Course Title	**Practical Physics IV and Literature Survey**		
Course Code	PHY301M4		
Credit Value	04		
Hourly breakdown	Theory	Practical	Independent Learning
	-	135	65

Objectives

- Prepare students with various modern and advanced experimental set-ups and orient them for research.
- Enhance the students' understanding of various basic concepts in physics through measuring physical quantities.
- Develop the students' soft skills such as writing scientific reports, learning through discussion and oral presentation of their scientific findings.

Intended Learning Outcomes

- Improve experimental skills to carry out laboratory practical in various topics
- Explain experimental findings in relation to existing theories
- Interpret the experimental results
- Design and construct electronic circuits
- Access e-resources effectively for writing scientific articles
- Improve reading, writing and presenting skills

Course Contents

- Solid state Physics: Solar Cells characterization, UV-VIS spectroscopy, Bandgap and Hall effect measurements.
- Optics: Velocity of light, Michelson Interferometer.
- Modern Physics: Millikan's Oil drop, Electron spin resonance, Fine beam tube, Planck's Constant, Gamma radiation, Black Body Radiation, Franck hertz tube, Zeeman effect.
- Electronics: Analog Computing Wein bridge/Colpitts Oscillator, Two-stage Amplifier, 555 Timer.

Literature survey: The students shall carry out extensive literature survey on pre-assigned topics by accessing e-resources and printed materials. A written report on the topic assigned shall be submitted and an oral presentation shall be delivered to a panel of examiners and the special degree students.

Teaching and Learning Methods

In person laboratory demonstration, e-learning, handouts and guided learning
Practical reports/Presentation
Literature survey and Presentation

Assessment Strategy

Practical	75 %
Literature survey	25 %

Recommended References

- Squires, G. L., Practical Physics, (4th Edition), University of Cambridge (2001)
- Sinclair, I., Practical Electronics Handbook, (6^{th} Edition) Elsevier publishers, Inc. (2007)
- Gupta, S.L., and Kumar. V., Handbook of electronics, Pragati Prakashan (2012)

<table>
<tr><td>Course Title</td><td colspan="3">Classical Mechanics and Relativity</td></tr>
<tr><td>Course Code</td><td colspan="3">PHY302M3</td></tr>
<tr><td>Credit Value</td><td colspan="3">03</td></tr>
<tr><td rowspan="2">Hourly breakdown</td><td>Theory</td><td>Practical</td><td>Independent Learning</td></tr>
<tr><td>45</td><td>-</td><td>105</td></tr>
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Objectives

- Introduce fundamental conservation laws to analyse mechanical systems.
- Outline the basic principles of the Lagrangian and Hamiltonian formulation of classical mechanics and apply these principles to solve key problems.
- Introduce Einstein's general and special relativity and cosmology.
- Outline the concept and uses of four vectors in relativistic kinematics.

Intended Learning Outcomes

- Solve advanced dynamical problems involving classical particles by applying the Lagrangian and Hamiltonian formulations
- Explain the calculus of variations and apply it to solve problems
- Formulate the Hamilton-Jacobi equations and apply them to the solution of problems
- Solve problems in basic calculations in relativistic kinematics and dynamics

Course Contents

Lagrangian mechanics:
Generalised coordinates, holonomic and non-holonomic constraints, Principle of least action and the derivation of Lagrange's equations of motion, Application of Lagrange's equations to solve simple problems, Conservation laws and symmetries in nature, Constraints and the method of Lagrange's undetermined multipliers, Generalized force and generalised momentum.

Central force problems:
Vector treatment of motion of a particle in three dimensions, moving frames of reference, effects of the earth's rotation, motion under a central conservative force, the inverse square law, scattering cross-sections, motion of a charge particle in uniform and non-uniform electric and magnetic fields.

The two-body problem:
The centre of mass and relative coordinates, elastic collisions, scattering cross-sections in centre of mass and laboratory frames.

Rigid body motion:
Rotational motion of a rigid body, moment of inertia, principal axes of inertia, gyroscopic motion. Small oscillations and normal modes

Hamiltonian Mechanics:
Hamiltonian and the Hamilton's equations of motion, simple applications, ignorable coordinates, the symmetric top, symmetries and conservation laws.

Relativity:

Special Relativity:
Review of postulates of special relativity and Lorentz transformation equations, four vectors, transformation of velocity, momentum and force using four vectors, field of a moving charge via force transformation, relativistic collision and decay problems.
Transformation of wave number vector, radial and transverse Doppler effects in optics.

General Relativity
Non-mathematical introduction to general relativity, Einstein's approach to gravity, black holes, concept of curved space time, experimental test of general relativity. Rudiments of cosmology.

Teaching and Learning Methods

In person lectures, tutorial discussions, e-learning, handouts and guided learning

Assessment Strategy

In-course Assessments	30%
End of course examination	70%

Recommended References

- Kogut, J., Introduction to Relativity, Harcourt Academic Press, USA (2000)
- Taylor, F. and Wheeler, A., Spacetime Physics: Introduction to special relativity, 2nd Edition, W. H. Freeman press (1992).
- Timon, I., Mechanics and Relativity, Delft University of Technology, (2018)

Course Title	Quantum Mechanics		
Course Code	PHY303M3		
Credit Value	03		
Hourly breakdown	Theory	Practical	Independent Learning
	45	-	105

Objectives

- Introduce a set of postulates and the necessary characteristics of quantum mechanics
- Solve the Time Independent Schrödinger Equation for simple quantum mechanical problems in one, two and three dimensions.
- Introduce the method of solving central field problems in spherical polar coordinates and the concept of angular momentum in quantum mechanics.
- Formulate matrix representation of operators and wavefunctions.

Intended Learning Outcomes

- Analyze physical processes/systems using the uncertainty principle.
- Evaluate the quantities: eigenvalues, eigenfunctions, position probability density function, expectation values, uncertainties, etc., associated with quantum systems, using wave functions and operators.
- Apply the Schrödinger equation to analyze idealistic (1D, 2D and 3D) potential systems.
- Apply the Schrödinger equation in spherical polar coordinates for a hydrogenic atom to obtain possible electronic energy levels and wave functions.
- Obtain matrix representation of operators and wave functions, specifically of angular momentum operators and their eigenfunctions.
- Derive the momentum space wave function of quantum systems and use it to extract information of these systems in a more convenient way.

Course Contents

Introduction:
Evidence of inadequacy of classical mechanics, Some necessary characteristics of quantum theory, The wave-particle duality, the wave function and probability amplitudes, wave packets, the Schrödinger equation, eigenvalue equations and their place in the quantum formalism, Calculation of expectation values of system parameters.

Solution of Schrödinger equation in some simple cases:
One dimensional potential well and energy quantization, potential barriers, reflection and transmission coefficients, tunnelling, one dimensional simple harmonic oscillator, symmetric potentials and parity.
Operator formalism and the basic postulates of quantum mechanics:
Linear Hermitian operators and observables, eigenvalues and eigenfunctions, expectation values, rate of change of expectation values, degeneracy, simultaneous observability and commutation, the uncertainty principle. The basic postulates of quantum mechanics.

Application of Schrödinger equation to three dimensional problems:
Free particle and particle confined to a box, Schrödinger equation in spherical polar coordinates and solving central field problems, Spherical Harmonics, orbital and magnetic quantum numbers.

Operators in quantum mechanics:
The ladder operators in the linear harmonic oscillator problem and the angular momentum. Introduction of spin as an intrinsic property of particles.

Schrödinger equation for two particle systems:
The energy of a rigid rotator, the deuteron; The energy, the energy level diagram and the wavefunctions of one-electron atoms.

Transformation of Representations in quantum mechanics:
Matrix representation of wave functions and operators. Matrix representation of angular momentum operators, eigenvalues and eigenvectors of matrices, Pauli spin matrices.

Total Angular momentum and addition of angular momenta:
The vector model, spectroscopic notation, magnetic dipole moment of an electron in an atom due to its orbital and spin angular momenta, Force experienced by an electron in an atom in the presence of an external magnetic field.

Identical particles:
The particle exchange operator, The effect of indistinguishability of atomic particles on quantum formalism, Pauli exclusion principle.

Teaching and Learning Methods

In person lectures, tutorial discussions, e-learning, handouts and guided learning

Assessment Strategy

In-course Assessments	30%
End of course examination	70%

Recommended References

- Anderson, E., Modern Physics and Quantum Mechanics (1st edition), Saunders College Publication (1971)
- Alastair, R., Quantum Mechanics, (5th edition), CRC Press, (2007).
- Griffiths, D., Introduction to Quantum Mechanics, (2nd edition), Pearson Prentice Hall, (2005).
- Sakurai, J. J., Napolitano, J Modern Quantum Mechanics, (2nd edition), Cambridge University Press, (2017).

Course Title	Advanced Electronics		
Course Code	**PHY304M3**		
Credit Value	03		
Hourly breakdown	Theory	Practical	Independent Learning
	45	-	105

Objectives

- Design simple amplifier and oscillator circuits using BJT and FET
- Analysis the BJT and FET amplifiers at wide range of frequencies
- Design analogue electronic circuits using operational amplifiers, combinational and sequential electronic circuits
- Discuss the basics of microprocessor and explore its applications

Intended Learning Outcomes

- Apply small signal analysis of a BJT and FET circuits using small signal hybrid π model at low and high frequencies
- Design frequency oscillators and amplifier circuits using BJT and FET
- Explain the use of operational amplifier in analogue electronics
- Design simple combinational and sequential electronic circuits
- Discuss the potential applications of microcontrollers and microprocessors in day-to-day life.

Course Contents

Transistor amplifiers:
Single-stage BJT amplifier configurations, small signal analysis and frequency response of common emitter and emitter follower amplifiers, multi-stage amplifiers, Introduction to field effect transistor (FET), types of FETs: junction-FET (JFET), metal-oxide-semiconductor FET (MOSFET), characteristics of JFET and MOSFET, JFET and MOSFET amplifier circuits. Small signal analysis of JFET amplifiers

Feedback circuits:
Positive feedback circuits: Theory of oscillation, RC oscillators: phase shift and Wein's bridge oscillators, LC oscillators: Hartley and Colpitt's oscillators, comparison between RC and LC oscillators, feedback amplifiers (negative feedback circuits): properties, topologies, design and application

Analogue computing:
Differential amplifiers, introduction to operational amplifiers, characteristics of ideal and non-ideal operational amplifiers, design of analogue electronic circuits with operational amplifiers, 555 timer and application

Digital electronics:
Logic gates, Boolean functions and operations, laws and rules of Boolean algebra, De-Morgan's theorem, introduction to TTL and CMOS logic, Boolean expressions and truth tables, Karnaugh maps, Combinational circuits, Sequential circuits: flip-flops, registers, counters, State diagrams and tables, State minimization, and output realization

Introduction to microcontrollers and microprocessors

Microcontroller: Architecture, instruction set, input, output, memory, data path and control, introduction to microcontrollers and application

Teaching and Learning Methods

In-person lectures, tutorial discussions, e-learning, handouts and guided learning

Assessment Strategy

In-course Assessments	30%
End of course examination	70%

Recommended References

- Donald, A., Semiconductor Physics and Devices-Basic Principles (4th edition), McGraw-Hill (2011)
- Anant, A., and Jeffrey, L., Foundations of Analog and Digital Electronic Circuits, The Morgan Kaufmann Series in Computer Architecture and Design, (1st edition) Elsevier publishers (2005)
- Thomas L. Floyd, David M. Buchla, Basic Operational Amplifiers and Linear Integrated Circuits (2nd edition), Prentice Hall (1999)
- M. Morris Mano and Michael D. Ciletti, Digital Design with an Introduction to the Verilog HDL (5th edition), Pearson Education (2013)

Course Title	**Advanced Statistical Physics**		
Course Code	**PHY305M3**		
Credit Value	03		
Hourly breakdown	Theory	Practical	Independent Learning
	45	-	105

Objectives

- Introduce the probability distribution function for a system in its allowed microstates
- Interpret entropy in terms of the information related to this probability distribution.
- Explain the Boltzmann equation for the equilibrium probability distribution in terms of micro-states' quantities, such as energy and particle number.
- Distinguish the microcanonical, canonical and grand canonical formalism
- Explain simple physical phenomena such as phase equilibrium and chemical reactions by applying statistical mechanics

Intended Learning Outcomes

- Explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics
- Discuss the quantum mechanical formulation of statistical mechanics
- Relate equilibrium thermodynamics quantities to some key statistical physics parameter
- Illustrate the behaviour of important physical system by the application of equilibrium statistical mechanics
- Apply Ensemble theory in classical statistical mechanics and thermodynamics
- Apply the principles of statistical mechanics to selected problems
- Combine techniques from statistical mechanics with range of situations relevant to statistical mechanics

Course Contents
Introduction: Elementary probability, Binomial, Gaussian and Poisson distributions. Basic postulates, quantum states and energy levels, micro-states and macro-states. **Isolated systems**: Thermodynamic probability, statistical definition of temperature and entropy, the micro canonical distribution. **Closed system in contact with a heat bath:** Boltzmann distribution and canonical partition function, applications to paramagnetic system, perfect gas, the Maxwell-Boltzmann velocity distribution, theorem of equipartition of energy. **System with variable number of particles:** Chemical potential μ, the grand canonical distribution and the grand partition function. Quantum systems of non-interacting identical particles, occupation number representation. Fermi - Dirac and Bose - Einstein statistics, application to black body radiation, specific heat capacity of electrons at low temperature, thermal emission of electrons, Bose-Einstein condensation. Region of validity of classical approximation. **The perfect gas in the Boltzmann limit:** Monatomic and diatomic gases, ortho and para hydrogen. Thermodynamic equations for single phase one component systems, the Gibbs-Duhem relation, chemical reactions and the law of mass action.

Teaching and Learning Methods
In-person lectures, tutorial discussions, e-learning, handouts and guided learning

Assessment Strategy	
In-course Assessments	30%
End of course examination	70%

Recommended References

- Swendsen, R., An Introduction to Statistical Mechanics and Thermodynamics, (1st edition) Oxford University Press (2012).
- Reif, F., Fundamentals of Statistical and Thermal Physics, Waveland Pr Inc, (2009).
- Charles, K., and Kroemer, H., W.H. Freeman (1980)
- Mandl, F., Statistical physics (2nd edition), Chichester,Wiley, (1988)
- Landsberg, P. T., Thermodynamics and statistical mechanics, Oxford University Press (1990)
- Stowe, K.,Introduction to Statistical Mechanics and Thermodynamics (1st edition). John Wiley & Sons (1983)
- Schroeder, D., An Introduction to Thermal Physics, Addison Wesley Longman (2000)
- Gould, H., and Tobochnik, J., Statistical and Thermal Physics. Princeton University Press (2010)

Course Title	**Instrumentation and Material Characterization Techniques**		
Course Code	**PHY306M2**		
Credit Value	02		
Hourly breakdown	Theory	Practical	Independent Learning
	20	30	50

Objectives

- Introduce basic principles of materials characterization techniques
- Introduce relevant measurement theories associated with varies material characterisation techniques.
- Describe varies measurement techniques for material characterization.
- Familiarize with selected materials characterization techniques
- Introduce the methods for analyzing the data obtained using the above techniques

Intended Learning Outcomes

- Explain principles of optical, microscopic, thermal and electrical techniques used in characterization of materials and devices
- Identify appropriate technique for characterization of materials and devices for different applications
- Solve practical problems in materials characterization utilizing appropriate techniques, skills, and modern analytical tools

Course Contents

Lab view for Instrumentation:

LabVIEW Programming Principles, LabVIEW Environment, Data Types, Arrays and Clusters, Error Handling, Documentation, Case Structures, Sequence Structures, Event Structures, Synchronization and Communication with instruments, Mechanical Actions of Booleans and Instrumentation workshops.

Characterisation:

Optical characterisation: Infrared spectroscopy, Photoluminescence, transient absorption spectroscopy, UV-VIS spectroscopy, Ellipsometry.

Structural characterisation: X-ray diffraction, Scanning Probe microscopy, Atomic Force Microscopy.

Electrical characterisation: The four-probe method, Resistivity profiling, Current-voltage, Capacitance - voltage, Hall effect, Deep level transient spectroscopy, Time of flight, Kelvin probe.

Thermal characterisation: Peltier effect, Seebeck effect, Thermo-gravimetric analysis, Differential Scanning Calorimetry, Thermo mechanical analyzer.

Teaching and Learning Methods

In person Lectures, tutorial discussions, e-learning, handouts, guided learning
practical demonstration

Assessment Strategy

In-course Assessments	30 %
Practical Examination	20 %
End of course examination	50 %

Recommended References
• Sidney, P , Optical Characterization of Semiconductors: Infrared, Raman, and Photoluminescence Spectroscopy, Elsevier, (1993) • Tyagi, A. K., Mainak, R., Kulshreshtha, S. K., Banerjee, S., Advanced Techniques for Materials Characterization, Trans Tech Publications, (2009) • Richard, A , Frances, M. R., James, B. H., Handbook of Instrumentation and Techniques for Semiconductor Nanostructure Characterization, (1st edition), World Scientific, (2012)