Subject: Physics
Semester: Four
Course Name: Classical Mechanics
Existing Base Syllabus: Mechanics of semester I
Course Level: PHY251
Syllabus showing each unit against class number and marks

Unit no.	Unit content	No. of classes	Marks/Credit
Unit I: Mechanics of point particles- the Lagrangian approach	Review of Newtonian mechanics; system of particles; constrained motion – types of constraints; concept of degrees of freedom; generalised coordinates and velocities; principle of virtual work and D'Alembert's principle and associated problems; Lagrange's (Euler-Lagrange, EL) equation; physical problems (construction of EL equations only) – simple and compound pendulums, two vibrating particles of equal mass attached to springs, Lagrange's equations for a particle in spherical and cylindrical coordinate systems, falling body in uniform gravitational field.	14	Credit - 4
Unit– II: Mechanics of point particles – the Hamiltonian approach	Generalised momenta; Legendre transformation; Hamilton's canonical equations; Hamiltonian from the Lagrangian; conservation of energy and momentum; physical problems – Hamiltonian for simple pendulum, particle moving in central force field (gravitational potential).	6	
Unit –III: Small oscillation	Minimum of potential energy and concept of stable equilibrium; expansion of potential energy around a minimum; kinetic and potential energy matrices; equation of motion of small oscillation.	5	
Unit–IV: Special theory of relativity	Inadequacy of Galilean transformation; postulates of special relativity; Lorentz transformation; simultaneity and order of events; length contraction and time dilation; relativistic addition of velocities; variation of mass with velocity and mass-energy equivalence. Lorentz transformation as a rotation in spacetime; relation between proper time and coordinate time; relativistic kinematics: energy-momentum relation.	15	

Unit–V: Fluid dynamics	Definition of a fluid; idea fluids; density and pressure of a fluid; velocity of a fluid element and its time derivative; mass conservation and equation of continuity; incompressible fluid; Euler's equation of fluid dynamics; Navier-Stokes equation (introduction only).	5	

Reading list

(1) Classical Mechanics, H. Goldstein, C.P. Poole and J.L. Safko (Pearson Education)
(2) Theoretical Mechanics, M. R. Spiegel (McGraw Hill Book Company)
(3) Classical Mechanics, P.S. Joag and N.C Rana (McGraw Hill Book Company)
(4) Mathematical Physics, B. S. Rajput (Pragati Prakashan)
(5) Classical Mechanics, T.W.B. Kibble and F.H. Berkshire (Imperial College Press)
(6) Mechanics: Courses in Theoretical Physics (Vol. 1), L.D. Landau and E.M. Lifshitz (Butterworth-Heinemann) (3rd Edn.)
(7) Classical Mechanics: With introduction to non-linear oscillations and chaos, V.B. Bhatia (Narosa Publishing House)

Graduate Attributes

i. Course Objective

The basic objectives of the course are

- *to introduce the laws of classical dynamics*
- *to train students in solving problems of motion of particles, systems of particles and fluids and*
- *to introduce relativity and hence the idea of how space and time play role in dynamics of matter.*

ii. Learning outcome

On successful completion of the course students will be able to apply the laws of classical dynamics to physical problems of motion of particles, systems of particles and fluids in various fields of physics and natural science as a whole. They will also get the exposure of the idea of how space and time play role in dynamics of matter.

Theory Credit: 04 (Four)

Practical Credit: 0 (Zero)

No. of Required Classes: 60 (45 Theory; 15 Tutorials)

No. of Contact Classes: 60

No. of Non-Contact Classes:

Particulars of Course Designer (Name, Institution, email id):

1) **Dr. Sanjeev Kalita,** Gauhati University, sanjeev@gauhati.ac.in
2) **Dr. Samrat Dey,** Pragjyotish College, samratdgr8@gmail.com
3) **Dr. Mausumi Bhuyan,** Rangiya College, moubhuyan83@gmail.com

Subject: Physics
Semester: Four
Course Name: Quantum Mechanics I
Existing Base Syllabus: HS Maths and Physics
Course Level: PHY252
Syllabus showing each unit against class number and marks

Unit no.	Unit content	No. of classes	Marks/Credit
Theory			
Unit I: Origin of Quantum Theory	Failure of classical theories, Explanation of Black body radiation, Photoelectric effect, Compton effect, different evidences in support of quantum theory, particle nature of radiation, Bohr's correspondence principle.	3	Credit - 3
Unit– II: Dynamical Variables as Operators and Uncertainty Principle	Dynamical variables as operators, definition of an operator, different types of operators and their properties, position, energy and momentum operator; commutation relations; introduction to Hilbert space, Dirac notation, eigenvalue and eigenfunctions; expectation value of an operator e.g. position, momentum operator etc, orthonormality condition, Ehrenfest's theorem. Simultaneous measurement and uncertainty principle; general statement of Heisenberg's uncertainty principle(for any two non commutating operators), different uncertainty relations involving canonical pair of variables; particle trajectory and fuzziness, applications of the position momentum uncertainty principle, application of energy time uncertainty principle to virtual particles and range of an interaction.	10	
Unit –III: Matter Wave and Wave-Particle Duality	Wave particle duality and de Broglie wavelength, particle as a wave or matter wave, wave description of particles by wave packets; phase and group velocity, wave function, wave amplitude, probability; Experimental verification of matter wave, Davisson and Germer experiment; linearity and superposition principle, two slit experiments with electrons and photons; Uncertainty	8	

	principle from wave packet description, Gaussian wave packet and its wave function.		
Unit–IV: Schrödinger Equation and it's applications	Time dependent Schrödinger Equation, Time independent Schrödinger Equation; Physical interpretation and properties of wave function, continuity of a wave function, boundary conditions and emergence of discrete and continuous energy levels; probabilities and normalisation in three and one dimension; equation of continuity, current density in both three and one dimension. Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigenfunctions; General solution of the time dependent Schrödinger equation in terms of linear combinations of stationary states, discrete and continuous spectrum, wave function of a free particle, spread of Gaussian wave function in one dimension, Fourier transforms and momentum space wave function. Applications of Time independent Schrödinger Equation in different problems like : (i) particle in a one dimensional infinite potential well (quantum dot as an example) (ii) particle in a one dimensional finite square potential well (iii) barrier penetration problems – potential step and rectangular potential barrier (tunnel effect) (iv) linear harmonic oscillator (v) spherically symmetric potential for hydrogen atom- radial solution, spherical harmonics, angular momentum operator and different quantum numbers, radial distribution function and shapes of the probability densities for ground & first excited states; degeneracy of states : s, p, d states.	24	
Laboratory			
	<u>**At least four from the following:**</u> 1. Measurement of Planck's constant using black body radiation and photo-detector.		Credit-1

	2. Photo-electric effect: Photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light. 3. To determine work function of material of filament of directly heated vacuum diode. 4. To determine the Planck's constant using LEDs of at least 4 different colours. 5. To determine the wavelength of H_α emission line of hydrogen atom. 6. To determine the ionisation potential of mercury. 7. To determine the absorption lines in the rotational spectrum of iodine vapour. 8. To determine the value of e/m by (a) magnetic focusing or (b) bar magnet. 9. To setup the Millikan's oil drop apparatus and determine the charge of an electron. 10. To show the tunnelling effect in tunnel diode using I-V characteristics. 11. To determine the wavelength of laser source using diffraction from single slit. 12. To determine the wavelength of laser source using diffraction from double slits. 13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating.		

Reading list

1. N. Zettili, Quantum Mechanics, John Wiley & Sons (2001).
2. J. J. Sakurai and J. Napolitano, Modern Quantum Mechanics, Cambridge Univ. Press, 2020.
3. Y. R.Waghmare, Fundamentals of Quantum Mechanics, Wheeler publishing (2014).

4. P. A. M. Dirac, Principles of Quantum Mechanics, Oxford University Press (1981).
5. B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson Education 2nd Ed. (2004).
6. K. Gottfried and T-M Yan, Quantum Mechanics: Fundamentals,2nd Ed., Springer (2003).
7. R. Shankar, Principles of Quantum Mechanics, Springer (India) (2008).
8. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson Education (2005).
9. L. Schiff, Quantum Mechanics, Mcgraw-Hill (1968).
10. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2002).
11. A. Bieser, Concepts of Modern Physics, McGraw Hill (2002).
12. Arno Bohm, Quantum Mechanics: Foundations and Applications, 3rd Edition, Springer (1993).
13. H. C. Verma, Quantum Mechanics, TBS publications (2019).
14. P M Mathews and K. Venkatesan, A Text book of Quantum Mechanics, 2nd Edition, McGraw Hill (2010).

Graduate Attributes

i. Course Objective

- *To learn about the inadequacies of classical mechanics, the origin and need of quantum mechanics, historical developments in quantum mechanics.*
- *Dual nature of radiation & matter, description of matter wave through wave packet.*
- *Probabilistic nature and wave function, Schrödinger equation, the uncertainty principle, stationary and non-stationary states.*
- *Applications of Schrödinger equation in different cases like infinite and finite potential well, tunneling effect, linear harmonic oscillator and H-atom.*
- *Formulation of quantum mechanics in terms of operators.*

ii. Learning outcome

On successful completion of the course students will be able to learn physical and mathematical fundamentals of Quantum physics, and various topics in it. These concepts are used in various branches of physics, like condensed matter physics, lasers, quantum statistics, atomic and molecular physics, particle physics, astrophysics and optics etc.

Theory Credit: 03 (Three)

Practical Credit: 01 (One)

No. of Required Classes: 45

No. of Contact Classes: 45

No. of Non-Contact Classes:

Particulars of Course Designer (Name, Institution, email id):

1) **Prof Kalpana Bora,** Gauhati University**,** kalpana@gauhati.ac.in
2) **Dr. Bhaskar Jyoti Hazarika,** Pandu College, bh53033@gmail.com
3) **Dr Arup Jyoti Choudhury,** Guwahati College, arupjchoudhury@gmail.com

Subject: Physics
Semester: Four

Course Name: Analog Electronics
Existing Base Syllabus: HS Physics
Course Level: PHY253
Syllabus showing each unit against class number and marks

Unit no.	Unit content	No. of classes	Marks/Credit
Theory			
Unit I: Semiconductor Diodes	P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width, and Current for Step Junction.	7	Credit - 3
Unit II: Two-terminal Devices and their Applications	Rectifier Diode: Half- wave Rectifiers. Centre-tapped and Bridge type Full-wave Rectifiers. Calculation of Ripple Factor and Rectification Efficiency. C-filter. Zener Diode and Voltage Regulation. Power supply without filter circuit and with C-filter circuit. Principle LEDs, Photodiode, and Solar Cell (Basic concept).	5	
Unit III: 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, Cut-off, and Saturation Regions.	5	
Unit IV: Amplifiers	Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as a 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. Classification of Class A, B & C Amplifiers. Differential amplifiers.	7	
Unit V: Coupled Amplifier	Two-stage RC-coupled amplifier and its frequency response.	2	

Unit VI: Feedback in Amplifiers	Effects of Positive and Negative Feedback on Input Impedance. Output Impedance. Gain. Stability. Distortion and Noise	4	
Unit VII: Sinusoidal Oscillators	Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator. Determination of Frequency. Colpitt's oscillator.	5	
Unit VIII: 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.	3	
Unit IX: Applications of Op-Amps	Inverting and non-inverting amplifiers. Adder. Subtractor. Differentiator. Integrator. Log and Anti Log amplifier. Zero crossing detector. Wein bridge oscillator. Comparator.	4	
Unit X: Introduction to CRO (Lectures 03)	Block Diagram of CRO. Electron Gun, Deflection System, and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.	3	
Laboratory			
	<u>At least four from the following:</u> 1. To study V-I characteristics of PN junction diode, and light emitting diode. 2. To study the V-I characteristics of a Zener diode and its use as a voltage regulator. 3. Study of V-I and power curves of solar cells, and find maximum power point and efficiency. 4. To study the characteristics of a Bipolar Junction Transistor in CE configuration. 5. To study the various biasing configurations of BJT for normal Class A operation. 6. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.		Credit-1

	7. To study the frequency response of voltage gain of an RC-coupled transistor amplifier. 8. Using an Op-amp, design a Wien bridge oscillator for a given frequency. 9. To design a phase shift oscillator of given specifications using BJT. 10. To design and study Colpitt's oscillator. 11. To design an inverting amplifier using Op-amp for the DC voltage of a given gain. 12. To design inverting amplifier using Op-amp and study its frequency response. 13. To design a non-inverting amplifier using Op-amp and study its frequency response. 14. To study the zero-crossing detector and comparator. 15. To add two DC voltages using Op-amp in inverting and non-inverting modes. 16. To design a precision Differential amplifier of given I/O specification using Op-amp. 17. To investigate the use of an Op-amp as an Integrator. 18. To investigate the use of an Op-amp as a Differentiator. 19. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO. Construct a series LR circuit. Display the two waveforms on the CRO and measure the phase differences between the voltages across R and L. 20. To test a Diode and Transistor using a Multimeter. Draw the forward bias characteristic of the diode. Using only the base-emitter junction of the transistor draw a characteristic curve and show that it behaves as a forward-biased diode.		

	Note: All students will have to do an electronic project on the circuits, for example, the power supply, the AM detector, etc. to get acquainted.		

Reading list

1. Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall.
3. Solid State Electronic Devices, B. G. Streetman & S. K. Banerjee, 6th Edn.,2009, PHI Learning
4. Electronic Devices & circuits, S. Salivahanan & N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
5. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
6. Microelectronic circuits, A. S. Sedra, K.C. Smith, A. N. Chandorkar, 2014, 6th Edn., Oxford University Press.
7. Electronic circuits: Handbook of design & applications, U. Tietze, C. Schenk,2008, Springer
8. Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd Ed., 2002, Wiley India
9. Microelectronic Circuits, M. H. Rashid, 2nd Edition, Cengage Learning
10. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India
11. Electronics Fundamentals and Applications, D. Chattopadhyay and P. C. Rakshit, 17^{th} Ed, 2023, New Age International Publishers

Graduate Attributes

i. Course Objective

- To introduce students to analog electronics with hands-on practice on implementing some of these in hardware.
- To make the students understand the physics of semiconductor p-n junction and application in devices like diodes, rectifiers, etc.
- To understand the working of bipolar junction transistors, biasing, stabilization circuits, and various applications like amplifiers, oscillators, etc. together with feedback.
- To know the basics of Operational Amplifiers and applications.

- To understand the basics of the use of CRO in measurements with hands-on experience with some applications

ii. Learning outcome

On successful completion of the course, students will be able to understand the physics of semiconductor p-n junction and devices such as rectifier diodes, Zener diode, photodiode, etc.; they will understand the basics of bipolar junction transistors, transistor biasing, and stabilization circuits; the concept of feedback in amplifiers and the oscillator circuits. Students will also have an understanding of operational amplifiers and their applications.

Theory Credit: 03 (Three)

Practical Credit: 01 (One)

No. of Required Classes: 45

No. of Contact Classes: 45

No. of Non-Contact Classes:

Particulars of Course Designer (Name, Institution, email id):

1) **Prof. Banty Tiru, Gauhati University,** btiru@gauhati.ac.in
2) **Dr. Shakeel Zaman, Handique Girls College,** shakeelzamal@gmail.com
3) **Dr. Sumanta Borthakur, B. Borooah College,** bortmontu1@gmail.com

Subject: Physics
Semester: Four
Course Name: Mathematical Physics
Existing Base Syllabus: HS Mathematics
Course Level: PHY254
Syllabus showing each unit against class number and marks

Unit no.	Unit content	No. of classes	Marks/Credit
Theory			
Unit I: Partial Differential Equations	Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.	10	Credit - 3
Unit II: 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. Complex representation of Fourier series. Application to square and triangular waves.	7	
Unit III: Complex Analysis	Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity. Integration of functions with complex variable. Cauchy's Integral theorem and Cauchy's Integral formula. Simply and multiply connected regions. Laurent and Taylor's series expansions. Residue Theorem with application.	17	
Unit IV: Tensor Algebra	Introduction to tensor, Transformation of co-ordinates, Einstein's summation convention. Contravariant, covariant and mixed tensors. Symmetric and antisymmetric tensors, Kronecker delta, LeviCivita tensor. Quotient law of tensors. Rules of combination of tensors: addition, subtraction, outer multiplication, contraction and inner multiplication.	6	
Unit V: Introduction to Probability	Independent random variables: Probability distribution functions; binomial, Gaussian and Poisson, with examples. Mean and variance.	5	
Laboratory			

	<u>At least four from the following:</u> 1. Solve the differential equations $\frac{dy}{dx} = e^x$ with $y = 0$ for $x = 0$ $\frac{dy}{dx} + e^{-x}y = x^2$ $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} = -y$ $\frac{d^2y}{dx^2} + e^{-x}\frac{dy}{dx} = -y$ 2. Perform the multiplication of two 3×3 matrices. 3. Compute the eigenvalues and eigenvectors of the following matrices. $\begin{bmatrix} 4 & 3 & 7 \\ 1 & 2 & 7 \\ 2 & 0 & 4 \end{bmatrix}, \begin{bmatrix} 1 & -i & 3+4i \\ i & 2 & 4 \\ 3-4i & 4 & 3 \end{bmatrix},$ $\begin{bmatrix} 2 & -i & 2i \\ i & 4 & 3 \\ -2i & 3 & 5 \end{bmatrix}$ 4. Using random number compute the areas of circle, square, volume of sphere and value of pi (π). 5. Evaluate trigonometric functions e.g. *sinθ; cosθ; tanθ* etc. using Interpolation by Newton Gregory Forward and Backward difference formula. 6. Find the solution of Partial Differential Equations: (a) Wave equation (b) Heat equation. 7. Evaluate the integral *I*,where, $I = \frac{1}{\sqrt{2\pi\sigma^2}} \int exp\left[\frac{(x-2)^2}{2\sigma^2}\right](x+3)dx$ for $\sigma = 1.0, 0.1, 0.01$ and show that $I \rightarrow 5$ 8. Compute the *n*th roots of unity for *n* = 2, 3, and 4. 9. Find the two square roots of 5 + 12i.		Credit-1

Reading list

1. Mathematical Physics; H K Dass and R Verma, S Chand and Company limited.
2. Mathematical methods for Physics and Engineering; K. F Riley, M. P Hobson, S.J Bence, Cambridge University Press.
3. Graduate Mathematical Physics (With Mathematica Supplement); J J Kelly, Willey-VCH VerlagGmbH and Co. KGaA.
4. Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier.
5. Ordinary and Partial Differential equations; M. D Raisinghania, S. Chand and Company Ltd.
6. Complex Variables; M R Spiegel,S Lipschutz, J J Schiller and D Spellman, Schaum's Outline Series, McGraw Hill Education.
7. Complex variables Demystified (A self-teaching guide); D McMahan, McGraw Hill Education.
8. A Student's Guide to vectors and Tensors; D A Fleisch, Cambridge University Press.
9. Vector analysis and an introduction to Tensor analysis; S Lipschutz, D Spellman, M R Spiegel, Schaum's Outline Series, McGraw Hill Education.
10. Tensors and applications with Scilab Programs; N D Soni, I.K International Publishing House Pvt. Limited.
11. Probability and Statistics; M R Spiegel, J J Schiller and R A Srinivasan, Schaum's Outline Series, McGraw Hill Education.

Graduate Attributes

i. Course Objective

- To solve partial differential equations using separation of variables, including Laplace's equation and the wave equation.
- To apply Fourier series expansion to represent periodic functions using sine and cosine functions.
- To understand complex analysis principles, including analytic functions, integration and residue theorem.
- To develop proficiency in tensor algebra, covering transformations, contravariant and covariant tensors and tensor algebra.
- To gain a preliminary knowledge to probability theory, focusing on independent random variables, probability distributions, and mean and variance calculations.

ii. Learning outcome

On successful completion of the course, the students will be equipped with the techniques related to solving partial differential equations using separation of variables method, application of Fourier series analysis, solving complex integrations, dealing with tensors and probability distributions which are relevant while dealing with wave mechanics, electrodynamics, quantum mechanics, theory of relativity and experimental physics.

Theory Credit: 03 (Three)

Practical Credit: 01 (One)

No. of Required Classes: 45

No. of Contact Classes: 45

No. of Non-Contact Classes:

Particulars of Course Designer (Name, Institution, email id):

1) **Dr. Subhankar Roy**, Gauhati University, subhankar@gauhati.ac.in
2) **Dr. Abhijit Das**, Gauhati University, abhijitdas@gauhati.ac.in
3) **Dr. Chabin Thakuria**, Tihu College, chabinthakuria@gmail.com