory Scattering cross-section, laboratory frame and centre-of-mass frame, scattering amplitude and differential cross-section, Green's function technique in scattering phenomena, Born approximation, validity of Born approximation, partial-wave analysis for elastic scattering. *8 Lectures*

Reference Books

[1] J. J. Sakurai and Jim Napolitano, *Modern Quantum Mechanics*, Cambridge University Press.
[2] Claude Cohen-Tannoudji, Bernard Diu and Franck Laloë, *Quantum Mechanics*, Vols. I and II, Wiley.
[3] R. Shankar, *Principles of Quantum Mechanics*, Springer.
[4] David J. Griffiths and Darrell F. Schroeter, *Introduction to Quantum Mechanics*, Cambridge University Press.
[5] Eugen Merzbacher, *Quantum Mechanics*, Wiley.
[6] L. I. Schiff, *Quantum Mechanics*, McGraw-Hill.
[7] Albert Messiah, *Quantum Mechanics*, Dover.

Physics - Major 15 Seminar

Seminar Evaluation The Seminar paper shall evaluate the student's ability to understand, organise and orally present a physics topic. The topic may be selected from any area of the undergraduate physics course and need not be restricted to Advanced Quantum Mechanics. The emphasis shall be on clarity of explanation, logical organisation in both the write-up and presentation, and quality of slides or visual material, time management and response to questions during presentation.

Component	Marks
Write-up	10
Presentation	5
Q & A	10
Total	**25**

Physics - Major 16 : Advanced Classical Dynamics (Credits: Theory-05, Tutorials-01) Theory: 75 Lectures

w/o RESEARCH

Variational Principles and Lagrangian Formalism Hamilton's principle for holonomic systems, techniques of calculus of variations: fixed endpoints and natural boundary conditions. Derivation of Lagrange's equations from Hamilton's principle. Extension to constrained systems: Lagrange multipliers and simple non-holonomic constraints. D'Alembert's principle. Advantages of variational formulation over Newtonian approach. Conservation theorems via Noether's theorem: symmetry $\leftrightarrow$ conservation law. Energy function and conservation of energy. Applications to central-force motion, coupled oscillators and charged particle motion. *15 Lectures*

Covariant Electrodynamics and Relativistic Motion Maxwell's equations in covariant form, electromagnetic field tensor, Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion. Field invariants. Covariance of the Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field. *8 Lectures*

Hamiltonian Mechanics and Canonical Methods Legendre transformation, Hamilton's equations, cyclic coordinates and conservation theorem. Routh's procedure for cyclic coordinates. Derivation of Hamilton's equations from variational principle. Principle of least action. Canonical transformations: criteria, generating functions F_1, F_2, F_3, F_4, equations of canonical transformations. Poisson brackets, canonical invariants and Liouville's theorem: incompressibility of phase fluid. *18 Lectures*

Hamilton–Jacobi Theory and Action-Angle Variables Hamilton-Jacobi equation. Hamilton's principal function and characteristic function. Separation of variables. Applications to simple systems such as the harmonic oscillator and central-force motion. Action-angle variables for one-degree-of-freedom systems and extension to completely separable systems. Adiabatic invariants and their physical meaning. *14 Lectures*

Elementary Nonlinear Dynamics and Stability Analysis One-dimensional autonomous flows: fixed points, graphical identification of stable, unstable and half-stable fixed points, linear stability analysis. Elementary bifurcations: saddle-node, transcritical and pitchfork bifurcations.

Two-dimensional autonomous systems: fixed points (critical points), phase plane and phase portraits. Linear systems: uncoupled and coupled systems, identification of stable nodes, unstable nodes, stars (proper nodes), and saddle points from phase portraits, classification of critical points based on the eigenvalues of the system matrix A for the linear system $\dot{x} = A\,x$, complex eigenvalues: centres, stable spirals, and unstable spirals, extension to coupled linear systems. Nonlinear systems: linearisation near critical points, Jacobian matrix and stability analysis using its eigenvalues. Applications to simple mechanical systems such as nonlinear pendulum, damped oscillator and coupled oscillators. *8 Lectures*

Rigid Body Dynamics – Advanced Euler angles: 3-1-3 convention, angular velocity $\boldsymbol{\omega}$ in terms of Euler angles, principal axes and principal moments of inertia. Euler's equations of motion in the body frame. Torque-free motion of asymmetric top: Poinsot construction – qualitative discussion. Symmetric top under gravity: steady precession, slow and fast top, "sleeping top" condition. Applications: gyroscope and gyro-compass. *12 Lectures*

Reference Books

[1] H. Goldstein, C. Poole and J. Safko, *Classical Mechanics*, Pearson.
[2] J. B. Marion and S. T. Thornton, *Classical Dynamics of Particles and Systems*, Brooks/Cole.
[3] N. C. Rana and P. S. Joag, *Classical Mechanics*, Tata McGraw-Hill.
[4] L. D. Landau and E. M. Lifshitz, *Mechanics*, Butterworth-Heinemann.
[5] V. I. Arnold, *Mathematical Methods of Classical Mechanics*, Springer.
[6] W. Rindler, *Relativity: Special, General, and Cosmological*, Oxford University Press.
[7] R. Resnick, *Introduction to Special Relativity*, Wiley.
[8] Steven H. Strogatz, *Nonlinear Dynamics and Chaos*, CRC Press.
[9] G. L. Baker and J. P. Gollub, *Chaotic Dynamics: An Introduction*, Cambridge University Press.
[10] A. J. Lichtenberg and M. A. Lieberman, *Regular and Chaotic Dynamics*, Springer.

Semester VIII

Physics - Major 17 : Advanced Solid State Physics (Credits: Theory-04, Practicals-02) Theory: 60 Lectures

Crystal Structure and Diffraction Review of crystal symmetry and point groups, space lattice and reciprocal lattice, Brillouin zones, Bragg's law, Laue method, equivalence of Bragg and Laue methods, Ewald's construction, X-ray diffraction, powder X-ray diffraction pattern, Debye-Scherrer camera, introduction to neutron diffraction and electron diffraction. *7 Lectures*

Lattice Dynamics Classical and quantum theory of lattice vibration under harmonic approximation. Dispersion relations of 1D lattice: monatomic and diatomic chains, quantisation of lattice vibrations, characteristics of phonon modes, acoustic and optical phonons, long wavelength limits, phonon momentum, inelastic scattering by phonons, anharmonic effects in crystals, thermal expansion and thermal conductivity. *9 Lectures*

Defects in Solids Point defects: vacancies, interstitial atoms, Frenkel and Schottky defects. Line defects: edge dislocation, screw dislocation and Burgers vector. Planar defects: grain boundaries and twin boundaries. Volume defects: voids, precipitates and inclusions. Diffusion in solids: diffusion mechanisms and Fick's law. *6 Lectures*

Free Electron Theory and Transport Phenomena in Solids Drude free-electron theory: assumptions, Drude equation, electrical conductivity, specific heat and thermal conductivity, origin of scattering, Hall effect using Drude model. Sommerfeld free-electron theory: particle in a box, boundary conditions, Fermi velocity, Fermi surface, conductivity expression, electronic specific heat. Boltzmann transport theory: relaxation-time approximation, electrical conductivity. Introductory idea of megneto-resistance.
9 Lectures

Band Theory Failures of the free electron theory. Electrons in periodic potentials, Fourier expansion of crystal potential, central equation, Bloch theorem, Kronig-Penney model, origin of energy bands, dispersion relation, crystal momentum, effective mass. Perturbation theory to free electron wave function and nearly-free-electron approximation, formation of energy band gap at zone boundaries, tight-binding approximation with application to 1D monatomic lattice chain, 2D square, and simple cubic lattices.
12 Lectures

Superconductivity Historical background of superconductors, Meissner effect, Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect, Ginzburg-Landau theory, outlines of BCS theory, Cooper pairing, flux quantisation, Josephson effects, SQUID, high-temperature superconductors and applications of superconductivity. *9 Lectures*

Low dimensional materials Effect of dimensionality in material properties, change in density of states, surface-to-volume ratio, quantum confinement, nano-structures: 2D, 1D, 0D. Graphene: geometry, structures, and properties (in brief). *8 Lectures*

Reference Books

[1] Charles Kittel, *Introduction to Solid State Physics*, 8th ed., Wiley India Pvt. Ltd., 2004.
[2] J. P. Srivastava, *Elements of Solid State Physics*, 2nd ed., Prentice-Hall India, 2006.
[3] Leonid V. Azaroff, *Introduction to Solids*, Tata McGraw-Hill, 2004.
[4] N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Cengage Learning, 1976.
[5] H. Ibach and H. Lüth, *Solid State Physics*, Springer, 2009.

[6] M. Ali Omar, *Elementary Solid State Physics*, Pearson India, 1999.
[7] M. A. Wahab, *Solid State Physics*, Narosa Publications, 2011.
[8] A. J. Dekker, *Solid State Physics*, Macmillan.
[9] H. P. Myers, *Introductory Solid State Physics*, Taylor and Francis.
[10] Steven H. Simon, *The Oxford Solid State Basics*, Oxford University Press.
[11] Stephen Blundell, *Magnetism in Condensed Matter*, Oxford University Press.
[12] F. C. Phillips, *An Introduction to Crystallography*, 3rd ed., Wiley.
[13] A. R. Verma and O. N. Srivastava, *Crystallographic Applications to Solid State Physics*, New Age International.

Physics - Major 17 Lab : Advanced Solid State Physics 60 Lectures

The practicals include numerical simulation based exercises using Python/Scilab/Octave/Matlab or any suitable computational platform. Students should analyse models related to lattice vibrations, magnetic systems, electronic band structure, density of states and energy bands in solids.

Numerically solve the following problems

1. Plot the variation of specific heat of solids with temperature using (a) Dulong–Petit law, (b) Einstein model and (c) Debye model. Compare the predictions of these three models at high and low temperatures.
2. Consider a system of N weakly interacting spin-$\frac{1}{2}$ particles, each having intrinsic magnetic moment μ, placed in an external magnetic field H at temperature T.
   (a) Plot the variation of magnetisation with the dimensionless parameter
   $$x = \frac{\mu H}{k_B T}.$$
   (b) Plot the variation of entropy and specific heat with x, or equivalently with
   $$\frac{k_B T}{\mu H}$$
   .
3. Calculate the effective mass of an electron,
   $$m^* = \hbar^2 \left(\frac{d^2 E}{dk^2}\right)^{-1},$$
   and plot its variation as a function of the wave vector k over the first Brillouin zone for the following dispersion relations:

   a) $E(k) = Ak^2$, b) $E(k) = Ak^2 + Bk^4$,

   c) $E(1 + \alpha E) = Ak^2$, d) $E(k) = \alpha - 2\beta\cos(ka)$.

   Numerical differentiation should be carried out using a finite-difference algorithm, without using any library function for numerical differentiation.

4. Using the free-electron parabolic dispersion relation

$$E(k) = \frac{\hbar^2 k^2}{2m},$$

numerically calculate the density of states (DoS) for one-, two- and three-dimensional systems using the Dirac delta-function definition of DoS given by

$$g(E) = \sum_k \delta\big(E - E(k)\big).$$

Approximate the delta function by Gaussian broadening and plot the DoS as a function of energy.

5. For the delta-function Kronig–Penney model, the dispersion relation is

$$\cos(ka) = \cos(\alpha a) + \frac{P}{\alpha a}\sin(\alpha a), \quad \text{where} \quad \alpha = \sqrt{\frac{2mE}{\hbar^2}}.$$

   (a) Generate a suitable range of electron energy E. Plot the right-hand side of the dispersion relation as a function of E.

   (b) Draw the reference lines $y = 1$ and $y = -1$, and identify the regions corresponding to the allowed energy bands.

6. Consider the lattice vibrations of a one-dimensional diatomic lattice chain. Numerically compute the eigenvalues of the dynamical matrix to obtain the phonon dispersion relation for the acoustic and optical branches. Plot the dispersion curves for both branches, with the wave vector k restricted to the first Brillouin zone.

7. **Band Gap in a One-Dimensional Periodic Potential:** An electron moves in a one-dimensional periodic potential

$$V(x) = V_0 \cos\left(\frac{2\pi}{a}x\right).$$

Applying the variational method, let the trial wavefunction be written as a linear combination of two plane waves,

$$\psi(x) = c_1 e^{ikx} + c_2 e^{i(k-g)x}, \qquad g = \frac{2\pi}{a}.$$

The energy eigenvalues E are obtained from the secular equation

$$\det\begin{vmatrix} \dfrac{\hbar^2 k^2}{2m} - E & \dfrac{V_0}{2} \\ \dfrac{V_0}{2} & \dfrac{\hbar^2 (k-g)^2}{2m} - E \end{vmatrix} = 0.$$

Write a program to compute and plot the dispersion relation $E(k)$ for the lower and upper energy bands across the first Brillouin zone,

$$k \in \left[0, \frac{2\pi}{a}\right], \qquad \text{for} \qquad V_0 = 1.5.$$

   (a) Identify the energy gap at the Brillouin zone boundary, $k = \pi/a$.

   (b) How does the width of this gap change if the potential strength V_0 is doubled?

   (c) Explain the physical significance of the two energy branches at the zone boundary in terms of the electron probability density $|\psi(x)|^2$.

8. **Indexing an X-ray Diffraction Pattern of a Cubic Crystal:** An experimental X-ray diffraction (XRD) study was conducted on a high-purity cubic metallic powder sample using a monochromatic X-ray source of wavelength $\lambda = 1.5406$ Å. The observed diffraction peaks (2θ values) are given in the table below.

Peak No.	2θ (degrees)
1	22.45
2	25.96
3	37.15
4	43.89
5	45.98
6	53.52
7	58.74
8	60.48
9	67.28
10	72.16

Observed diffraction peaks for an unknown cubic crystal.

For a cubic crystal, Bragg's law gives

$$2d \sin\theta = \lambda,$$

and the interplanar spacing is related to the lattice constant a by

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}.$$

Hence,

$$\sin^2\theta = \frac{\lambda^2}{4a^2}\left(h^2 + k^2 + l^2\right).$$

Let

$$S = h^2 + k^2 + l^2.$$

Then

$$\sin^2\theta = \frac{\lambda^2}{4a^2} S.$$

(a) Calculate the values of $\sin^2\theta$ for each of the ten observed diffraction peaks.

(b) Use the ratio method,

$$\frac{\sin^2\theta_i}{\sin^2\theta_1},$$

to match the experimental data with the theoretical sequence

$$S = h^2 + k^2 + l^2.$$

Determine the possible (hkl) indices of the observed peaks.

(c) Perform a linear least-squares regression of $\sin^2\theta$ versus

$$S = h^2 + k^2 + l^2.$$

(d) Determine the lattice constant a from the slope of the regression line.

(e) Calculate the coefficient of determination R^2 to assess the goodness of fit.

(f) Discuss how the use of ten diffraction peaks reduces the impact of experimental uncertainties compared with a two-point calculation.

Physics - Major 18 : Atomic and Molecular Physics
(Credits: Theory-05, Tutorials-01)
Theory: 75 Lectures

One-Electron Atom Hamiltonian and time-independent Schrödinger equation for a hydrogenic atom in spherical polar coordinates. Explicit expression of the radial part of the wavefunction for the ground state and first excited state. Probability density and expectation values of relevant observables. Orbital angular momentum quantum numbers and degeneracy of hydrogenic levels. Parity of wavefunctions and change of parity in electric dipole transitions. *7 Lectures*

Fine and Hyperfine Structure of Hydrogenic Atoms Quantum mechanical treatment of energy corrections due to relativistic correction to the kinetic energy, spin-orbit coupling and Darwin term. Fine-structure splitting of hydrogenic energy levels. Qualitative discussion of selection rules for atomic transitions. *8 Lectures*

Many-Electron Atom Pauli exclusion principle, symmetric and antisymmetric wavefunctions and exchange interaction. L-S coupling: term symbols for non-equivalent and equivalent electrons, Hund's rules and prediction of ground-state electronic configurations. j-j coupling with qualitative comparison with L-S coupling. Electron's magnetic moment and gyromagnetic ratio. *8 Lectures*

Interaction of Atoms with External Electric and Magnetic Fields Quantum mechanical treatment of Larmor precession. Hamiltonian of an atom in external magnetic and electric fields: statement and physical interpretation. Normal Zeeman effect, anomalous Zeeman effect and Paschen-Back effect using quantum mechanical perturbation theory. Perturbing Hamiltonian for a hydrogenic atom in an external electric field. First-order energy correction to the ground state and first excited state. Linear and quadratic Stark effects: qualitative discussion. *8 Lectures*

Microwave Spectroscopy Rotation of molecules: linear molecules, symmetric tops, spherical tops and brief mention of asymmetric tops. Rotational spectra of a rigid diatomic molecule: rotational energy levels, selection rules and intensities of spectral lines. Rotational spectrum of a non-rigid rotator. Spectrum of polyatomic molecules: linear molecules and symmetric top molecules at an introductory level.
8 Lectures

Infrared Spectroscopy Energy of a vibrating diatomic molecule as a harmonic oscillator and anharmonic oscillator, selection rules and intensities of spectral lines. Diatomic vibrating rotator: Born-Oppenheimer approximation, energy levels, selection rules and wavenumber of spectral lines. Interaction of rotation and vibration and limitations of the Born-Oppenheimer approximation. *9 Lectures*

Raman Spectroscopy Qualitative quantum explanation of Raman effect. Classical theory of Raman effect: molecular polarizability. Pure rotational Raman spectra and vibrational Raman spectra.
5 Lectures

Laser Physics Radiative and non-radiative transitions. Absorption, spontaneous emission and stimulated emission. Einstein's A and B coefficients. Metastable states, population inversion, necessary condition for lasing and threshold population inversion. Two-level system and unattainability of population inversion. Three-level and four-level laser systems. Basic components of a laser system: active medium, pumping system and optical resonator. Characteristics of laser light. Ruby laser and He-Ne laser as representative examples. *7 Lectures*

Reference Books

[1] B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules*, Pearson.

[2] Robert Eisberg and Robert Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, Wiley.
[3] David J. Griffiths and Darrell F. Schroeter, *Introduction to Quantum Mechanics*, Cambridge University Press.
[4] Raj Kumar, *Atomic and Molecular Spectra: Laser*, Kedar Nath Ram Nath.
[5] Colin N. Banwell and Elaine M. McCash, *Fundamentals of Molecular Spectroscopy*, McGraw-Hill.
[6] Christopher J. Foot, *Atomic Physics*, Oxford University Press.
[7] H. E. White, *Introduction to Atomic Spectra*, McGraw-Hill.
[8] G. K. Woodgate, *Elementary Atomic Structure*, Oxford University Press.
[9] Gerhard Herzberg, *Molecular Spectra and Molecular Structure I: Spectra of Diatomic Molecules*, Van Nostrand.
[10] Wolfgang Demtröder, *Atoms, Molecules and Photons: An Introduction to Atomic, Molecular and Quantum Physics*, Springer.
[11] A. Yariv, *Quantum Electronics*, Wiley.
[12] K. Thyagarajan and Ajoy Ghatak, *Lasers: Fundamentals and Applications*, Springer.

Physics - Major 19 : Advanced Statistical Mechanics (Credits: Theory-05, Tutorials-01) Theory: 75 Lectures

w/o RESEARCH

Recapitulation of Basic Concepts Thermodynamic limit. Concept of ensemble and ergodicity. Microcanonical ensemble, number of microstates, canonical ensemble and partition function. Grand canonical ensemble, grand potential and its connection with thermodynamics. *7 Lectures*

Density Operator Quantum states, pure states and mixed states. Density operator and statistical average. Trace and time evolution of the density matrix. Expectation value in terms of density matrix. Density matrix in the basis of eigenfunctions of the Hamiltonian. Concept of stationary ensemble in terms of density matrix. Density matrix for microcanonical, canonical and grand canonical ensembles. Applications of density matrix: free particle, N-free-particle system, electron in a magnetic field and free particle in a box. *12 Lectures*

System Composed of Identical Particles Identical particles in classical mechanics. Identical particles in quantum mechanics: exchange degeneracy. Explanation of exchange degeneracy for a system of two spin-$\frac{1}{2}$ particles. Permutation operators for a two-particle system: definition, properties, symmetrizer and antisymmetrizer, transformation of observables by permutation and symmetric observables. Generalisation to arbitrary number of particles: permutation operators, group formation by permutation operators, transpositions and parity of a permutation operator, symmetrizer and antisymmetrizer. Symmetrisation postulate and removal of exchange degeneracy. Construction of physical kets for bosons and fermions. Derivation of Pauli exclusion principle. Many-particle states for a system of identical particles distributed over different single-particle quantum states for bosons and fermions. *14 Lectures*

Quantum Ideal Gas Grand canonical formulation of non-interacting fermions and bosons. Derivation of Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distributions from the grand canonical ensemble. Chemical potential. Classical limit of quantum statistics. Density of states, thermal de Broglie wavelength and criterion for quantum degeneracy. *9 Lectures*

Ideal Bose Gas Bose-Einstein functions. Derivation of equation of state, internal energy and specific heat of ideal Bose gas in the high-temperature limit. Bose-Einstein condensation, critical temperature, condensate fraction and thermodynamic properties below and above the critical temperature. *8 Lectures*

Ideal Fermi Gas Thermodynamic quantities in terms of Fermi-Dirac functions. High-temperature limit of a Fermi gas, namely the highly non-degenerate Fermi gas. Behaviour at finite temperature. Completely degenerate Fermi gas at $T = 0$. Strongly degenerate Fermi gas at low temperature. Fermi energy, Fermi temperature, electronic specific heat and elementary applications to electrons in metals. *9 Lectures*

Photon Gas Photons as a Bose gas with zero chemical potential and no restriction on the conservation of total number of particles. Planck distribution from quantum statistics. Energy density, pressure, entropy and specific heat of black-body radiation using photon statistics. *6 Lectures*

Ising Model Ising Hamiltonian, spontaneous magnetisation, Bragg-Williams approximation, Bethe-Peierls approximation and one-dimensional Ising model. *5 Lectures*

Introductory Ideas of Interacting Systems Need for interactions in real many-particle systems. Mean-field approximation. Qualitative idea of exchange and correlations. Brief mention of phase transitions: Ehrenfest classification of first-order and second-order phase transitions. Examples of first-order and second-order phase transitions. Introductory ideas of order parameter. *5 Lectures*

Reference Books

[1] R. K. Pathria and Paul D. Beale, *Statistical Mechanics*, Academic Press/Elsevier.
[2] Kerson Huang, *Statistical Mechanics*, Wiley.
[3] Charles Kittel and Herbert Kroemer, *Thermal Physics*, W. H. Freeman.
[4] F. Reif, *Fundamentals of Statistical and Thermal Physics*, Waveland Press.
[5] Mehran Kardar, *Statistical Physics of Particles*, Cambridge University Press.
[6] Daniel V. Schroeder, *An Introduction to Thermal Physics*, Oxford University Press.
[7] Donald A. McQuarrie, *Statistical Mechanics*, University Science Books.
[8] L. D. Landau and E. M. Lifshitz, *Statistical Physics, Part 1*, Butterworth-Heinemann.
[9] R. Kubo, *Statistical Mechanics*, North-Holland.
[10] N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Cengage Learning.

MINOR COURSES (PHYSICS)

Semester I (III)

Physics - Minor 1† (3‡) : Mechanics and General Properties of Matter (Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

†Minor 1 for Mathematics (Major) students and

‡Minor 3 for Chemistry (Major) and Computer Science (Major) students

Vector Calculus Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and Curl of a vector field. Del and Laplacian operators. Vector identities.

Vector Integration: Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes' Theorems and their applications (no rigorous proofs).

Orthogonal Curvilinear Coordinates: Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

Fundamentals of Dynamics Reference frames. Inertial frames; Galilean transformations. Review of Newton's Laws of Motion. Projectile motion, Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum, Impulse. Momentum of variable-mass system: motion of rocket. Components of Velocity and Acceleration in plane polar, Cylindrical and Spherical Coordinate Systems.

Laws of physics in rotating coordinate systems, Centrifugal force. Coriolis force and its applications.

Work and Energy Work and Kinetic Energy Theorem. Conservative and non- conservative forces. Potential Energy. Stable and unstable equilibrium. Force as gradient of potential energy. Work done by non-conservative forces. Law of conservation of Energy. Elastic and inelastic collisions. Centre of Mass frame and Laboratory frame.

Rotational Dynamics Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Moment of Inertia, parallel and perpendicular axes theorem, moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.

Gravitation and Central Force Motion Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS). Physiological effects on astronauts.

Elasticity Hook's Law, Relation between Elastic constants. Poisons ratio, Strain energy in a stretched wire, Twisting torque on a Cylinder or Wire.

Fluid Motion Surface Tension: Surface Energy, Phenomena involving surface tension, Angle of Contact, Capillary rise.

Viscosity: Streamline flow, Turbulent motion, Stokes Law, Reynold's Number, Equation of Continuity, Bernoulli's Theorem, Poiseuille's equation for flow of a liquid through a Capillary Tube.

Reference Books

[1] R. Sengupta and H. Chatterjee, A Treatise on General Properties of Matter, New Central Agency.
[2] D.S. Mathur, Elements of Properties of Matter, S. Chand.
[3] R.P. Feynman, R.B. Leighton and M. Sands, The Feynman Lectures in Physics, vol.1, B I Publications.
[4] L. Pachuau and L. Sailo, A Textbook of Properties of Matter, Oscillations and Acoustics, PUC and GSC.

Physics - Minor 1 (3) Lab : Mechanics and General Properties of Matter
60 Lectures

Student should study the measurements of length (or diameter) using Vernier caliper, screw gauge and travelling microscope.

Experiments

1. To determine the height of a building using a Sextant.
2. To study the motion of Spring and calculate (a) Spring constant; (b) Acceleration due to Gravity.
3. To determine the Modulus of Rigidity of material of a cylindrical wire by Statical Method.
4. To determine the Modulus of Rigidity of material of a cylindrical wire by Dynamical Method.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine the Moment of Inertia of a cylindrical/rectangular bar.
7. To determine the value of g and velocity for a freely falling body using Digital Timing Technique.
8. To determine the Coefficient of Viscosity of a viscous liquid using Stokes' Law.
9. To determine Coefficient of Viscosity of water by Poiseuille's flow Method.
10. To determine the Young's Modulus of a Bar by Flexure Method.
11. To determine the Young's Modulus of a Wire by Optical Lever Method.
12. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
13. To determine the Young's Modulus of a wire by Searle's method.
14. To determine the value of g using Bar Pendulum.
15. To determine the value of g using Kater's Pendulum.

Reference Books

[1] B.L. Flint and H.T. Worsnop, Advanced Practical Physics for Students, Asia Publishing House, 1971.
[2] Michael Nelson and Jon M. Ogborn, Advanced Level Physics Practicals (4ed), Heinemann, 1985.
[3] I. Prakash and Ramakrishna, A Text Book of Practical Physics (11ed), Kitab Mahal, 2011.
[4] G.L. Squires, Practical Physics (4ed), Cambridge, 2015.

Semester II (IV)

Physics - Minor 2† (4‡) : Electricity and Magnetism
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

†Minor 2 for Mathematics (Major) students and
‡Minor 4 for Chemistry (Major) and Computer Science (Major) students

Electric Field and Electric Potential Coulomb's Law, Electric field: Electric field lines. Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Conservative nature of Electrostatic Field and Potential. Potential energy of system of charges, Electrostatic energy of a charged sphere, Laplace's and Poisson equations. The Uniqueness Theorem. Electrostatic force on a charged particle. Electric dipole, Electric Potential and Field due to a dipole. Force, torque on a dipole, potential energy of a dipole.

Electric field in Conductor and Dielectric material Electric Field in conductor, Dielectric Polarisation ($\vec{P}$), Polarisation Charges. Electrical Susceptibility and Dielectric Constant. Displacement vector ($\vec{D}$). Relations between $\vec{E}$, $\vec{P}$ and $\vec{D}$. Gauss' Law in dielectrics.

Capacitance Capacitance of a conductor, Charging, discharging of a capacitor, Capacitance of parallel plate, spherical, cylindrical capacitor, combination of capacitors.

Magnetic Field Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to straight wire, Solenoid and Toroid. Properties of $\vec{B}$: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire. Torque on a current loop in a uniform Magnetic Field.

Magnetic Properties of Matter Magnetisation vector ($\vec{M}$). Magnetic Intensity ($\vec{H}$). Magnetic Susceptibility and Permeability. Relation between $\vec{B}$, $\vec{H}$ and $\vec{M}$. Dia-, Para- and Ferromagnetism. B-H curve and hysteresis.

Electromagnetic Induction Faraday's Law. Lenz's Law. Motional emf, eddy current, Self-Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field.

Electrical Circuits DC Circuits: Transient phenomena, growth and decay of currents in LR, CR and LCR circuits. AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit. LC oscillations, transformer.

Network theorems Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin's theorem, Norton's theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits.

Reference Books

[1] H.K. Malik and A.K. Singh, Engineering Physics, McGraw Hill, 2018.
[2] D.J. Griffiths, Introduction to Electrodynamics (3ed), Prentice-Hall, 2002.
[3] E. M. Purcell, Electricity and Magnetism: Berkeley Physics Course vol. 2, McGraw Hill, 2017.
[4] D.C. Tayal, Electricity and Magnetism (4ed), Himalaya Publishing, 2019.
[5] D. Chattopadhyay and P.C. Rakshit, Electricity and Magnetism, Central Book Agency, 2005.

Physics - Minor 2 (4) Lab : Electricity and Magnetism
60 Lectures

Student should study the use a Multimeter for measuring (a) Resistances; (b) AC and DC Voltages; (c) Direct Current; (d) Capacitances; and (e) Checking electrical fuses.

Experiments

1. To determine an unknown Low Resistance using Potentiometer/fall of potential method.
2. To determine an unknown Resistance using Carey Foster's Bridge.
3. To compare capacitances using De'Sauty's bridge.
4. Measurement of field strength B and its variation in a solenoid (determine dB/dx).
5. To verify the Thevenin's and Norton's theorems.
6. To verify the Superposition, and Maximum power transfer theorems.
7. To determine self inductance of a coil by Anderson's bridge.
8. To study the ac characteristics of a series CR Circuit.
9. To study the ac characteristics of a series LR Circuit.
10. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency; (b) Impedance at resonance (c) Quality factor Q and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti resonance frequency; and (b) Quality factor Q.
12. To determine self-inductance of a coil by Rayleigh's method.
13. To determine the self-inductance of two coils separately by using Anderson's Bridge and the total equivalent inductance when they are connected in series and hence estimate the coefficient of coupling between the two coils.
14. To determine the horizontal component of the Earth's magnetic field and the magnetic moment of a magnet using a deflection and oscillation magnetometer.

Reference Books

[1] D. Chattopadhyay and P.C. Rakshit, Electricity and Magnetism, Central Book Agency, 2005.
[2] B. Ghosh, K.G. Mazumdar, Advanced Practical Physics, vol. 1, Sreedhar Publications, 2013.

Semester VII (VIII)

Physics - Minor 5† (6‡) : Electronics
(Credits: Theory-04, Practicals-02)
Theory: 60 Lectures

†Minor 5 for Mathematics (Major) students and

‡Minor 6 for Chemistry (Major) and Computer Science (Major) students

Analog Electronics

Semiconductor Diodes p-type and n-type semiconductors, energy-level diagram of semiconductors, conductivity and mobility, concept of drift and diffusion currents, barrier formation in a p-n junction diode, static and dynamic resistance, current-flow mechanism in forward- and reverse-biased diodes.

Two-Terminal Devices and Their Applications Rectifier diode: half-wave rectifier, centre-tapped and bridge full-wave rectifiers, calculation of ripple factor and rectification efficiency. Zener diode and voltage regulation.

Bipolar Junction Transistors n-p-n and p-n-p transistors, characteristics of CB, CE and CC configurations, current gains α and β, relation between α and β, load-line analysis of transistors, DC load line and Q-point, physical mechanism of current flow, active, cut-off and saturation regions, transistor biasing and stabilisation circuits, fixed bias and voltage-divider bias.

Operational Amplifiers Operational amplifier using black-box approach. Characteristics of ideal and practical operational amplifiers, IC 741, open-loop and closed-loop gain, frequency response, CMRR, slew rate and concept of virtual ground.

Applications of Operational Amplifiers Inverting and non-inverting amplifiers, adder, subtractor, differentiator and integrator.

Digital Electronics

Boolean Algebra and Digital Circuits Decimal-to-binary and binary-to-decimal conversion, BCD, octal and hexadecimal number systems. AND, OR and NOT gates and their realisation using diodes and transistors. NAND and NOR gates as universal gates. XOR and XNOR gates. De Morgan's theorems, Boolean laws and simplification of logic circuits using Boolean algebra.

Data Processing Circuits Basic idea of multiplexers, demultiplexers, decoders and encoders.

Arithmetic Circuits Binary addition, binary subtraction using 2's complement, half adder, full adder, half subtractor, full subtractor and 4-bit binary adder/subtractor.

Sequential Circuits SR, D and JK flip-flops. Clocked, level-triggered and edge-triggered flip-flops. Preset and clear operations. Race-around condition in JK flip-flop. Master-slave JK flip-flop. Serial-in-parallel-out shift registers up to 4 bits. 4-bit ripple counter.

Reference Books

[1] J. Millman and C. C. Halkias, *Integrated Electronics*, Tata McGraw-Hill, 1991.
[2] J. D. Ryder, *Electronics: Fundamentals and Applications*, Prentice-Hall, 2004.
[3] B. G. Streetman and S. K. Banerjee, *Solid State Electronic Devices*, 6th ed., PHI Learning, 2009.
[4] S. Salivahanan and N. S. Kumar, *Electronic Devices and Circuits*, 3rd ed., Tata McGraw-Hill, 2012.
[5] A. S. Sedra, K. C. Smith and A. N. Chandorkar, *Microelectronic Circuits*, 6th ed., Oxford University Press, 2014.

[6] A. P. Malvino, D. P. Leach and G. Saha, *Digital Principles and Applications*, 7th ed., Tata McGraw-Hill, 2011.
[7] Anand Kumar, *Fundamentals of Digital Circuits*, PHI Learning, 2009.
[8] T. L. Floyd, *Digital Fundamentals*, Pearson.
[9] R. J. Tocci and N. S. Widmer, *Digital Systems: Principles and Applications*, PHI Learning, 2001.
[10] G. K. Kharate, *Digital Electronics*, Oxford University Press, 2010.
[11] S. P. Vingron, *Logic Circuit Design*, Springer, 2012.
[12] Subrata Ghoshal, *Digital Electronics*, Cengage Learning, 2012.

Physics - Minor 5 (6) Lab : Electronics
60 Lectures

Experiments

1. To study the V-I characteristics of a p-n junction diode.
2. To study the V-I characteristics of a Zener diode and its use as a voltage regulator.
3. To study the characteristics of a bipolar junction transistor in CE configuration.
4. To design an inverting amplifier using op-amp 741/351 for a DC voltage of given gain.
5. To design a non-inverting amplifier using op-amp 741/351 for a DC voltage of given gain.
6. To add two DC voltages using an op-amp in inverting and non-inverting modes.
7. To design a precision differential amplifier of given input-output specification using an op-amp.
8. To investigate the use of an op-amp as an integrator.
9. To investigate the use of an op-amp as a differentiator.
10. To design a switch, or NOT gate, using a transistor.
11. To verify and design AND, OR, NOT and XOR gates using NAND gates.
12. To design a combinational logic system for a specified truth table.
13. To convert a Boolean expression into a logic circuit and design it using logic-gate ICs.
14. To minimise a given logic circuit.
15. To study half adder, full adder and 4-bit binary adder.
16. To study half subtractor, full subtractor and adder-subtractor using full-adder IC.
17. To build flip-flop circuits, namely RS, clocked RS, D-type and JK flip-flops, using NAND gates.
18. To build JK master-slave flip-flop using flip-flop ICs.

Reference Books

[1] D. Chattopadhyay and P.C. Rakshit, Electricity and Magnetism, Central Book Agency, 2005.
[2] B. Ghosh, K.G. Mazumdar, Advanced Practical Physics, vol. 1, Sreedhar Publications, 2013.

SKILL ENHANCEMENT COURSE (PHYSICS)

Semester I

Physics - SEC 1 : Computational Physics 1
(Credits: 03)
Lab: 60 Lectures

Report Writing and Presentation Tools

Getting Started with Python Introduction to programming, constants, variables and data types, dynamical typing, operators and expressions, modules, I/O statements, iterables, compound statements, indentation in python, the if-elif-else block, for and while loops, nested compound statements, lists, set, tuples, classes, dictionaries and strings, basic ideas of object oriented programming.

NumPy Arrays; Indexing; Iterating. Creating Arrays : array(), arange(), linspace(), zeros(). Basic Operations : Add, Subtract, Multiply, Divide, and Exponentiation. Vector/Linear Algebra.

MatPlotLib and PyPlot 2D Plot; Interactive Plotting; Plot method; Labels; Log and Polar Plots; Multiple Figures and Curves; Subplots;

Interpolation and Curve Fitting Interpolation Schemes : Nearest Neighbor; Linear; Quadratic; Spline. Least-Squares Fit: Linear and Polynomial.

Roots of equations Real roots of single variable function; iterative approach; qualitative behavior of the function; Closed domain methods (bracketing): Bisection; False position method; Open domain methods: Newton-Raphson, Secant method; Roots of polynomials; Roots of non-linear equations.

Reference Books

[1] Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers (8ed), McGraw-Hill.
[2] Rubin H. Landau, Manuel J. Páez and Cristian C. Bordeianu, Computational Physics: Problem Solving with Python (3ed), Wiley.
[3] Alex Gezerlis, Numerical Methods in Physics with Python, Cambridge.
[4] Jaan Kiusalaas, Numerical methods in engineering with Python 3, Cambridge.

Semester II

Physics - SEC 2 : Computational Physics 2
(Credits: 03)
Lab: 60 Lectures

Linear algebra Matrix Factorizations: QR Factorization; Gram-Schmidt Orthogonalization; Householder Triangularization; LU and Cholesky factorization; Schur factorization; Direct elimination methods: Gauss elimination (pivoting, scaling); Tri-diagonal systems; Iterative methods: Jacobi iteration; Conjugate Gradients; Eigenvalue problems: Rayleigh Quotient; Arnoldi and Lanczos methods.

Monte Carlo Simulation Random Sequences; Random-Number Generation; Examples : Value of π, Random Walk, Spontaneous Decay.

Differentiation Forward Difference; Central Difference; Backward Difference; Extrapolated Difference; Second Derivatives.

Integration Quadrature as Box Counting; Trapezoid Rule; Simpson's Rule; Gaussian Quadrature; One and Multidimensional Monte Carlo Integration.

Ordinary Differential Equations Initial-Value Problems : Euler's Method; 2^{nd} and 4^{th} Order Runge-Kutta Methods; Simultaneous Differential Equations. Boundary-Value Problems : Shooting Method; Matrix Approach.

Reference Books

[1] Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers (8ed), McGraw-Hill.
[2] Rubin H. Landau, Manuel J. Páez and Cristian C. Bordeianu, Computational Physics: Problem Solving with Python (3ed), Wiley.
[3] Alex Gezerlis, Numerical Methods in Physics with Python, Cambridge.
[4] Jaan Kiusalaas, Numerical methods in engineering with Python 3, Cambridge.

Semester III

Physics - SEC 3 : Computational Physics 3
(Credits: 03)

Each student has to complete a numerical project which gives the student exposure to computer simulation. The student has to submit a report based on his/her studies on the specific topic during the entire semester. It will develop the ability of scientific writing among the students.

The evaluation of the student for this paper will be based on the following criteria:

- 5 marks : Overall attendance.
- 10 marks : Internal assessment based on performance like sincerity, regularity, quality of work done etc.
- 20 marks : Written project report.
- 15 marks : Presentation / viva voce as will be suitable for evaluation (decided by the college).

MULTIDISCIPLINARY COURSE (PHYSICS)

Semester I

Physics - MDC : Physics I
(Credits: 03)
Theory: 45 Lectures

Module 1: Physical World and Measurement Introduction to physics; nature of physical laws, need for measurement; units of measurement; systems of units; fundamental and derived units; dimension analyses; order of magnitudes of physical quantities; structure of the macroscopic and microscopic world.

Module 2: Scalars and Vectors Scalar and vector quantity; general vectors and notation; position and displacement vectors; equality of vectors; addition and subtraction of vectors; unit vector; rectangular components; scalar and vector product and their significance.

Module 3: Kinematics Frame of reference; Rest and motion; distance and displacement; average speed and instantaneous speed; average and instantaneous velocity; average and instantaneous accelerations; motion in straight line; projectile motion; uniform circular motion.

Module 4: Laws of motion Intuitive concepts of force; discussion and fundamental forces; inertia; newton's laws of motion; Pseudo forces; Friction (Qualitative discussion).

Module 5: Work, Energy and Power Kinetic energy; work done; work energy theorem; potential energy; gravitational and elastic potential energy; Conservation of mechanical energy.

Module 6: Gravitation Kepler's laws of planetary motion; the universal law of gravitation; acceleration due to gravity and its variation with altitude, depth and rotation of earth; escape velocity (qualitative discussion); orbital velocity of satellites.

Module 7: Properties of Bulk Matter Elastic behaviour; stress-strain relationship; Hook's law; Young modulus; bulk modulus.

Pressure due to a fluid column; Pascal's law and its applications.

Viscosity; coefficient of viscosity; Stokes' law, terminal velocity; streamline and turbulent motion; critical velocity and Reynold's number.

Surface energy and surface tension; angle of contact; excess pressure; applications of surface tension: liquid drops, bubbles and capillary rise.

Heat and temperature; principle of calorimetry; heat transfer- conduction, convection and radiation.

Module 8: Current Electricity Electric current; flow of electric charge in a conductor; drift velocity; Ohm's law; electrical resistance; Series and parallel combination of resistances; temperature dependence of resistance.

V-I characteristics; electrical energy and power; electrical resistivity and conductivity; EMF of a cell; AC and DC (qualitative discussion).

Module 9: Semiconductor Energy bands in conductor, semiconductor and insulators; types of semiconductors; I-V characteristics of p-n junction diode.

Semester III

Physics - MDC : Physics II
(Credits: 03)
Theory: 45 Lectures

Module 1: Electric Charges and Fields Electric Charges. Conservation of charge. Coulomb's law-force between two point charges. Forces between multiple charges. Superposition principle. Continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Module 2: Electrostatic Potential and Capacitance Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges. Equipotential surfaces, electrical potential energy of a system of two point charges and of electric dipole in an electrostatic field. Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarisation, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor.

Module 3: Current Electricity Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current. Ohm's law, electrical resistance, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity. Carbon resistors, colour code for carbon resistors; series and parallel combinations of resistors; temperature dependence of resistance. Internal resistance of a cell, potential difference and EMF of a cell, combination of cells in series and in parallel. Kirchhoff's laws and simple applications. Wheatstone bridge, metre bridge. Potentiometer: Principle and its applications to measure potential difference and for comparing EMF of two cells, Measurement of internal resistance of a cell.

Module 4: Moving Charges and Magnetism Concept of magnetic field: Oersted's experiment. Biot - Savart law and its application to current carrying circular loop. Ampere's law and its applications to infinitely long straight wire. Straight and toroidal solenoids. Force on a moving charge in uniform magnetic and electric fields. Cyclotron. Force on a current-carrying conductor in a uniform magnetic field. Force between two parallel current-carrying conductors-definition of ampere. Torque experienced by a current loop in uniform magnetic field; moving coil galvanometer-its current sensitivity and conversion to ammeter and voltmeter.

Module 5: Magnetism and Matter Current loop as a magnetic dipole and its magnetic dipole moment. Magnetic dipole moment of a revolving electron. Magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis. Torque on a magnetic dipole (bar magnet) in a uniform magnetic field. Bar magnet as an equivalent solenoid. Magnetic field lines. Earth's magnetic field. Magnetic elements. Para-, dia- and ferro - magnetic substances, with examples. Electromagnets and factors affecting their strengths. Permanent magnets.

Semester V

Physics - MDC : Physics III
(Credits: 03)
Theory: 45 Lectures

Module 1: Optics Reflection of light, spherical mirrors, mirror formula. Refraction of light, total internal reflection and its applications, optical fibres, refraction at spherical surfaces, lenses, thin lens formula, lens-maker's formula. Magnification, power of a lens, combination of thin lenses in contact combination of a lens and a mirror. Refraction and dispersion of light through a prism.

Scattering of light – blue colour of the sky and reddish appearance of the sun at sunrise and sunset. Optical instruments: Human eye, image formation and accommodation, correction of eye defects (myopia and hypermetropia) using lenses. Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

Wave optics: Wavefront and Huygens' principle, reflection and refraction of plane wave at a plane surface using wavefronts. Proof of laws of reflection and refraction using Huygens' principle. Interference, Young's double hole experiment and expression for fringe width, coherent sources and sustained interference of light. Diffraction due to a single slit, width of central maximum. Resolving power of microscopes and astronomical telescopes. Polarisation, plane polarised light; Brewster's law, uses of plane polarised light and Polaroids.

Module 2: Dual Nature of Matter and Radiation Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation – particle nature of light. Matter waves – wave nature of particles, de Broglie relation. Davisson-Germer experiment (experimental details should be omitted; only conclusion should be explained.)

Module 3: Atoms and Nuclei Alpha - particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum. Composition and size of nucleus, atomic masses, isotopes, isobars; isotones. Radioactivity – alpha, beta and gamma particles/rays and their properties; radioactive decay law. Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission and fusion.

Module 4: Electronic Devices Energy bands in solids (qualitative ideas only), conductors, insulators and semiconductors; semiconductor diode – I-V characteristics in forward and reverse bias, diode as a rectifier; I-V characteristics of LED, photodiode, solar cell, and Zener diode; Zener diode as a voltage regulator. Junction transistor, transistor action, characteristics of a transistor; transistor as an amplifier (common emitter configuration) and oscillator. Logic gates (OR, AND, NOT, NAND and NOR). Transistor as a switch.

Reference Books

[1] H.C. Verma, Concept of Physics, vol. 1 & 2, Bharati Bhawan.
[2] David Halliday, Robert Resnick and Kenneth S. Krane, Physics, vol. 1 & 2, Wiley.

INTERNSHIP

The students of physics department will participate in an internship at the end of the second semester. They can opt any of the following field of study as their internship and submit a written report for overall evaluation.

1. Research activities at the department.
2. Academic visit to renowned research/academic institutes.
3. Work as intern in different central, state govt and private farms (Railway, Electricity board, local automobile workshop etc.).
4. Being part of NSS activities.
5. College may also decide/arrange topics of interest apart from the above.