UNIVERSITY OF CALICUT

Abstract

General and Academic IV - Faculty of Science- Scheme and Syllabus of M Sc Physics CCSS PG programme, in accordance with the Regulations for CCSS in the University Teaching Departments, with multiple entry and exit options (2024), w.e.f 2024 admission - Implemented- Orders Issued.

G & A - IV - J

U.O.No. 15148/2024/Admn   Dated, Calicut University.P.O, 04.10.2024

Read:-1. UO No.3459/2024/Admn dated 27/02/2024.
2. Minutes of the online meeting of the Board of Studies in Physics (P G) held on 19/07/2024
3. Item No.I.11 in the minutes of the meeting of Faculty of Science held on 29/07/2024
4. Item No.II.A in the minutes of the meeting of the LXXXVIII meeting of the Academic Council held on 17/08/2024
5. Orders of the Vice-chancellor on 11/09/2024

ORDER

1. The Regulations for CCSS in the University Teaching Departments, with multiple entry and exit options (2024) were implemented w.e.f 2024 admission, vide paper read (1) above.
2. The Board of Studies in Physics (PG), vide paper read (2), approved the scheme and syllabus of M Sc Physics programme offered by Department of Physics, University of Calicut, with effect from 2024 admission, in accordance with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024).
3. The Faculty of Science, vide paper read (3), approved the minutes of the meeting of the Board of Studies in Physics (PG) .
4. The LXXXVIII meeting of the Academic Council held on 17/08/2024, approved the minutes of the meeting of Faculty of Science, vide paper read (4).
5. The Vice Chancellor has approved the minutes of the LXXXVIII meeting of the Academic Council and accorded sanction to implement the syllabus of M.Sc Physics programme offered by Department of Physics, University of Calicut,with effect from 2024 admission, in accordance with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024),
6. The Scheme and Syllabus of M.Sc Physics CCSS programme, in accordance with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), is thus Implemented with effect from 2024 Admission.
7. Orders are issued accordingly. (Syllabus appended)

Arsad M

Deputy Registrar

To

The Head, Department of Physics
Copy to: PS to VC/PA to PVC/ PA to Registrar/PA to CE/JCE I/JCE V/DoA/EX and EG Sections/GA I F/CHMK Library/Information Centres/SF/DF/FC

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Section Officer

UNIVERSITY OF CALICUT

Syllabus for

M.Sc. (Physics) Programme (CCSS-PG-2024)

for the University Physics Department (w.e.f. 2024 - 25 admission)

1

Semester I

Course Code	Course Name	Course Type	Credits	T-P	CE	EE	Total
PHY7C501	Classical Mechanics & Chaos	DSC	4	4-0	50	50	100
PHY7C502	Electromagnetic Theory and Plasma Physics	DSC	4	4-0	50	50	100
PHY7C503	General Physics I & Electronics Lab	DSC	4	0-4	50	50	100
DSE1							
PHY7E501	Mathematical Methods for Physics	DSE	4	4-0	50	50	100
PHY7E502	Probability Theory and Statistical Techniques	DSE	4	4-0	50	50	100
DSE2							
PHY7E503	Elementary Astrophysics	Open elective	4	4-0	50	50	100
PHY7E504	Fundamentals of Semiconductors and Optoelectronics	Open elective	4	4-0	50	50	100
PHY7E505	Ideation to Entrepreneurship: The Journey from Concept to Market-Ready Electronics	Open elective	4	4-0	50	50	100
MOOC							
PHY7M501	MOOC - Electronics	DSO	4	4-0	50	50	100

Semester II

Course Code	Course Name	Course Type	Credits	T-P	CE	EE	Total
PHY8C501	Advabced Quantum Mechanics –I	DSC	4	4-0	50	50	100
PHY8C502	Statistical	DSC	4	4-0	50	50	100

	Mechanics						
PHY8C503	General Physics II & Computational Techniques Lab	DSC	4	0-4	50	50	100
DSE3							
PHY8E501	Computational Techniques in Physics	DSE	4	4-0	50	50	100
PHY8E502	Machine Learning and AI	DSE	4	4-0	50	50	100
MOOC							
PHY8M501	MOOC – Molecular Spectroscopy	DSO	4	4-0	50	50	100

Semester III

Course Code	Course Name	Course Type	Credits	T-P	CE	EE	Total
PHY9C601	Advanced Quantum Mechanics –II	DSC	4	4-0	50	50	100
PHY9C602	Nuclear and Particle Physics	DSC	4	4-0	50	50	100
PHY9C603	Modern Physics Lab	DSC	4	0-4	50	50	100
DSE 4							
PHY9E601	Advanced Solid State Physics	DSE	4	4-0	50	50	100
PHY9E602	Vacuum techniques and Thin film technology	DSE	4	4-0	50	50	100
DSE 5							
PHY9E603	Advanced Astrophysics	DSE	4	4-0	50	50	100
PHY9E604	Radiation Physics	DSE	4	4-0	50	50	100

PHY9E605	Soft Matter Physics	DSE	4	4-0	50	50	100
PHY9E606	Experimental Techniques	DSE	4	4-0	50	50	100

Semester IV

Course Code	Course Name	Course Type	Credits	T-P	CE	EE	Total
PHY10P601	Research Project	Project	15		50	50	100
PHY10V601	Comprehensive viva	Viva	1			100	100
DSE6							
PHY10E601	Advanced Nuclear Physics	DSE	4	4-0	50	50	100
PHY10E602	Advanced Material Science	DSE	4	4-0	50	50	100
PHY10E603	Quantum Field Theory	DSE	4	4-0	50	50	100
MOOC							
PHY10M601	MOOC – Research Methodology	DSO	4	4-0	50	50	100

DSC

PHY7C501 **Credits: 4**

CLASSICAL MECHANICS AND CHAOS **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Apply the Lagrangian and Hamiltonian formalisms to simple classical systems and compare with Newtonian systems.	Apply
CO2	Solve problems like motion under central force, rigid body dynamics and periodic motions using Lagrangian and Hamiltonian mechanisms using appropriate mathematical equations	Analyse
CO3	Analyze non linear nature of many of the simple systems.	Analyse

1. **Lagrangian and Hamiltonian Formulation :** Preliminary ideas about Constraints and Generalized coordinates, D'Alemberts principle and Lagrange's equation, Velocity dependent potentials, Simple applications of Lagrangian formulation, Hamilton's Principle, Conservation theorems and symmetries, Lagrange's equation from Hamilton's principle, Two- body central force problems, Equivalent one - body and one dimensional problem, Kepler problem, Inverse square law of force, Laplace-Lenz vector, Scattering in a central force field, Transformation to lab coordinates. **(15 hours)**

   Text : Goldstein et al.

2. **Hamiltonian Formulations:** Legendre Transformation and Hamilton's equations, Cyclic co-ordinates and conservation theorems, Principle of least action, Canonical transformations and examples, Infinitesimal canonical transformations, Poisson brackets and other canonical invariants, Equation of motion in Poisson bracket form, Angular momentum Poisson brackets, Hamilton-Jacobi equation, Hamilton's principal and characteristic function, H-J equation for the linear harmonic oscillator, Separation of variables, Action-angle variables, H-J formulation of the Kepler problem, H-J equation and the Schrodinger equation. **(15 hours)**

Text : Goldstein et al.

3. **Kinematics of Rigid Bodies :** Independent co-ordinates, orthogonal transformation, Transformation matrix, Euler angles, Euler theorem, Infinitesimal rotation, Rate of change of a vector, Centrifugal and Coriolis forces, Inertia tensor, Euler's equation of motion, Torque-free motion of a rigid body, Precession of Equinoxes and satellite orbits.**(14 hours)**

   Text : Goldstein et al.

4. **Small Oscillations :** Formulation of the problem, Eigenvalue equation, Eigenvectors and Eigenvalues, Orthogonality, Principal axis transformation, Frequencies of free vibrations, Normal coordinates, Free vibrations of a linear triatomic molecule, Forced vibration and Dissipative forces. **(8 hours)**

   Text: Goldstein et al.

5. **Nonlinear Equations and Chaos :** Introduction, Singular points of trajectories, Nonlinear oscillations, Limit cycles, Chaos : Logistic map, Definitions, Fixed points, Period doubling, Universality.(**8 hours)**

   Text: Bhatia

Text Books:

1. Herbert Goldstein, Charles P.Poole and John Safko : "Classical Mechanics" (3rd Edition, Pearson Education, 2011)

2. V. B. Bhatia: "Classical Mechanics" (Narosa Publications, 1997)

Books for Reference:

1. Michael Tabor: "Chaos and Integrability in Nonlinear Dynamics" (Wiley, 1989)

2. N. C. Rana and P. S. Joag: "Classical Mechanics" (Tata McGraw Hill, 2011)

3. R. G. Takwale and P. S. Puranik: "Introduction to Classical Mechanics" (Tata McGraw Hill, 1978)

4. Atam P. Arya: "Introduction to Classical Mechanics, " (2nd Edition, Addison Wesley, 1998)

5. Muthusamy Lakshmanan, Shanmuganathan Rajaseekar: "Nonlinear Dynamics" (Springer Verlag, 2002)

DSC

PHY7C502 **Credits: 4**

ELECTROMAGNETIC THEORY AND PLASMA PHYSICS

T-P: 4-0

	Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
CO1	Solve boundary value problems and wave equations. Carry out multipole expansions and interpret the results.	Apply
CO2:	Describe basic concepts related to wave propagation and few of their applications.	Understand
CO3	Analyse electromagnetic wave propagation through wave guides and their storage in cavity resonators.	analyse
CO4	Correlate the theory of relativity and electrodynamics and its possible applications in quantum field theory, the study of fields, interactions and symmetries.	Analyse
CO5	Describe the criteria for a medium to be called plasma and the various properties of it.	Understand

1. **Electrostatics, Magnetostatics and Time varying fields**: Coulomb's law, Gauss's law, Laplace and Poisson equations, Boundary value problems, uniqueness theorem, Method of images with simple examples, Multipole expansion, Ponderable media, Dielectrics. Biot-Savart law, Ampere's law, Boundary value problems, Multipoles, Electromagnetic induction, Maxwell's equations **(12 hours)**

   Text : J. D. Jackson

2. **Plane electromagnetic waves** : Plane waves in nonconducting medium, Polarization, Reflection and Refraction, Dispersion in dielectrics, conductors and plasma, Superposition of waves, Group velocity, Kramers-Kronig relations. **(12 hours)**

   Text : J. D. Jackson

3. **Wave guides and cavity resonators**: Penetration of fields into the conductors, Wave guides, Cylindrical, Rectangular, Energy flow and

attenuation, Resonance cavities, Power losses, Fields and radiation of localized oscillating source, Electric dipole fields and radiation. **(12 hours)**

Text : J. D. Jackson

4. **Relativistic electrodynamics:** Special theory of relativity, Lorentz transformations, Addition of velocities, 4-vectors, Covariance of electrodynamics, Transformations of electromagnetic fields, Lienard-Wiechert potentials, Larmors formula and its relativistic generalization. **(12 hours)**

   Text : J. D. Jackson

5. **Plasma Physics** : Plasma -Definition, concepts of plasma parameter, Debye shielding, Motion of charged particles in an electromagnetic field - Uniform electric and magnetic fields, Distribution function, Boltzmann and Vlasov equations, Derivation of moment equation, Fluid theory, Plasma oscillations, Hydromagnetic waves, Magnetosonic waves and Alfven waves (Basic concepts only).**(12 hours)**

   Text : F. F. Chen

Text Books :

1. J.D.Jackson : "Classical Electrodynamics" (3rd Ed., Wiley,1999)

2. F. F. Chen :" Introduction to Plasma Physics and Controlled Fusion", Volume I :Plasma Physics, (Springer Verlag, 2006).

Books for Reference:

1. David K. Cheng : " Field and Wave Electromagnetics" (2nd Ed., Addisson Wesley)

2. David Griffiths : " Introductory Electrodynamics" (4th Ed.,Prentice Hall of India, 2012)

3. K.L. Goswami, Introduction to Plasma Physics – Central Book House, Kolkata

DSC

PHY7C503 Credits:4

GENERAL PHYSICS I AND ELECTRONICS LAB T-P: 0-4

PART A (2 credits)

	Course Outcomes	**Cognitive level**
CO1	Gain proficiency in using laboratory equipment and instruments.	Apply
CO2	Learn to identify sources of error and quantify their impact.	Apply
CO3	Interpret results and draw meaningful conclusions from experiments	Analysis
CO4	Deepen understanding of fundamental physics concepts through hands-on experimentation.	Understand
CO5	Develop problem-solving skills through troubleshooting experimental setups	Apply

Experiments:

1. Y and σ - Interference method (a) elliptical (b) hyperbolic fringes. To determine Y and σ of the material of the given specimen by observing the elliptical and hyperbolic fringes formed in an interference set up
2. Y and σ by Koenig's method
3. Viscosity of a liquid - Oscillating disc method. To determine the viscosity of the given liquid by measurements on the time period of oscillation of the disc in air and in the liquid
4. Variation of surface tension with temperature - Jaeger's method. To determine the surface tension of water at different temperatures by Jaeger's method of observing the air bubble
5. Mode constants of a vibrating strip. To determine the first and second mode constants of a steel vibrating strip; Y is to be measured by the Cantilever method and frequency of vibration by the Melde's string method

6. AC bridge circuits: Maxwell's, De Sauty's and Anderson's bridges (any two).
7. Calibration of Silicon Diode.
8. Stefan's constant of radiation
9. Thermal diffusivity of brass
10. High resistance by leakage
11. Temperature coefficient of resistance of copper
12. Measurement of Self Inductance of a coil
13. Dielectric constant of a non polar liquid
14. Magnetic field variation along the axis of a solenoid
15. Mutual Inductance with Lock-in amplifier
16. Band gap of semiconductor using diode
17. Optical fibre – evaluation of numerical aperture
18. Design of passive filter (first and second order) RC circuit

Laser experiments.

19. Wavelength determination using grating
20. Intensity distribution
21. Diameter of a thin wire
22. Diffraction at a slit - determination of slit width
23. Fraunhoffer Diffraction at Single Slit
24. Young's Double slit experiment.

Books for Reference:

1. A.C. Melissinos, J.Napolitano : "Experiments in Modern Physics" (Academic Press, 2003)
2. B.L. Worsnop and H.T. Flint :"Advanced Practical Physics for students" (Methusen & Co., 1950)
3. E.V. Smith :" Manual of experiments in applied Physics" (Butterworth 1970)

4. R.A. Dunlap :"Experimental Physics - Modern methods"(Oxford University Press, 1988)

5. D. Malacara (ed) : " Methods of experimental Physics - series of volumes " (Academic Press Inc., 1988)

6. S.P. Singh : "Advanced Practical Physics – Vol I & II (13th Edition, Pragati Prakasan, Meerut , 2003)

PART B (2 Credits)

Notes : Students have to do 10 experiments from the list. They have to carry out a minor electronic project under the supervision of the teacher as a partial fulfilment of the course. From each module, one has to do at least one experiment and at the most 3 experiments.

I Voltage Regulator

1. Half-wave and full-wave rectifier experiments with ExpEYES-17 kit.

2. Diode I-V characteristics (ExpEYES-17) and voltage regulation using transistors with feedback (regulation characteristics with load for different input voltages and variation of ripple factor with load)

3. Diode I-V characteristics (ExpEYES-17) and voltage regulation using Op Amp with feedback (regulation characteristics with load for different input voltages and variation of ripple factor with load

1. BJT Amplifiers

1. CE input and output characteristics with ExpEYES-17 kit and transistor characteristics.
2. Single stage RC coupled amplifier with and without Negative feedback (input, output resistance, frequency response)
3. Two stage RC coupled amplifier (input and output resistance and frequency response including Bode plots)
4. Complementary symmetry Class B push-pull power amplifier (transformerless) (I/O impedances, efficiency and frequency response)
5. Darlington pair amplifier (gain, frequency response, input &output resistances)
6. Differential amplifier using transistors (I/O impedances, frequency response, CMRR)
7. Bootstrap Amplifier (frequency response, input & output resistance)
8. Two-stage IF amplifier (Gain and frequency response, bandwidth)
9. Amplitude modulation and detection using transistors (modulation index & recovery of modulating signal)

2. FET and MOSFET

10. RC coupled FET amplifier - common source (frequency response, input & output impedances).
11. MOSFET amplifier (frequency response, input & output impedances)
12. UJT characteristics and relaxation oscillator (construct relaxation oscillator & sharp pulse generator)
13. Characteristics of a Silicon controlled rectifier (Half-wave and full wave) Negative resistance oscillator. (for different frequencies)

3. Operational Amplifiers

14. Use of IC 741 - Determination of input offset voltage, current, CMRR, slew rate, and use as Inverting and non-inverting amplifier and difference amplifier,

    summing amplifier and comparator.
15. Sawtooth generator using transistors and Miller sweep circuit using OPAMPS (for different frequencies)
16. Schmidt trigger using transistors and OPAMPS - Trace hysteresis curve , determine LTP and UTP
17. Analog integration and differentiation using OPAMPS (study the integrator characteristics & differentiator)
18. Analog computation using OPAMPS (LM324) Differential equations / Simultaneous equations
19. Second order Low pass, High Pass and Band Pass filters using OPAMP.(study the frequency response)
20. Square, Triangular and Saw tooth generator, Voltage controlled oscillator using Op Amp (Refer R. A. Gayakwad, Ch.8)
21. IC 555 Timer circuit- Astable and monostable multi vibrators,
22. IC 555 Timer circuit -VCO missing pulse detector and sawtooth generator.
23. Op-Amp experiments with ExpEYES-17: Inverting & non-inverting amplifiers, RC differentiation and integration amplifiers.
24. IC555 oscillator experiments with ExpEYES-17:

4. Oscillators

25. Wien bridge oscillator using OP AMP (For different frequencies, distortion due to feedback resistor, compare with design values)
26. Phase shift and Quadrature oscillator with OP AMP (Refer R. A. Gayakwad)
27. Crystal Oscillator (for different frequencies & evaluation of

frequency stability)

5. Digital Circuits, Microprocessors and Microcontrollers

28. Logic gates experiments with ExpEYES-17 kit: AND, OR, EX-OR, NOT gates, Clock divider etc.
29. Operation and working of Arithmetic and Logic circuits IC 7483, IC 74181
30. Shift registers IC 74166 and IC 74198 with ExpEYES-17 or other kits.
31. Counters IC 7490 A, IC 7493 A, IC 74193 with ExpEYES-17 or other kits
32. Organize M X N random access memory with basic memory unit (Verify the READ and WRITE operations)
33. Microprocessors experiments (simple experiments) addition, subtraction, multiplication and division using 8085
34. Square wave generation using Microprocessor 8085 and programmable peripheral interface 8255.
35. Programming Atmel microcontroller (square wave generation, sine wave generation with inbuilt D/A converter)
36. Programming experiments with Atmega32 microcontroller training kit, KuttyPy: 8bit-LED operations, A/D and D/A convertor, square wave generation etc.

Mini-Project

(Students have to do a mini electronic project leading to understanding and applications of the theory. A few examples are given below. They can choose other projects in consultation with the teacher-in-charge.

1. Construction of a complete power supply circuit.
2. Experimental projects / coding with ExpEYES-17 kit.
3. Microcontroller projects with KuttyPy kit.

DSE
PHY7E501 **Credits:4**
MATHEMATICAL METHODS FOR PHYSICS **T-P: 4-0**

	Course outcome **After completion of the full course the student should be able to**	**Cognitive level**
CO1	Distinguish the class of objects called tensors, their classifications and use. Perform transformation operations and get the corresponding transformation matrices. Learn procedures for matrix diagonalisation.	Evaluate
CO2	Identify differential equations of special nature and the ways to solve them.	Analyse
CO3	Illustrate special functions as solutions to problems in atomic molecular nuclear, and solid-state physics etc. and will put them in use.	Analyse
CO4	Distinguish Fourier series and integral transforms of different types and their properties. This will enable him/her to analyse or solve different mathematical problems in physical sciences.	Analyse

1. **Matrices and Tensors:** Basic properties of matrices (Review only), Orthogonal matrices, Hermitian and Unitary matrices, Similarity and unitary transformations, Diagonalization of matrices, Definition of Tensors, Contraction, Direct products, quotient rule, Pseudo tensors, Dual tensors, Levi Cevita symbol, irreducible tensors. **(10 hours)**

2. **Second Order Differential Equations:** Partial differential equations of Physics, Separation of variables, Singular points, Ordinary series solution, Frobenius method, A second solution, Self-adjoint differential equation, eigen functions and values, Boundary conditions, Hermitian operators and their properties, Schmidt orthogonalization, Completeness of functions. **(14 hours)**

3. **Special functions I:** Gamma function, Beta function, Delta function, Dirac delta function, Bessel functions of the first and second kinds, Generating function, Recurrence relation, Orthogonality, Neumann function, Spherical Bessel function. **(12 hours)**
4. **Special functions II:** Legendre polynomials, Generating function, Recurrence relation, Rodrigue's formula, Orthogonality, Associated Legendre polynomials, Spherical harmonics, Hermite polynomials,

Laguerre polynomials. **(12 hours)**

5. **Integral Transforms:** Fourier Series, General properties, Advantages, Uses of Fourier series, Properties of Fourier series, Fourier integral, Fourier transform, Properties, Inverse transform, Transform of the derivative, Convolution theorem, Laplace transform, Inverse Transform and Convolution theorem. **(12 hours)**

Text Book:

1. G.B.Arfken and H.J.Weber: "Mathematical Methods for Physicists" (6th Edition, Academic Press, 2005)

Books for Reference:

1. J.Mathews and R.Walker: "Mathematical Methods for Physics" (2nd Edition, Benjamin)
2. L.I.Pipes and L.R.Harvill: "Applied Mathematics for Engineers and Physicists" (3rd Edition, McGrawHill)
3. Erwin Kreyzig: "Advanced Engineering Mathematics" (8th edition, Wiley)
4. M. Greenberg: "Advanced Engineering Mathematics" (2nd edition, Pearson India, 2002)
5. A.W. Joshi: "Matrices and tensors in Physics" (New Age International Publishers)
6. Nazrul Islam: "Tensors and Their Applications" (New Age International, 2006)

DSE

PHY7E502 **Credits: 4**

PROBABILITY THEORY AND STATISTICAL TECHNIQUES **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Describe the various probability distributions, enabling the analysis and modelling of random processes in physics	Understand
CO2	Interpret the data using statistical inference, including hypothesis testing, confidence interval estimation, and regression analysis.	Apply
CO3	Analyse complex datasets using PCA and Monte Carlo simulations	Analysis
CO4	Analyse the characteristics and properties of various statistical distributions using the Central Limit Theorem	Analysis

1. **Introduction to Probability:** Random experiment, Sample space, events, classical definition of probability, statistical regularity, field, sigma field, axiomatic definition of probability and simple properties, **(12 hours)**
2. **Probability Rules:** addition theorem (two and three events), conditional probability of two events, multiplication theorem, independence of events-pair wise and mutual, Bayes theorem and its applications. **(12 hours)**
3. **Introduction to Statistics:** Nature of Statistics, Uses of Statistics, Statistics in relation to other disciplines, Abuses of Statistics. Concept of primary and secondary data. Designing a questionnaire and a schedule. Concepts of statistical population and sample from a population, quantitative and qualitative data, Nominal, ordinal and time series data, discrete and continuous data. Presentation of data by table and by diagrams, frequency distributions by histogram and frequency polygon, cumulative frequency distributions (inclusive and exclusive methods) and ogives. **(14 hours)**
4. **Analytical Techniques:** Measures of central tendency (mean, median, mode, geometric mean and harmonic mean) with simple applications. Absolute and relative measures of dispersion (range, quartile deviation, mean deviation and standard deviation) with simple applications. Co-efficient of variation, Box Plot. Importance of moments, central and non-central moments, and their interrelationships. Measures of skewness based on quartiles and moments; kurtosis based on moments **(14 hours)**
5. **Correlation and Regression:** Scatter Plot, Simple correlation, Simple regression, two regression lines, regression coefficients. Fitting of straight line, parabola, exponential, polynomial (least square method). **(10 hours)**

Text Books and References

1. S.C. Gupta and V.K .Kapoor. Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi
2. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
3. Mukhopadhyay P. (2011): Applied Statistics, 2nd ed. Revised reprint, Books and Allied
4. Hoel P.G. Introduction to mathematical statistics, Asia Publishing house
5. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
6. S.C.Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons.
7. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn., (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
8. John E Freund, Mathematical Statistics, Pearson Edn, New Delhi 5. Hoel P.G. Introduction to mathematical statistics, Asia Publishing house.

DSE (Open Elective)
PHY7E503 **Credits: 4**
ELEMENTARY ASTROPHYSICS **T-P: 4-0**

	Course Outcome: **After completion of the full course the student should be able to**	**Cognitive level**
CO1	Perform the observation of celestial objects	Apply
CO2	Estimate the physical properties of stars using photometric techniques	Apply, Analyse
CO3	Describe the evolutionary states of stars based on the masses	Understand
CO4	Explain the formation and evolution of galaxies	Understand
CO5	Describe the planetary system and explain the basic formation scenario of exoplanets	Understand

1. **COORDINATES AND OBSERVATION TECHNIQUES:** The celestial sphere, The horizontal system, The equatorial system, The Galactic coordinates , The sidereal time, Stellar distances – parallax method, Optical telescopes – Properties and aberrations, Radio telescopes, other wavelength regions**(12 hours)**

   Section 2.3, 2.4, 2.8, 2.13, 3.2, 3.3, 3.4, 3.5 of Fundamental Astronomy by Karttunen et al

2. **PHOTOMETRIC CONCEPTS AND MAGNITUDES:** Intensity, Flux density, Luminosity, Apparent Magnitudes, Absolute magnitudes, Magnitude systems, Spectral formation, Saha and Boltzmann equation, Spectral classification: The Harvard spectral classification, The Yerkes Spectral Classification, Peculiar Spectra, The Hertzsprung-Russel Diagram **(12 hours)**

   Sections 4.1 to 4.4 and Section 8.1 to 8.5 of Fundamental Astronomy by Karttunen et al

   Sections 4.2 and 4.3 of Baidyanath Basu M : “An introduction to Astrophysics” (Prentice Hall of India)

3. **STELLAR EVOLUTION:** The contraction of stars towards the main-sequence , The main-sequence phase, The Giant phase, The final stages of evolution, White dwarfs, Neutron stars, Black holes (qualitative idea only) **(10 hours)**

   Sections 11.2 to 11.5, 14.1 to 14.3 of of Fundamental Astronomy by Karttunen et al

4. **GALAXIES:** The Milky way Galaxy, Stellar luminosity function, The rotation of the Milky way, Structural components of the Milky way, The formation and evolution of the Milky way, The classification of Galaxies, Luminosities and Masses, Galactic Structure, Dynamics of Galaxies, Systems of Galaxies , Active galaxies and quasars, The origin and Evolution of Galaxies **(14 hrs)**

   Section 17.2 to 17.5 and Section 18.1 to 18.9 of Fundamental Astronomy by Karttunen et al

5. **THE SOLAR SYSTEM:** Planetary configurations, Orbit of the earth and visibility of Sun, Orbit of the moon, Eclipses and Occultations, The structure and surface of planets, Atmospheres and Magnetospheres, Photometry, polarimetry and spectroscopy, Thermal radiations of the planets, Minor bodies of the solar system, origin of the solar system **(12 hours)**

   Section 7.1 to 7.9 and 7.17 and 7.18 of Fundamental Astronomy by Karttunen et al

Books and References

1. H. Karttunen, P. Kroger, H. Oja, M. Poutanen, K. J. Donner (Eds.): " Fundamental Astronomy"

2. Baidyanath Basu M : "An introduction to Astrophysics" (Prentice Hall of India)

3. B.W. Carroll & D.A. Ostille : "Modern Astrophysics", (Addison Wesley, 1996)

4. Frank H Shu: The Physical Universe: An Introduction to Astronomy

DSE (open elective) **Credits: 4**
PHY7E504 **T-P: 4-0**

FUNDAMENTALS OF SEMICONDUCTORS AND OPTOELECTRONICS

	Course Outcome	Cognitive level
CO1	Understand the knowledge about the radiative transition processes and other optoelectronic phenomenon.	Understand
CO2	Understanding of semiconductor physics, including band theory, carrier transport, and semiconductor device operation principles.	Understand
CO3	Understanding of the different types of PN junctions	Understand
CO4	Analysis of the types, characteristics and applications of light emitting diodes	Analyse
CO5	Differentiate between the function and science of different optoelectronic devices	Analyse

1. **Basics of optoelectronics**: Emission and absorption processes; Photon statistics; The behaviour of electrons; Electrons in a periodic lattice, Metals, insulators and semiconductors; refraction; Absorption and emission; Fluorescence; Scattering; The absorption and emission of light by semiconductors **(12 hours)**

2. **Semiconductor Science:** Energy Band diagrams; The density of States; fermi–dirac function and metals; Extrinsic Semiconductors: n-type and p-type ; Semiconductors compensation doping; non-degenerate and degenerate Semiconductors; Energy Band Diagrams in the Applied field; Direct Band and Indirect band semiconductors: E-K Diagrams **(10 hours)**

3. **PN junction**: PN-Junction principles; tunnel junctions, Schottky barriers, and ohmic contacts, and heterojunctions; Open circuits, PN Junction forward and reverse circuits (Basic ideas only: derivations not required); I-V characteristics; Physical Description of p-n junction, Basic device technologies for fabrication of a p-n junction; small signal switching models; Avalanche breakdown; Zener diode; Schottky diode **(10 hours)**

4. **Optoelectronic Devices:** Photodetectors; Photodiodes; photovoltaic effects; Solar Cells; phototransistors; Semiconductor lasers; Population Inversion at a Junction; emission Spectra for p-n Junction Lasers; The

Basic Semiconductor Laser; heterojunction Lasers; Materials for Semiconductor Lasers **(13 hours)**

5. **Light emitting Diodes**: Visible light-emitting diodes; Physics of LEDs; Optical properties of LEDs; Radiative and non-radiative recombination; Electrical properties; Current-voltage characteristics; Efficiencies; Material systems for visible LEDs; GaP and GaAsP, AlGaAs/GaAs, AlGaInP/GaAs, InGaN; High-efficiency LEDs and novel technologies; White LED; White light; Phosphor-converted white LEDs; Multi-chip white; Applications of LEDs; Packaging of LEDs **(15 hours)**

Textbook:

1. Optoelectronics and Photonics: Principles and Practices, S.O. Kasap, Pearson, 2nd Ed., 2013
2. Solid State Electronic Devices, Ben G. Streetman and S K Banerjee Pearson, 7th Ed., 2016

References:

1. Handbook of Optoelectronics Volume I, John P Dakin & Robert G W Brown, 2006 by Taylor & Francis Group
2. S. M. Sze and K. N. Kwok, “Physics of Semiconductor Devices,” 3rd edition, John Wiley & Sons, 2006

DSE (open elective)

PHY7E505 **Credits: 4**

IDEATION TO ENTREPRENEURSHIP: THE JOURNEY FROM CONCEPT TO MARKET READY ELECTRONICS **T-P: 4-0**

	Course Outcome	Cognitive Level
CO1	Innovation and Problem-Solving Skills: Apply ideation techniques such as Design Thinking, Brainstorming, and SWOT analysis to identify real-world problems and develop innovative solutions leading to viable product concepts.	Apply
CO2	Embedded Systems Design and Programming: Design and program microcontroller-based circuits using Atmega32 and C programming, and interface embedded devices with computers to develop science application-oriented projects.	Create
CO3	Practical Circuit Design and Fabrication: Simulate, design, and fabricate electronic circuits using tools like KICAD and LTSPICE, including the creation of PCB layouts and hands-on circuit building.	Analyze
CO4	Peripheral Device Integration and IoT Development: Design and implement systems that interface microcontrollers with peripheral devices using communication protocols (I2C, SPI, UART) to build IoT devices and control systems.	Create
CO5	Product Prototyping and Fabrication: Integrate electronics, PCBs, and 3D-printed mechanical components to fabricate functional prototypes, transforming a concept into a market-ready product.	Synthesize

1. Ideation and Concept Development: Introduction to Innovation and Entrepreneurship: Role of innovation in entrepreneurship; importance of creativity in problem-solving, Idea Generation Techniques: Brainstorming, Mind Mapping, SCAMPER, SWOT Analysis, Problem Identification and Solution Mapping: Identifying real-world problems, defining value propositions, and mapping out potential solutions, Design Thinking: Empathy mapping, user-centered design, ideation, prototyping, and testing, Case Studies: Examples of successful product ideas and how they were conceptualized.**(10 hours):**

2. Embedded device fundamentals: Introduction to microcontrollers (Atmega32): Overview of microcontroller architecture using KuttyPy Plus

training platform, Programming Basics: Introduction to programming microcontrollers with C. Interpreting datasheets, shortlisting bill of materials for making circuit boards, interfacing embedded devices with computers. Creating a microcontroller based circuit on a breadboard. Creating science application oriented projects such as smart temperature control, basic input/output scheduled operation, and timers.
Lab Sessions: Hands-on experience with writing and uploading code using the IDE.**(12 hours):**

3. Circuit design fundamentals: Basic electronics training using SEELab, Signal processing circuits such as filters, and amplifiers, creating schematic diagrams, layouts, and PCBs with KICAD (with practical demo), introduction to device packages (through hole, SMD, various connectors), SMD soldering: creating scalable projects circuit testing, simulating circuits with circuit simulator built into SEELab software., Simulating circuits with LTSPICE.**(12 hours)**

4. Interfacing Peripheral Devices with Microcontroller: Interfacing Techniques: Working with sensors, actuators, and communication protocols (I2C, SPI, UART), practical Applications: connecting microcontrollers to various sensors and devices, focusing on real-time data acquisition and control, advanced projects: developing IoT devices, home automation systems, and simple robotic applications using KuttyPy Plus, Lab Sessions: Real-world projects where students design, program, and test systems that incorporate sensor data and device control, Interfacing scientific instruments with laptops using Python. Will cover communication protocols such as GPIB, USBTMC, and RS232, plotting datasets, and feature extraction (curve fitting) using scipy.**(14 hours)**

5. Fabrication of a Product: Prototyping and Design – Basics of 3D printing, laser cutting, mechanical design: designing enclosures and mechanical components for devices using 3D printing and laser cutting, integrated product fabrication: combining electronics, PCB, and mechanical components into a fully functional product, fabrication of projects: including designing, building, and testing a complete product from concept to final prototype.**(12 hours)**

TEXT BOOKS

1. The AVR Microcontroller and Embedded systems using Assemble and C by M.A. Mazidi, S Naimi and S. Naimi.

2. Design Thinking: New Product Development Essentials from the PDMA by Abbie Griffin, Charles H. Noble, and Serdar S. Durmusoglu.

3. **Embedded C Programming and the Atmel AVR**, by Richard H. Barnett, Larry O'Cull, and Sarah Cox.

4. The Art of Electronics, by Paul Horowitz and Winfield Hill.

REFERENCES:

1. **Kuttypy Documentation : https://kuttypy.readthedocs.io/en/latest/**
2. **Atmega32 Reference : https://www.microchip.com/en-us/product/atmega32**
3. **Atmega32: https://ww1.microchip.com/downloads/en/DeviceDoc/doc2503.pdf**
4. **KiCAD Handbook : https://docs.kicad.org/**

Online course (optional for MOOC)

PHY7M501 **Credits: 4**

ELECTRONICS **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Master the operation and application of transistor technologies, operational amplifiers, and digital logic circuits, enabling the design and analysis of amplifiers, signal processors, and control systems.	Analysis
CO2	Acquire skills in programming and deploying microprocessors and microcontrollers, particularly focusing on assembly language and embedded C programming for the AVR architecture, to implement real-world applications and devices.	Apply
CO3	Integrate theoretical knowledge from physics and electronics to design, troubleshoot, and optimize electronic circuits and systems, enhancing their functionality and efficiency in lab-based and real-world scenarios	Understand
CO4	Demonstrate an understanding of arithmetic circuits, flip-flops, registers, counters, D/A-A/D converters, arithmetic and logic units, and memory organization, and their implementation in digital systems.	Understand
CO5	Analyze various amplifier configurations, analog integrators, differentiators, electronic analog computation, active filters, oscillators, comparators, zero crossing detectors, and Schmitt triggers to enhance performance and application	Apply

1. **Transistor Amplifiers : BJT**: Biasing and AC models, voltage amplifiers, power amplifiers, emitter follower, **FET**: H-parameters, FET small signal model, biasing the FET, analysis of common source and common drain amplifiers at low and high frequencies, FET as VVR and its applications., **MOSFET**: Circuit symbol and equations, small signal model, CMOS and Digital MOSFET gates.**(12 hours)**

2. **Operational Amplifier:** Covers dual input differential amplifier DC and AC analysis, Op-Amp block diagram representation, analysis of a typical Op-Amp equivalent circuit, and open loop configurations. Discusses Op-Amp parameters and applications with negative feedback.**(12 hours)**

3. **OPAMP Applications:** Focuses on various amplifier configurations, analog integrators and differentiators, electronic analog computation, active filters, oscillators, comparators, zero crossing detectors, and Schmitt triggers.**(12 hours)**

4. **Digital Electronics:** Includes arithmetic circuits, flip-flops, various types of registers, counters, and D/A-A/D converters, arithmetic and logic unit, memory organization.**(12 hours)**

5. **Microprocessors and Microcontrollers:** Examines the architecture of the 8085 microprocessor, microcontroller basics, registers and memory, assembly language programming and introduces AVR microcontroller, registers, memory, programming and applications.**(12 hours)**

Text Books and References

General Recommended Textbooks:

a. Malvino, "Electronic Principles" (6th Edition, TMH India)
b. Millman and Halkias, "Integrated Electronics" (TMH India)
c. R. A. Gayakwad, "Op-Amps and Linear Integrated Circuits" (3rd Edition, PHI)
d. Fundamentals of Microprocessors and Microcomputers, 2nd Edition, B. Ram, Dhanapathi Rai & Sons
e. Mazidi & Mazidi: "The AVR Microcontroller and Embedded Systems: Using Assembly and C" (Prentice Hall)

Additional Reference Books:

1. Robert L. Boylstead & L. Nashelsky: “Electronic Devices and Circuit Theory” (Pearson Education)
2. Floyd: “Electronic Devices” (5th Edition, Pearson Education)
3. Alen Motorshed
4. Microelectronic Circuits: Analysis & Design, M. H. Rashid, PWS Publishing Company
5. Linear Integrated Circuits, D. R. Choudhuri, S. Jain, New Age International Publishers
6. **Embedded C Programming and the Atmel AVR, Barnett, O’cull, Cox, Cengage Learning**

DSC

PHY8C501 **Credits: 4**

ADVANCED QUANTUM MECHANICS – I **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Illustrate the importance of Hilbert space in quantum mechanics	Apply
CO2	Solve Schrödinger equation in different situations	Apply
CO3	Calculate the Clebsch-Gordan coefficients in angular momentum addition	Apply
CO4	Compute eigenvalues and eigenstates of three-dimensional central field problems	Apply
CO5	Describe the wave function of a multi-fermionic system slater determinant	Analyse

1. **Mathematical Tools for Quantum Mechanics** Essential structure of Classical Mechanics and its Inadequacy. Linear Vector Spaces-Hilbert Space; Dimension and Basis of a Vector Space; Square-Integrable Functions; Wave Functions; Dirac's Bra and Ket notation; Schwarz Inequality. Operators- Adjoint of an Operator; Hermitian Operators; Unitary Operators; Commutator Algebra; Commutator of Operators and Uncertainty Relation; Functions of Operators; Eigenvalues and Eigenvectors of an Operator. Representation in Discrete Bases- Matrix Representation of Bras, Kets and Operators; Change of Bases and Unitary Transformations; Matrix Representation of the Eigenvalue Problem. Representation in Continuous Bases- Position and Momemtum Representations and relation between them. **(12 hours)**

2. **Postulates of Quantum Mechanics and Exactly Solvable Problems in one Dimension** The State of a System; Probability Density; The Superposition Principle, Observables and Operators. Measurement in Quantum Mechanics- How Measurements Disturb Systems; Expectation Values; Complete Sets of Commuting Operators; Measurement and the Uncertainty Relations. Time Evolution of the System's State- Time Evolution Operator; Schrodinger Equation and Wave Packets; The Conservation of Probability; Time Evolution of Expectation Values. Connecting Quantum to Classical Mechanics- Poisson Brackets and Commutators; The Ehrenfest Theorem. Time-independent Schrodinger equation- Stationary States; Infinite square well; Delta function Potential;

Finite square well; Finite Potential Barrier; Harmonic Oscillator. **(12 hours)**

3. **Quantum Dynamics and Angular Momentum** The equation of motion. Schrodinger, Heisenberg and the Interaction pictures of time development. The linear harmonic oscillator in the Schrodinger and Heisenberg pictures. Orbital Angular Momentum- Angular Momentum Opeartors; Angular Momentum Algebra; Simultaneous Eigenfunctions of L_z and L^2; Properties of the Spherical Harmonics; Matrix Representation of Angular Momentum Operators; Addition of angular momenta; Clebsh-Gordon coefficients. Spin Angular Momentum- Spin 1/2 and the Pauli Matrices. Coupling of Orbital and Spin Angular Momenta.**(14 hours)**

4. **Exactly Solvable Problems in three Dimensions & Symmetry and Conservation Laws** The Free Particle in Spherical Coordinates; The Spherical Square Well Potential; The Isotropic Harmonic Oscillator; The Hydrogen Atom; Effect of Magnetic Fields on Central Potentials. Space-time symmetries- Space translation and conservation of linear momentum; Time translation and conservation of energy; Space rotation and conservation of angular momentum; Space inversion and time reversal. **(14 hours)**

5. **Identical particles** Identical Particles in Classical and Quantum Mechanics; Exchange Degeneracy; Construction of symmetric and antisymmetric wave functions; Slater determinant; Pauli exclusion principle; Bosons and Fermions; Spin wave functions for two electrons; The ground state of He atom. **(8 hours)**

Text Books

1. Nouredine Zettili, Quantum Mechanics: Concepts and Applications, Second Edition, John Wily & Sons Ltd, 2009
2. V. K. Thankappan, Quantum Mechanics, Second Edition, New Age International Publishers, 1993.
3. David J. Griffiths, Introduction to Quantum Mechanics, Second Edition, Pearson education International, 2005
4. R. Shankar, Principles of Quantum Mechanics, Second Edition, Kluwer Academic/ Plenum Publishers, 1994

Reference Books

1. R. Eisberg & R. Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei & Particles, John Wiley
2. Thomas E Jordan, Quantum Mechanics in Simple Matrix Form, John Wiley & Sons Ltd, 1986
3. Claude Cohen Tannoudji, Bernard Diu and Frank Laloe, Quantum Mechanics, Volumes I and II, 1996

4. L. I. Schiff, Quantum Mechanics, McGraw Hill, 1968
5. J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley, 2010
6. J. D. Bjorken and S. D. Drell, Relativistic Quantum Mechanics, McGraw Hill, 1998
7. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, TataMcGraw Hill, 1978

DSC
PHY8C502 **Credits: 4**
STATISTICAL MECHANICS **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Discuss the connection between statistics and thermodynamics	Analyse
CO2	Demonstrate an understanding of the terminology, concepts and principles of describing equilibrium properties of physical systems in a statistical mechanical framework	Apply
CO3	Derive partition function and compute thermodynamics relations for various real-world physical systems	Create
CO4	Comprehend the statistical behaviour of ideal Bose and Fermi systems	Analyse
CO5	Qualitatively explain aspects of the statistical physics of systems with an interaction between its constituent components	Understand

1. **Foundations of statistical mechanics:** Specification of states of a system, Contact between statistics and Thermodynamics, Classical Ideal gas, Entropy of mixing and Gibbs paradox, Sackur-Tetrode Equation.

   Text book: Pathria, Chapter 1. **(10 hours)**

2. **Ensemble Theory:** Microcanonical ensemble, phase space, trajectories and density of states, Liouville's theorem, canonical and grand canonical ensembles, partition function, Equipartition Theorem, calculation of statistical quantities. **(13 hours)**

   Text book: Pathria, Chapter 2 and Secs. 3.1, 3.3, 3.5, 4.1- 4.3 of chapters 3 and 4

3. **Quantum Statistical Mechanics:** Density matrix, statistics of Microcanonical, Canonical and Grand canonical Ensemble, Example: Electron in a magnetic field, Free Particle in a box, Statistics of indistinguishable particles **(14 hours)**
   Text book: Pathria, Sec. 5.1 – 5.4

4. **Ideal Systems**: Density matrix of a system of non-interacting particles. Ideal gas in quantum mechanical ensembles, Maxwell-Boltzman, Fermi-Dirac and Bose-Einstein statistics, Thermodynamics of ideal Bose and Fermi gases, Bose-Einstein condensation. **(14 hours)**
   Text book: Pathria, Sec. 5.5, 6.1- 6.3, 7.1, 8.1, 8.2A.

5. **Phase Transitions and Fluctuations:** Cooperative phenomena, Dynamical model of Phase transitions, Bragg-William approximation, Ising Model, Equilibrium thermodynamic Fluctuations, Brownian motion and Langevin theory **(9 hours)**

Text Book: R. K. Pathria & Paul D Beale, "Statistical Mechanics" 4th Ed, Elsevier, 2021

Reference Books:

(1)K Huang, "Statistical Mechanics", John Wiley(NY), 2nd Edition, 1987.
(2)F. Reif, "Statistical and Thermal Physics", Tata McGraw Hill(ND), 2008.
(3)Landau and Lifshitz, "Statistical Physics Part 1", 3rd edition, Elsevier, 2011.

DSC

PHY8C503 **Credits: 4**

GENERAL PHYSICS II AND COMPUTATIONAL TECHNIQUES LAB

T-P: 0-4

	Course Outcomes	**Cognitive level**
CO1	Gain proficiency in using laboratory equipment and instruments.	Apply
CO2	Learn to identify sources of error and quantify their impact.	Apply
CO3	Interpret results and draw meaningful conclusions from experiments	Analysis
CO4	Deepen understanding of fundamental physics concepts through hands-on experimentation.	Understand
CO5	Develop problem-solving skills through troubleshooting experimental setups	Apply

PART A (2 credits)

Experiments

1. Study of magnetic hysteresis - B-H Curve.
2. Dielectric constant by Lecher Wire - To determine the wavelength of the waves from the given RF oscillator and the dielectric constant of the given oil by measurement of a suitable capacitance by using Lecher wire setup.
3. Young's modulus- vibrating strip
4. Cauchy's constants. – Liquid prism (different concentrations)
5. Michelson's interferometer - (a) λ and dλ (b) and the thickness of a mica sheet.
6. Measurement of electrical and thermal conductivity of copper.
7. Band gap of a semiconductor.
8. Thermal conductivity of a liquid and air (poor conductor) by Lee's Disc Method.
9. Temperature of sodium flame. - To determine the temperature of the sodium flame by comparison with an incandescent lamp using a spectrometer
10. Dipole moment of an organic molecule
11. Verification of Curie-Weiss law.

12. B-H curve of a ferromagnetic material.
13. Measurement of a low resistance.
14. Time constant of a serial light bulb.
15. Mode constants of a vibrating strip.
16. Measurement of magnetic susceptibility – Quincke's method
17. e/m Millikan oil drop experiment
18. Frequency estimation using EXPEYES

Elementary experiments using Laser :

19. Laser beam parameters.
20. Diffraction Grating.
21. Diffraction at Circular aperture
22. Refractive Index of liquids.
23. Magneto-striction.
24. Diffraction at rectangular aperture.
25. Diffraction at two circular apertures.
26. Evaluation of beam profile, half divergence and beam waist of the laser

Books for Reference:

1. B.L. Worsnop and H.T. Flint - Advanced Practical Physics for students - Methusen & Co (1950)

2. E.V. Smith - Manual of experiments in applied Physics - Butterworth (1970)

3. R.A. Dunlap - Experimental Physics - Modern methods - Oxford University Press (1988)

4. D. Malacara (ed) - Methods of experimental Physics - series of volumes - Academic Press Inc (1988)

5. S.P. Singh –Advanced Practical Physics – Vol I & II – Pragati Prakasan, Meerut (2003) – 13th Edition

PART B (2 Credits)

General Programs

1. Find the roots of a quadratic equation which can give even complex roots.
2. List the prime numbers between two integers specified.
3. Write a program for finding the determinant and inverse of a 3 x 3 matrix
4. Write a program for plotting square wave using Fourier series coefficients.
5. Find the roots of a transcendental equation using Bisection / Regula Falsi/ Newton-Raphson method with an accuracy specified.
6. Interpolate from the list of data given using Newton's forward / backward interpolation formula and visualize the curve.
7. Interpolate from the list of data given using Newton's general / Lagrange interpolation formula and visualize the curve.
8. Fit the set of data to a straight line using least square curve fitting formula and visualize it.
9. Fit the set of data to a polynomial of degree 2 or 3 using least square curve fitting formula and visualize it.
10. Find the integral of the given function between the limits supplied using Trapezoidal formula
11. Find the integral of the given function between the limits supplied using Simpson's 1/3 or 3/8 rule and find the error in evaluation.
12. Evaluate the indefinite integral Exp[$-x^2$] between the limits 0 to infinity.
13. Solve the first order differential equation using Euler's formula or modified Euler's formula.
14. Solve the first order differential equation using second /fourth order Runge-Kutta formula.
15. Solve the simple harmonic oscillator problem with /without damping and visualize the phase-space diagram.
16. Write a program for finding the inverse of a 3 x 3 matrix using Gauss / Gauss-Jordan method.
17. Find the Eigen values & Eigen vectors of a 3 x 3 symmetric matrix by Householder method.

18. Solving wave equation (parabolic PDE) using finite difference/Crank-Nicolson method
19. Solving Laplace equation (elliptic PDE) using finite difference metho
20. dSolving Hyperbolic PDE using difference approximation approach.
21. Evaluation of Pi using Monte Carlo method
22. Random walk simulation in 2D

Mini-Project

Students have to do a mini project leading to understanding and applications of the theory in consultation with the teacher in charge.

Text Books :

1. Computational Physics -An introduction., R.C.Varma, P.K.Ahluwalia and K.C.Sharma, New Age International Publishers

2. Numpy Reference guide, http://docs.scipy.org/doc/numpy/numpy-ref.pdf (also, free resources available on net)

3. Matplotlib , http://matplotlib.sf.net/Matplotlib.pdf (and other free resources available on net)

4. Numerical Methods in Engineering and Science, Dr. B S Grewal, Khanna Publishers, New Delhi (or any other book)

5. Numerical Methods, E Balagurusamy, Tata McGraw-Hill

6. Numerical Methods , T Veerarajan, T Ramachandran, Tat MCGraw-Hill

7. Numerical Methods with Programs I BASIC, Fortran & Pascal, S Balachandra Rao, C K Shantha. Universities Press

8. Numerical methods for scientists and engineers, K. Sankara Rao, PHI

9. Introductory methods of numerical analysis, S.S.Shastry , (Prentice Hall of India,1983)

10. Numerical Methods in Engineering with Python by Jaan Kiusalaas

DSE
PHY8E501 **Credits: 4**
COMPUTATIONAL TECHNIQUES IN PHYSICS **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Gain expertise in a range of numerical techniques essential for solving complex physical problems, including the ability to apply root finding, numerical integration, and differential equation solving using one of the programming languages like Fortran, C, and Python.	Application
CO2	Develop skills in interpolation, curve fitting, and Fourier transforms to analyze data, model physical systems, and conduct simulations, thus enhancing their capability to predict outcomes and solve practical physics problems.	Analysis
CO3	Achieve a high level of proficiency in scientific programming, focusing on developing efficient, maintainable code for diverse applications in physical sciences, thereby enabling students to handle computational tasks effectively and innovatively.	Synthesis
CO4	Utilize various numerical methods to solve ordinary and partial differential equations, and apply transform techniques such as Fourier transforms to process signals and analyze physical phenomena.	Evaluation
CO5	Develop the ability to evaluate numerical determinants, solve linear systems using methods like Gauss-Jordan and LU Decomposition, and find eigenvalues using techniques suitable for symmetric tridiagonal matrices	Analysis

1. **Roots of Transcendental Equations (10 hours)** Techniques include the Location Theorem, Bisection Method, Method of False, Position (Regula Falsi), Iteration Method, and Newton-Raphson Method.
2. **Interpolation and Curve Fitting (12 hours):** Difference Calculus, Error Detection, Forward, Backward, Central & Divided, Differences, Newton's Forward and Backward Interpolation Formulas,, Lagrange's Interpolation Formula, and Least Squares Curve Fitting for both, Linear and Non-linear models.
3. **Numerical Integration (12 hours):** Trapezoidal Rule, Simpson's Rule, and Gauss Quadrature Methods, indefinite integrals, Random Number Generation, Monte Carlo Integration techniques, emphasizing their importance in simulations and probabilistic analysis used in physical sciences.

4. **Differential Equations and Fourier Transforms** (14 hours): Ordinary Differential Equations (ODEs): Euler's Method, Modified Euler Method, and Runge-Kutta Methods (2nd and 4th order) for solving ODEs, Higher order ODEs. Partial Differential Equations (PDEs): classification of second order PDEs, Finite Difference Approximations to Derivatives, and solving Elliptical, Parabolic, and Hyperbolic Equations, Jacobi's, Gauss-Seidel, and matrix methods. Fourier Transforms and their use in solving differential equations and processingsignals, applications in physics such as waveform analysis and heat equations.

5. **Determinants and Matrices (12 hours):** Evaluation of numerical determinants, Solution of linear systems, Gauss-Jordan Method, LU Decomposition, and Solution of Tridiagonal Systems. Eigenvalue Problems: Techniques for finding Eigenvalues of Symmetric Tridiagonal Matrices, and Householder's Method for matrix transformations.

Text Books:

1. J.B. Scarborough, "Numerical Mathematical Analysis" (6th Edition, Oxford and IBH)

2. S.S. Shastry, "Introductory Methods of Numerical Analysis" (Prentice Hall of India,

1983)

Reference Books:

1. V. Rajaraman, "Computer Programming in Fortran 90" (PHI)

2. "Numerical Recipes in C: The Art of Scientific Computing", Press, Teukolsky, Vetterling; Flannery (Cambridge University Press)

3. "A Guide to Python in Science", dealing with numerical methods and scientific computing (a hypothetical title, replace with an actual relevant Python book if available)

DSE

PHY8E502 **Credits: 4**

MACHINE LEARNING AND AI **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Master the fundamental concepts and algorithms of machine learning, including supervised and unsupervised learning, enabling the analysis and modeling of complex data.	Comprehension
CO2	Develop skills in applying AI techniques such as neural networks, deep learning, and reinforcement learning to solve problems in physics, enhancing their capability to handle large datasets and perform predictive modeling	Application
CO3	Integrate theoretical knowledge with practical skills to design, implement, and optimize machine learning models and AI systems for real-world physics applications.	Synthesis
CO4	Acquire proficiency in evaluating model performance, hyperparameter tuning, and deploying machine learning models, ensuring the effectiveness and efficiency of AI systems in various physics applications.	Evaluation

1. **Introduction to Machine Learning**: Overview of machine learning and its applications in physics. Supervised learning: regression, classification, decision trees, and support vector machines. Unsupervised learning: clustering, dimensionality reduction (PCA, LDA) **(12 hours)**
2. **Neural Networks and Deep Learning**: Basics of neural networks:perceptrons, activation functions, backpropagation, Deep learning architectures: convolutional neural networks (CNNs), recurrent neural networks (RNNs), Training deep networks: optimization techniques, regularization, dropout. **(12 hours)**
3. **Reinforcement Learning:** Fundamentals of reinforcement learning: Markov decision processes, policy and value functions, Basic algorithms: Q-learning, SARSA, Deep Q-Networks (DQN), Applications of reinforcement learning in physics simulations. **(12 hours)**
4. **Advanced AI Techniques (12 hours)** : Natural Language Processing (NLP): textprocessing, sentiment analysis, language models, Generative models: Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs).. AI in scientific computing: automated data analysis, AI-driven experiments. **(12 hours)**
5. **Practical Implementations and Projects** Implementing machine learning models using Python libraries (NumPy, SciPy, Scikit-Learn,

TensorFlow, PyTorch). • Case studies and projects: applying machine learning and AI techniques to real-world physics problems. • Evaluating model performance, hyperparameter tuning, and deployment. **(12 hours)**

Text Books and References •

1. Bishop, "Pattern Recognition and Machine Learning" (Springer)
2. Goodfellow, Bengio, and Courville, "Deep Learning" (MIT Press)
3. Murphy, "Machine Learning: A Probabilistic Perspective" (MIT Press)
4. Russell and Norvig, "Artificial Intelligence: A Modern Approach" (Pearson)

Additional Reference Books:

3. Hastie, Tibshirani, and Friedman: "The Elements of Statistical Learning" (Springer)
4. Chollet: "Deep Learning with Python" (Manning Publications)
5. Sutton and Barto: "Reinforcement Learning: An Introduction" (MIT Press)
6. • Jurafsky and Martin: "Speech and Language Processing" (Pearson)

ONLINE course (optional for MOOC)

PHY8M501 **Credits: 4**

MOLECULAR SPECTROSCOPY **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Interpret the microwave spectra of the molecule and deduce various parameters	Apply
CO2	Interpret the IR spectra of molecule and deduce information about the molecule	Apply
CO3	Deduce molecular structure from combined analsis of raman and IR spectra	Apply
CO4	Interpret the UV-visible spectra and deduce properties of the molecules in ground and excited states	Apply
CO5	Identify the chemical environment of the molecule and apply the concept for imaging internal anatomy of samples	Analyse

1. **Microwave Spectroscopy :** Introduction, The Spectrum of a nonrigid rotator, Example of HF, Spectrum of a symmetric top molecule, Examples, Instrumentation for Microwave Spectroscopy – Information derived from rotational spectra. (9 hours)

   Text : Relevant sections of Banwell and McCash and Barrow

1. **Infrared Spectroscopy :** Vibrational energy of an anharmonic oscillator - diatomic molecule (Morse Curve), IR spectra - Spectral Transitions and Selection Rules, The Vibration - Rotation Spectra of diatomic molecule, Born- Oppenheimer Approximation, Effect of Breakdown of Born-Oppenheimer Approximation, Normal modes of vibration of H2O and CO2, Spectra of symmetric top molecules, Examples, Instrumentation for Infrared Spectroscopy, Fourier transform IR spectroscopy. **(12 hours)**

   Text : Relevant sections of Aruldas, Banwell

2. **Raman Spectroscopy :** Introduction, Rotational Raman Spectrum of diatomic and polyatomic molecules- linear and Symmetric top molecules, Vibrational Raman Spectrum of a Symmetric top molecule, Combined use of Raman and Infrared Spectroscopy in structure determination, Examples, Instrumentation for Raman Spectroscopy, Laser Raman Spectroscopy, Non linear Raman effects, Hyper Raman Effect, Stimulated Raman effect and inverse Raman effect. **(12 hours)**

   Text :(a) Relevant sections of Aruldas, Banwell & McCash and Straughan & Walker

3. **Electronic Spectroscopy of molecules :** Vibrational coarse structure of electronic spectra, Vibrational analysis of band systems, Deslander's table, Progressions and sequences, Information derived from vibrational analysis, Franck-Condon Principle, Rotational fine structure and the R, P and Q branches, Fortrat Diagram, Dissociation Energy, Example of daitomic molecule. **(12 hours)**

   Text :(a) Relevant sections of Aruldas, Banwell & McCash

4. **Spin Resonance Spectroscopy :** Interaction between nuclear spin and magnetic #eld, Level population, Larmor Precession, Resonance condition, Bloch equations, Relaxation times, Spin-Spin and spin-lattice relaxation, The Chemical shift, Instrumentation for NMR spectroscopy, CWNMR and FTNMR, Imaging, Electron Spin Spectroscopy of the unpaired electron, Total Hamiltonian, Fine structure, Electron-Nucleus coupling and hyper#ne structure, ESR spectrometer, Mossbauer Spectroscopy : Resonance Fluorescence of gamma - rays, Recoilless emission of gamma - rays and Mossbauer Effect, Chemical shift, Effect of electric and magnetic fields, Example of Fe-57, Experimental techniques.**(15 hours)**

Text : For ESR & NMR : Relevant sections of Aruldas, Banwell & McCash and Straughan & Walker; For Mossbauer E#ect : Aruldas and G.K. Wertheim

Text books :

1. G Aruldas : Molecular structure and Spectroscopy (Prentice Hall of India, 2002)

2. C.N.Banwell and E.M. McCash : Fundamentals of Molecular Spectroscopy (Tata McGrow Hill, 1994)

3. Gunther K. Wertheim : Mossbauer E#ect : Principles and applications, (Academic Press)

4. Straughan and Walker (Eds): Spectroscopy- Vol. I and II (Chapman and Hall)

5. G.M. Barrow : Introduction to molecular Spectroscopy (McGraw Hill)

Books for Reference:

1. Long D.A : Raman spectroscopy (Mc Graw Hill, 1977)

DSC

PHY9C601 **Credits: 4**

ADVANCED QUANTUM MECHANICS – II **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Calculate the differential cross section of a scattering process	Apply
CO2	Investigate quantum mechanical systems using approximation methods	Apply
CO3	Investigate quantum mechanical systems using variational method	Apply
CO4	Calculate the energy and wave function of a system under the effect of harmonic perturbation	Apply
CO5	Solve free Dirac and Klein – Gordon equation and interpret their solutions	Analyse

1. **Scattering: C**ross section and scattering amplitude; Low energy scattering by a central potential; The method of partial waves; Phase shifts; Optical theorem, Convergence of partial wave series; Scattering by a rigid sphere; Scattering by a square well potential; High energy scattering; Scattering integral equation and Born approximation. **(10 hours)**
2. **Perturbation Theory:** The WKB approximation, Connection formulae, Barrier tunneling, Application to decay- bound states, Penetration of a .potential barrier, Time- independent perturbation theory, Non-degenerate and degenerate cases, Anharmonic oscillator, Stark and Zeeman effects in hydrogen. **(12 hours)**
3. **Variational Metho**d : The variational equation, ground state and excited states, the variation method for bound states, Application to ground state of the hydrogen and helium atoms. **(8 hours)**
4. **Time dependent perturbation theory:** Transition probability, Harmonic perturbation, Interaction of an atom with the electromagnetic field, Induced emission and absorption, The dipole approximation, The Born approximation and scattering amplitude. **(10 hours)**
5. **Relativistic Quantum Mechanics:** The Dirac equation, Dirac matrices, Solution of the free-particle Dirac equation, Equation of continuity, Spin of the electron, Non-realistic limit, Spin-orbit coupling, Covariance of the Dirac equation, Bilinear covariants, Hole theory, The Weyl equation for the neutrino, Non-conservation of parity, The Klein Gordon equation, Charge and current densities, The Klein -Gordon equation with potentials,

Wave equation for the photon, Charge conjugation for the Dirac, Weyl and Klein Gordon equation. **(20 hours)**

Text Books:

1. V. K. Thankappan, Quantum Mechanics, Second Edition, New Age International Publishers, 1993.
2. Nouredine Zettili, Quantum Mechanics: Concepts and Applications, Second Edition, John Wily & Sons Ltd, 2009.
3. J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley, 2010
4. J. D. Bjorken and D. Drell, Relativistic Quantum Mechanics, McGraw Hill, 1998.
5. Greiner and Reinhardt, Field Quantization, Spinger Verlag, 1996

Reference Books:

1. L. I. Schiff, Quantum Mechanics, McGraw Hill, 1968
2. P. M. Mathews and K. Venkatesan, A Text Book of Quantum Mechanics, Tata McGrawHill
3. Stephen Gasiorowicz, Quantum Physics, 3rd edition, Wiley, 2003
4. D. A. Bromley, W. Greiner, Relativistic Qunatum Mechanics, Wave Equations, 3rd ed., Springer
5. Amit Goswami, Quantum Mechanics, 2nd Ed., Waveland Press, 2003.
6. Lewis H. Ryder, Quantum Field theory, Cambridge University Press, 1995
7. Pierre Ramond, Field Theory – A modern primer, Bengamin, 1996

DSC

PHY9C602 **Credits: 4**

NUCLEAR AND PARTICLE PHYSICS **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Describe the basic aspects of nuclear structure and fundamentals of radioactivity.	Understand
CO2	Apply the different types of nuclear reactions.	Apply
CO3	Describe the principle and working of particle and radiation detectors, and particle accelerators	Understand
CO4	Describe the basic principles of elementary particle physics.	Understand

1. **Nuclear Forces:** The deuteron and two-nucleon scattering experimental data, Simple theory of the deuteron structure, Low energy n-p scattering, characteristics of nuclear forces, Spin dependence,Tensor force, Scattering cross sections, Partial waves, Phase shift, Singlet and triplet potentials, Effective range theory, p-p scattering. **(10 hours)**

   Text: K.S.Krane : "Introductory Nuclear Physics" (Wiley)

2. **Nuclear Models, Fission and Fusion:** Shell model potential, Valence Nucleons, Spin-orbit potential, Magnetic dipole moments, Electric quadrupole moments, limitations, Collective structure, Nuclear vibrations, Nuclear rotations, Liquid drop Model, Semi-empirical Mass formula, stability of the neucelus, Energetics of Fission process, Controlled Fission reactions, reactor stability, Fusion process, Characteristics of fusion, solar fusion, Controlled fusion reactors. **(12 hours)**

   Text: K.S.Krane : "Introductory Nuclear Physics" (Wiley)

3. **Nuclear Decay:** Basics of alpha decay and theory of alpha emission, Beta decay, Energetics of beta decay, Fermi theory of beta decay, Comparative half-life, Allowed and forbidden transitions, Selection rules, Parity violation in beta decay. Neutrino-characteristics. Energetics of Gamma Decay, Multipole moments, Decay rate, Angular momentum and parity selection rules, Internal conversion, Lifetimes. **(12 hours)**

Text: K.S.Krane : "Introductory Nuclear Physics" (Wiley)

4. **Nuclear Radiation Detectors and Nuclear Electronics:** Gas detectors – Characteristics, Ionization chamber, 4p counters, Proportional counter and G M counter, Scintillation detector, Photo Multiplier Tube (PMT), Semiconductor detectors – Ge(Li), Si(Li) and surface barrier detectors, Detector efficeincy, intrinsic and geomemtry dependand efficency Preamplifiers, Amplifiers, Single channel analyzers, Multi- channel analyzers, counting statistics, energy measurements, timing meaurements, 4p measurements,**(12 hours)**

   Text: S S Kapoor and V S Ramamurthy: "Nuclear Radiation Detectors" (Wiley)

5. **Particle Physics:** Four basic forces - Gravitational, Electromagnetic, Weak and Strong - Relative strengths, Classification of particles, Yukawa's theory, Conservation of energy and masses, Electric charges, Conservation of angular momentum, Baryon and lepton numbers, Conservation of strangeness, Conservation of isospin and its components, Conservation of parity, Charge conjugation, CP violation, time reversal and CPT theorem. Extremely short lived particles, Resonances - detecting methods and experiments, Internal symmetry, The Sakata model, SU (3), The eight fold way, Gellmann and Okubo mass formula, Quarks and quark model, Confined quarks, Experimental evidence, Coloured quarks. **(14 hours)**

Text Book: Y.Neeman and Y.Kirsh: ''The particle hunters' (Cambridge University Press)45

Books for Reference :

1. H.S.Hans : "Nuclear Physics – Experimental and theoretical" (New Age International, 2001).
2. G.F.Knoll : "Radiation Detection and Measurement, (Fourth Edition, Wiley , 2011)
3. G.D.Couoghlan, J.E.Dodd and B.M.Gripalos "The ideas of particle physics – an introduction for scientists", (Cambridge Press)
4. David Griffiths – "Introduction to elementary particles" – Wiley (1989)
5. S.B.Patel : "An Introduction to Nuclear Physics" (New Ag e International Publishers)
6. Samuel S.M.Wong: "Introductory Nuclear Physics" (Prentice Hall,India)

7. B.L.Cohen : "Concepts of Nuclear Physics" (Tata McGraw Hill)
8. E.Segre : "Nuclei and Particles" (Benjamin, 1967)
9. **K Muraleedhara Varier: "Nuclear Radiation Detection: Measurement and Analysis" (Narosa).**

DSC

PHY9C603 : MODERN PHYSICS LAB T-P: 0-4

(Any 8 experiments to be done from Part A and Part B respectively)

Part A (2 Credits)

1. Ultrasonic interferometer – velocity of sound in liquids - To determine the velocity of ultra sonic waves in the given liquid and hence the compressibility.

2. Determination of band gap energy in Si and Ge by Four probe method.

3. Absorption spectrum of KMnO4 - To determine the wavelengths of the absorption bands for KMnO4 solution.

4. Hall effect in semiconductors - To determine the carrier concentration in the given specimen of semiconducting material by means of the Hall effect.

5. Photoelectric effect - Determination of Planck's constant (White light and filters or LEDs of different colours may be used)

6. Thomson's e/m measurement - To determine the charge to mass ratio of the electron by Thomson's method using a CRT.

7. Frank-Hertz experiment - To measure the critical ionization potentials of Mercury by drawing current vs. applied voltage in a discharge tube

8.ESR spectrometer – Determination of g factor.

.9. Thermionic work function - To determine the thermionic work function of the material of the cathode of the given vacuum diode/triode from the characteristics at different filament currents.

10. Optical fibre characteristics - To determine the numerical aperture, attenuation and band width of the given optical fibre specimen

11. Study of LED characteristics - Determination of wavelength of emission, I-V characteristics and variation with temperature, variation of output power vs. applied voltage.

12. Fabry Perot etalon - Determination of wavelength and thickness of air film

13. Thermo emf of bulk samples – Al, Cu, Brass etc.

14. Determine the thermal conductivity of the given bulk specimen using the given setup.

15. Zener voltage characteristics at low and ambient temperatures - To study the variation of the Zener voltage of the given Zener diode with temperature.

16. Study of LED characteristics - Determination of wavelength of emission, I-V characteristics and variation with temperature, variation of output power vs. applied voltage.

Part B (2 Credits)

1. G.M. Counter plateau and statistics of counting - To obtain the plateau, operating voltage and to verify the distribution law satisfied by the radioactive decay.

2. Absorption coefficient for gamma rays -To determine the absorption coefficient of the given material for Cs-137 gamma rays using a G.M. Counter.

3. Absorption coefficient for beta rays -To determine the absorption coefficient of the given material for beta rays from beta sources using a G.M. Counter.

4. Feather analysis – End point energy - To determine the end point energy of the beta particles from a given source using Feather analysis.

5. Scintillation counter - To calibrate the given gamma ray (scintillation) spectrometer using standard gamma sources and to determine the energy of an unknown gamma ray source.

6. Compton scattering - To verify the theoretical expression for the energy of the Compton scattered gamma rays at a given angle using a Scintillation gamma spectrometer / determine the rest mass energy of the electron.

7. To verify the inverse square law in the emission of gamma rays from a radioactive source.

8. Half life of Indium – thermal neutron absorption - To determine the half life of In-116 by irradiation of In foil with neutron and beta counting using a GM counter.

9. Alpha spectrometer - To calibrate the given alpha spectrometer and determine the resolution.

10. Photoelectric effect in lead - To get the spectrum of X rays emitted from lead target by photo electric effect using Cs-137 gammas

11. Band gap energy of the given thin film sample by four probe method.

12. Find the thermal conductivity of the given crystal sample.

13. Obtain the UV-Visible absorption spectra of the given liquid/solid.

14. Determine the dielectric constant of the given material using LCR high tester.

15. Obtain the powder diffraction data of the given sample and study its crystalline behavior. Compare the values with ICDD.

16. Obtain the surface features of a thin film sample using AFM.

17. Find the etched pattern of the given crystal using optical microscope.

18. Find the sheet resistivity of the given thin film sample.

DSE

PHY9E601 **Credits: 4**

ADVANCED SOLID STATE PHYSICS **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Describe the relevance of vibratory excitations in crystals. Arrive at a proper explanation for specific heat based on various models	Analyse
CO2	Explain the free electron model and interpret the properties of metals. Gain a deeper understanding of the energy bands based on the properties of carriers.	Understand
CO3	Apply the Quantum mechanical and statistical mechanical knowledge into the understanding solid state properties	Apply
CO4	Interpret properly the thermal, electrical and magnetic properties of materials. Enable the student to understand the current research going on in the related areas	Analyse
CO5	Illustrate using phase diagrams, phase transitions in materials leading to superconductivity and different types of superconductors	Analyse

1. **Crystal structure and Lattice Vibrations**: Reciprocal lattice, Brillouin zones, Vibrations of monatomic and diatomic lattices, Quantization of lattice vibrations, Inelastic scattering of neutrons, Einstein and Debye models of specific heat. **(10 hours)**
2. **Electron States and semiconductors**: Free electron gas in three dimensions, heat capacity of electron gas, electrical conductivity and Ohm's law, Experimental electrical resistivity of metals, Motion in magnetic fields, Hall effect, Thermal conductivity of metals (Wiedemann-Franz law), Nearly free electron model-origin of energy bands, Magnitude of energy gap, Bloch functions, Kronig Penny model, Semiconductor crystals: band gap, direct/indirect bad gap SCs, Equation of motion, Holes, Effective masses in semiconductors. **(14 hours)**
3. **Dielectric and Ferroelectric properties**: Theory of Dielectrics: Polarisation, Dielectric constant, Local Electric field, Dielectric polarisability, Clausius- Mossotti relation, Polarisation from dipole orientation, Dielectric losses, Ferroelectric crystals, Order-disorder type ferroelectrics, Properties of BaTiO3, Polarisation catastrophe, Displacive type ferroelectrics, Landau theory of ferroelectric phase transitions, Ferroelectric domain, Antiferroelectricity, Piezoelectricity, Applications of

Piezoelectric Crystals **(12 hours)**

4. **Magnetic properties:** Langevin's diamagnetism equation, Quantum theory of diamagnetism of mononuclear systems, Quantum theory of paramagnetism, Hund's rule, Paramagnetic susceptibility of conduction electrons, Ferro, Anti and Ferri magnetism: Curie point and the exchange integral, Magnons, Ferrimagnetic order, Curie temperature and susceptibility of ferrimagnets, Antiferromagnetic order. Weiss theory of ferromagnetism, Ferromagnetic domains, Bloch walls, Origin of domains, Novel magnetic materials: GMR-CMR materials (qualitative). **(12 hours)**
5. **Superconductivity :** Meissner effect, Type I and Type II superconductors, Heat capacity, Microwave absorption, Energy gap, Isotope effect, Free energy of superconductor in magnetic field and the stabilization energy, London equation and penetration of magnetic field, Cooper pairs and the B C S ground state (qualitative), Flux quantization, Single particle tunneling, DC and AC Josephson effects, High Tc superconductors (Qualitative) - description of thecuprates). Technological applications of superconductivity **(12 hours)**

Textbooks :

1.C.Kittel: "Introduction to Solid State Physics" (7^{th} Ed., Wiley Eastern)

2. Srivastava J.P.: "Elements of Solid State Physics", (2^{nd} Edition, Prentice Hall of India)

References

1.A.J.Dekker : "Solid State Physics" (Macmillan, 1958)

2.N.W.Ashcroft and Mermin, "Solid State Physics", Brooks Cole, 1976)

3.Ziman J.H. : "Principles of the Theory of Solids" (Cambridge, 1964)

4. Hari Singh Nalwa, Ed., "Nanoclusters and Nanocrystals" (American Scientific Publishers, 2003)

DSE

PHY9E602 **Credits: 4**
VACUUM TECHNIQUES AND THIN FILM TECHNOLOGY **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Explain vacuum, Gauges to measure vacuum, types of pumps and their utility, cryogenics etc.	Understand
CO2	Demonstrate different thin film fabrication techniques and their thickness measurement	Analyse
CO3	Describe the applications of Thin films	Understand
CO4	Analyse the crystal structure using X-ray Diffraction technique	Apply
CO5	Articulate various morphological analysis techniques related to nanomaterials	Understand

5. **Vacuum Techniques** : Units and basic definitions, Roughing pumps - Oil sealed rotary vacuum pump and Sorption pump, High vacuum pumps – Turbo molecular pump, Diffusion pump, Oil vapour booster pump, Ion pumps - Sputter ion pump, Cryo pump, Vacuum gauges - Pirani gauge, Thermocouple gauge, penning guage Vacuum accessories – Diaphragm, Gate valve, Butterfly valve, Baffle and isolation valves, magnetic valves, adjustable valves, air inlet valves, Traps - Liquid nitrogen trap, Sorption traps, and gaskets and O rings **(16 hours)**

6. **Thin film fabrication**: Introduction, Fabrication of thin films, Physical vapour deposition, chemical vapour deposition, Thermal evaporation in vacuum – Resistive heating, Electron beam evaporation, Pulsed laser deposition, Sputter deposition, Magnetron sputtering, Spray pyrolysis, Spin coating methods.
(13 hours)

7. **Film thickness measurement and Characterization** : Thickness measurement by quartz crystal monitor, optical interference method, electrical conductivity measurement, Thermo electric power, Interference filters - Multi layer optical filters, Technological Applications of thin films.

   (10 hours)

8. **Structural Analysis using XRD:** Introduction, Lattice planes and Bragg's Law, Diffractometer - Instrumentation, Single crystal and Powder diffraction, Scherrer equation, Structure factor, Applications of XRD - Crystallinity, Unit Cell Parameters, Phase transition studies, thin film studies, Powder Diffraction File (PDF) of the International Centre for Diffraction Data. **(9 hours)**

9. **Morphological Analysis of nanomaterials:** Introduction, Interaction of electron beam with matter, Scanning Electron Microscope (SEM), Instrumentation, Imaging using Secondary electrons, Backscattered electron imaging, Applications of SEM, Energy Dispersive X-ray spectroscopy, Transmission electron Microscopy, Scanning Probe Microscopes (SPM), Scanning Tunneling Microscope (STM), Atomic Force Microscope (AFM). **(12 hours)**

Textbooks:

1. Guozhong Cao, Nanostructures and Nanomaterials- Synthesis, Properties, Imperial College Press, 2004
2. Muraleedhara Varier, Antony Joseph and P.P.Pradyumnan: "Advanced Experimental Techniques in Modern Physics" (Pragati Prakashan, 2006)
3. Jens Als Nielsen and Des McMorrow Elements of Modern X-ray Physics,, (John Wiley and Sons 2000)
4. Nanotechnology: Principles and Practices, Sulabha K. Kulkarni, Springer, 3rd Edition Springer 2015

Books for Reference:

1. Scientific foundations of vacuum techniques – S. Dushman and J.M. Laffer, John Wiley New York (1962)
2. Thin film phenomena – K.L. Chopra, Mc Graw Hill (1983)
3. R. Berry, P.M. Hall and M.T. Harris – Thin film technology – Van Nostrand (1968)
4. Lafferty J.M, Foundations of Vacuum Science and Technology, Wiley, 1998.
5. Bharat Bhushan, Encyclopedia of nanotechnology, Springer, 2012
6. B.D. Cullity, Elements of X-ray diffraction, Addison Wesley Inc (1978)
7. Useful Link for XRD-http://pd.chem.ucl.ac.uk/pdnn/powintro/whatdiff.htm

DSE

PHY9E603 **Credits: 4**

ADVANCED ASTROPHYSICS **T-P: 4-0**

	Course Outcome: **After completion of the full course the student should be able to**	**Cognitive level**
CO1:	Describe the basic structure and evolution of stars	Understand
CO2:	Demonstrate different kinds of stars	Apply
CO3:	Describe the formation, structure and evolution of galaxies	Understand
CO4:	Describe the importance of the general theory of relativity and its applications	Understand, Apply
CO5:	Elaborate the different cosmological concepts	Understand

1. **STELLAR STRUCTURE AND EVOLUTION:** The contraction of stars towards the main-sequence, The main-sequence phase, The Giant phase, The final stages of evolution, White dwarfs, Neutron stars, Black holes (qualitative idea only)**,** Stellar structure: Hydrostatic equilibrium , Pressure equation of state, Energy generation in stars: Gravitation and the Kelvin – Helmholtz time scale, nuclear time scale, Stellar nucleosynthesis, Energy transport and thermodynamics: Conduction, Convection, Radiation **(12 hours)**

   Sections 11.2 to 11.5, 14.1 to 14.3 of Fundamental Astronomy by Karttunen et al

   Relevant portions from Chapter 10 of B.W. Carroll & D.A. Ostille : "Modern Astrophysics", (Addison Wesley, 1996)

2. **THE NATURE OF STARS: Binary systems-**The classification of binary stars, Mass determination using Visual binaries, Eclipsing, Spectroscopic binaries. **Variable stars:** Observations of pulsating stars, The physics of stellar pulsations, Non-radial stellar pulsations **(12 hours)**

   Text: Relevant sections from Chapter 7 and Chapter 14 of B.W. Carroll & D.A. Ostille : "Modern Astrophysics", (Addison Wesley, 1996)

3. **GALAXIES:** The Milky Way Galaxy, Stellar luminosity function, The rotation of the Milky Wy, Structural components of the Milky Way, The formation and evolution of the Milky Way, The classification of Galaxies,

Luminosities and Masses, Galactic Structure, Dynamics of Galaxies, Systems of Galaxies, Active galaxies and quasars, The origin and Evolution of Galaxies **(14 hours)**

Section 17.2 to 17.5 and Section 18.1 to 18.9 of Fundamental Astronomy by Karttunen et al

4. **GENERAL RELATIVITY**: General Considerations – Space, time and gravitation, Tensors, Metric for weak gravitational field, The Energy-momentum tensor, Einstein's equations, Some applications of general relativity : Gravitational redshift, The Schwarzschild metric- motion of massless particle, The bending of light, Gravitational waves **(10 hours)**

   Text : Arnab Rai Choudhuri, Relevant portions from Chapters 12

5. **INTRODUCTION TO COSMOLOGY**: Isotropy and homogeneity, The Red Shift, Scale factor and Distance , Cosmic microwave background, Equivalence principle, describing curvature, Robertson-Walker metric, proper distance, The Friedmann model, The history of the Universe (qualitative idea) **(12 hours)**

   Text : Barbara Ryden Chapters 2 and 3

   Relevant sections of Chapter 19 of Fundamental Astronomy by Karttunen et al

Books for Reference :

1. Steven Weinberg : "Gravitation & Cosmology", (John Wiley (1972)

2. T. Padmanabhan : "Theoretical Astrophysics", Vol 1 and 2 (Cambridge University Press, 2000)

3. Ajit K Kembhavi and Jayat V Narlikar: "Quasars and Active Galactic Nuclei", (Cambridge University Press, 1999)

4. F. Shu : "The Physical Universe, An Introduction to Astronomy", (Oxford University Press, 1982)

5. Fred Hoyle, Geoffrey, Jayant V Narlikar :"A Different Approach to Cosmology", (Cambridge University Press, 2000)

6. Baidyanath Basu :"An Introduction to Astrophysics", (Prentice Hall India , 1997)

7. R.C. Bless : "Discovering the Cosmos", (University Science Books,1996)

8. V.B. Bhatia : "Text Book of Astronomy and Astrophysics with Elements of Cosmology", (Narosa publications, 2001)

9. B.W. Carroll & D.A. Ostille : “Modern Astrophysics”, (Addison Wesley, 1996)

10. J. Binney & M. Merrifield :”Galactic Astronomy”,(Princeton University Press)

11. J. Binney & S. Tremaine :”Galactic Dynamics”, (Princeton University Press)

12. J. V. Narlikar,:”An Introduction to Cosmology”, (Third Edition, Cambridge University Press, 2002)

13. Barbara Ryden: “An Introduction to Cosmology”, (Second Edition, Cambridge University Press, 2017)

14. Arnab Rai Choudhuri: “Astrophysics for Physicists”, Cambridge University Press

15. H. Karttunen, P. Kroger, H. Oja, M. Poutanen, K. J. Donner (Eds.): “ Fundamental Astronomy

DSE

PHY9E604 **Credits: 4**

RADIATION PHYSICS **T-P: 4-0**

	Course Outcome: **After completion of the full course the student should be able to**	**Cognitive level**
CO1	Verify through experiments that radiations are primarily divided into ionising and nonionising. Alsounderstand diffrent sources under each category. Production methods of each will also be identifid.	Analyse
CO2	Analyse the interaction mechanism of eachcategory, giving emphasize to scattering and absorption.	Analyse
CO3	Elaborate the beneficial or harmful effects of radiations.	Understand
CO4	Analyse both stochastic and deterministic effects useful in planning for diagnosis and treatment.	Understand, Apply
CO5	Implement proper shielding in laboratories where sources are stored and in transportation.	Analyse

1. **Radiation source** : Types of radiations, ionizing, non ionizing, electromagnetic, particles, neutral – gamma- neutrino-neutron, charged alpha, beta, gamma, and heavy ion sources, radioactive sources - naturally occurring production of artificial isotopes, accelerators -cyclotrons, nuclear reactors. **(9 hours)** Ref 1, 2

2. **Interaction of radiations with matter** : Electrons - classical theory of inelastic collisions with atomic electrons, energy loss per ion pair by primary and secondary ionization, specific energy loss, bremsstrahlung, range energy relation, energy and range straggling Heavy charged particles - stopping power, energy loss, range and range - energy relations, Bragg curve, specific ionization, Gamma rays - Inter action mechanism - Photoelectric absorption, Compton scattering, Pair production, gamma ray attenuation, attenuation coefficients, Elastic and inelastic scattering, Cross sections, linear and mass absorption coefficients, stopping power, LET, Neutrons - General properties, fast neutron interactions, slowing down and moderation. **(15 hours)** Ref 1,2

3. **Radiation quantities, Units and Dosimeters :** Particle flux and fluence, calculation of energy flux and fluence, Curie, Becquerel, exposure

and its measurements, absorbed dose and its relation to exposure, KERMA, Biological effectiveness, weighting factors, (WR and WT), Equivalent dose, Effective dose, Dosimeters, Primary and secondary dosimeters, Pocket dosimeter, Films and solid dosimeter (TLD and RPL), Clincal and calorimetric devices , Radiation survey meter for area monitoring. **(12 hours)** Ref 2,3

4. **Biological effects :** Basic concepts of cell biology, Effects of ionizing radiations at molecular, sub molecular and cellular levels, secondary effects, free radicals, deterministic effects, stochastic effects, Effects on tissues and organs, genetic effects, Mutation and chromosomal aberrations, applications in cancer therapy, food preservation, radiation and sterilization. **(10 hours)** Ref 3,4

5. **Radiation protection, shielding and transport :** Effective radiation protection, need to safeguard against continuing radiation exposure, justifcation and responsibility, ALARA, concept of radiologic practice. time distance and shielding, safety specifications. method of radiation control, Shielding factor for radiations, Choice of material, Primary and secondary radiations, Source geometry, Beta shielding, Gamma shielding, neutron shielding, Shielding requirements for medical, industrial and research facilities, handling of the source, sealing, transport and storage of sealed and unsealed sources. records, spills, waste disposal. **(14 hours)**

Books for Reference:

1. G.F.Knoll : Radiation detection and measurement (John Wiley & sons, Newyork, 2000)

2. K.Thayalan : Basic radiological physics (Jaypee Brothers Medical Publishers, New Delhi, 2003)

3. W.J. Meredith and J.B. Masse: Fundamental Physics of radiology (Varghese publishing house)

DSE

PHY9E605 **Credits: 4**

SOFT MATTER PHYSICS **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Illustrate the thermodynamic properties of soft materials	Apply
CO2	Explain the basic ideas of colloidal systems	Understand
CO3	Explore the liquid crystal phases and its relevance in biology	Apply
CO4	Correlate the Pair Correlation Function and Radius of Gyration	Analyze
CO5	Illustrate the thermodynamics of self-assembly	Apply

1. **Introduction to soft matter :** Overview of soft matter, entropy in disordered systems; forces, energies, and time scales in soft matter, intermolecular forces, macromolecules, Rheological and Microbiological studies.**(12 hours)**
2. **Colloidal systems:** Surface phenomenon and stability of colloidal systems; The Poisson–Boltzmann equation, DLVO theory: van der Waals versus Electrostatic Interactions, Solutions of Colloidal Particles. **(12 hours)**
3. **Liquid Crystals :** Introduction to liquid crystals, Classification of liquid crystals, Electric and magnetic field effects, Kerr effect, Biological importance of liquid crystals, Elastic continuum theory.**(12 hours)**
4. **Polymers:** Single-chain conformations, The ideal (or Gaussian) chain, Pair correlation function and radius of gyration, The Flory chain, Chains in interaction, The mean field approach, Scaling laws for athermal solutions. **(12 hours)**
5. **Self-assembly and interface science :** Thermodynamics of self-assembly, formation of aggregates, critical micellar concentration, soluble monolayer and Gibbs adsorption, insoluble (Langmuir) monolayers, characterization of Langmuir monolayers; interactions in lamellar flexible systems, elasticity of neutral membranes. **(12 hours)**

Text Books:

8. Soft condensed matter by R. A. L. Jones, Oxford University Press
9. Experimental and computational techniques in soft condensed matter physics edited by Jeffrey Olafsen, Cambridge University Press 2010
10. Liquid Crystals: Nature delicate phase of matter by P. J. Collings, Princeton University Press
11. Liquid crystals by S. Chandrashekar
12. Polymer Physics by Tanaka Fumihiko, Cambridge University Press

Reference Books:

7. Intermolecular and surface forces by Jacob N. Israelachvili. Published by Academic Press.
8. 2. The physics of liquid crystals by P. G. de Gennes and J. Prost. Published by Oxford Science Publications.
9. Soft matter physics- An introduction by Maurice Kleman and Oleg D. Lavrentovich. Published by Springer.

DSE

PHY9E606 **Credits: 4**

EXPERIMENTAL TECHNIQUES **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Explain vacuum, Gauges to measure vacuum, types of pumps and their utility, cryogenics etc.	Understand
CO2	Demonstrate different thin film fabrication techniques, thickness measurement and application of thin films.	Apply
CO3	Explain different types of particle accelerators and their working and specific applications.	Understand
CO4	Explain methods of materials analysis using different nuclear techniques.	Understand
CO5	Apply X-ray techniques to characterise materials.	Apply

1. **Vacuum Techniques** : Units and basic definitions, Roughing pumps - Oil sealed rotary vacuum pump and Sorption pump, High vacuum pumps – Turbo molecular pump, Diffusion pump, Oil vapour booster pump, Ion pumps - Sputter ion pump and Getter ion pump, Cryo pump, Vacuum guages - Pirani gauge, Thermocouple gauge, penning guage (Cold cathode Ionization guage) and Hot filament ionization gauge, Vacuum accessories – Diaphragm, Gate valve, Butterfly valve, Baffle and isolation valves, magnetic valves, adjustable valves, air inlet valves, Traps - Liquid nitrogen trap, Sorption traps, and gaskets and O rings, **(15 hours)**

   Texts : Muraleedhara Varier et al. "Advanced Experimental Techniques in Modern Physics", Sections 1.4, 1.6 – 1.8, 1.9.2.3 – 1.9.2.5, 1.10.1, 1.10.6, 1.10.3

2. **Thin film techniques** : Introduction, Fabrication of thin films, Thermal evaporation in vacuum – Resistive heating, Electron beam evaporation and laser evaporation techniques, Sputter deposition, Glow discharge, Thickness measurement by quartz crystal monitor, optical interference method, electrical conductivity measurement, Thermo electric power, Interference filters - Multi layer optical filters, Technological Applications of thin films, Enough exercises. **(12 hours)**

   Text : Muraleedhara Varier, et al. "Advanced Experimental Techniques in Modern Physics" Sections 2.1, 2.2.1.1, 2.2.1.4, 2.2.1.5, 2.2.2, 2.3.2, 2.3.3, 2.3.1, 2.7, 2.6.1

3. **Accelerator techniques** : High voltage DC accelerators, Cascade generator, Van de Graaff accelerator, Tandem Van de Graaff accelerator, Linear accelerator, Cyclotron, Synchrotron (Electron and proton), Ion sources – Ionization processes, simple ion source, ion plasma source and

RF ion source, Ion implantation – techniques and profiles, Ion beam sputtering– principles and applications, Enough exercises. **(12 hours)**

Text : Muraleedhara Varier, et al. "Advanced Experimental Techniques in Modern Physics", Sections 4.3, 4.4, 4.5.1, 4.5.4, 4.5.5, 4.6, 4.8.1 – 4.8.3, 4.9

4. **Materials Analysis by nuclear techniques**: Introduction, Basic principles and requirements, General experimental setup, mathematical basis and nuclear reaction kinematics, Rutherford backscattering – introduction, Theoretical background – classical and quantum mechanical, experimental set up, energy loss and straggling and applications. Neutron activation analysis – principles and experimental arrangement, applications, Proton induced X-ray Emission – principle and experimental set up, applications to water samples, human hair samples and forensic samples, limitations of PIXE , Enough exercises. **(12 hours)**

   Text: Advanced Experimental Techniques in Modern Physics – K. Muraleedhara Varier, Antony Joseph and P.P.Pradyumnan, Pragati Prakashan, Meerut (2006)

5. **X- Ray Diffraction Technique:** Introduction, Lattice planes and Bragg's Law, Diffractometer - Instrumentation, Single crystal and Powder diffraction, Scherrer equation, Structure factor, Applications of XRD - Crystallinity, Unit Cell Parameters, Phase transition studies, thin film studies, Awareness on Powder Diffraction File (PDF) of the International Centre for Diffraction Data. **(9 hours)**

Text Book: Elements of Modern X-ray Physics, Jens Als Nielsen and Des McMorrow, (John Wiley and Sons 2000)

Books for Reference:

1. Scientific foundations of vacuum techniques – S. Dushman and J.M. Laffer, John Wiley New York (1962)
2. Thin film phenomena – K.L. Chopra, Mc Graw Hill (1983)
3. R. Sreenivasan – Approach to absolute zero - Resonance magazine Vol 1 no 12 , vol 2 nos 2, 6 and 10
4. R. Berry, P.M. Hall and M.T. Harris – Thin film technology – Van Nostrand (1968)
5. Dennis and Heppel – Vacuum system design
6. Nuclear Micro analysis – V. Valkovic
7. B.D. Cullity, Elements of X-ray diffraction, Addison Wesley Inc (1978)
8. Useful Link for XRD-http://pd.chem.ucl.ac.uk/pdnn/powintro/whatdiff.htm

DSE

PHY10E601 **Credits: 4**

ADVANCED NUCLEAR PHYSICS **T-P: 4-0**

	Course Outcome	Cognitive level
CO1	Explain the basics of nucleus, nuclear properties and necessity of shell model and collective models.	Analyse
CO2	Apply these models to explain the filling up of neutron and protons inside shells and explain the properties of the nuclei.	Apply
CO3	Calculate the moment of inertia of any rotational nuclei, energy levels of vibrational nuclei	Evaluate
CO4	Explain the different models of particle accelerators and their use.	Analyse

1. **Nuclear Shell Model:** Shell structure and magic numbers, The nuclear one particle potential, spin orbit term, realistic one body potentials, Nuclear volume parameter, single particle spectra of closed shell + 1 nuclei, Harmonic oscillator and infinite square well potentials in 3-dimensions, coupling of spin and orbital angular momentum, magnetic dipole moment and electric quadrupole moment, Schmidt diagram; Single particle orbitals in deformed nuclei, perturbation treatment, asymptotic wave functions, single particle orbitals in an axially symmetric modified oscillator potential**(16 hours)**

   Text :S.G. Nilsson and I. Ragnarsson: "Shapes and Shells in Nuclear Structure", (Cambridge University Press; Revised ed. Edition, 2005)

2. **Nuclear Collective Models**: Nuclear rotational motion- rotational energy spectrum and wave functions for even-even and odd A nuclei - Nuclear moments- collective vibrational excitations, Rotational Bands – The particle rotor model, strong coupling- deformation alignment, Decoupled bands - rotational alignment; two particle excitations and backbending; Fast nuclear rotation- the cranking model; Rotating harmonic oscillator**(12 hours)**

   Text : 1. R.R. Roy and B.P. Nigam :"Nuclear Physics- Theory and Experiment", (Wiley Eastern)

S.G. Nilsson and I. Ragnarsson: “Shapes and Shells in Nuclear Structure”, (Cambridge University Press; Revised ed. Edition, 2005)

M K Pal : “Theory of Nuclear Structure”,(East West Press Pvt. Ltd).

3. **Nuclear Reactions:** Reactions and Cross-sections, Resonances, Breit-Wigner formula for l = 0, Compound Nucleus formation, continuum theory, statistical theory, evaporation probability, Heavy ion reactions. **(10 hours)**

   Text : R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)

   Kenneth S. Krane : “ Introductory Nuclear Physics”, (Wiley)

4. **Nuclear Fission:** The semi-empirical mass formula , The stability peninsula, nuclear fission and the liquid drop model, some basic fission phenomena, fission barrier. Nuclear Fission- cross- section, spontaneous fission, Mass and energy distribution of fragments, Statistical model of Fission**(10 hours)**

   Text : R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)

5. **Accelerators:** Electrostatic accelerator, cyclotrons, synchrotrons, linear accelerators , colliding beam accelerators **(12 hours)**

Text:

1. R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)

2. Samuel M. Wong : “Introductory Nuclear Physics”, (Prentice Hall India 1996)

3. H.S. Hans : “Nuclear Physics – Experimental and theoretical”, (New Age International, 2001)

DSE

PHY10E602 **Credits: 4**

ADVANCED MATERIAL SCIENCE **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Define different types of imperfections in crystals.	Understand
CO2	Analyse different phase diagrams and elucidate the expected properties.	Apply
CO3:	Identify different types of silicates and understand the importance and application of ceramic materials.	Analyse
CO4:	Explain unsaturated hydrocarbons, different types of polymerization and its application.	Analyse
CO5:	Define types of liquid crystals, quasi crystals, fullerenes, nano structures and their applications.	Understand

1. **Imperfections in crystalline materials** : Materials and its classifications, Thermodynamics of Schottky and Frenkel Defects, Equilibrium number of Point Defects as a function of temperature, Interstitial Diffusion, Self-diffusion, Determination of Diffusion constant, Edge and Screw Dislocations, Energy of Dislocation, Dislocation motion, Dislocation Multiplication: Frank-Read mechanism, Work Hardening of Metals, Exercises.**(10 Hours)**

2. **Alloys and Phase diagrams** : Binary phase diagrams from Free energy considerations, case of complete miscibility, Gibbs phase rule, The lever rule, Rules of solid solubility, Hume-Rothery Electron compounds, case of limited solid solubility, the Eutectic temperature. Design of alloys, Applications of alloys. **(12 Hours)**

3. **Ceramic Materials** : Silicate structure, Polymorphism, Solid solution, Non-ductile fracture, Plastic deformation of layered structures, Viscous deformation of glass, Electrical properties of ceramics, Application of ceramic materials.**(10 hours)**

4. **Polymers:**Unsaturated hydrocarbons, Polymer size, Addition polymerization, Copolymerization, Condensation polymerization,

Thermoplastic and thermosetting resins, Elastomers, Cross-linking, Branching, Application of polymers**.(12 Hours)**

5. **Liquid crystals, Quasi crystals and Nanomaterials:** Structure and symmetries of liquids, Liquid crystals and amorphous solids, Application of liquid crystals, Aperiodic crystals and quasicrystals, Formation and characterization of Fullerenes and tubules, Carbon nanotube based electronic devices, Synthesis and properties of nanostructured materials, Experimental techniques for characterizing nanostructured materials, Quantum size effect and its applications, Exercises. **(16 Hours)**

Text books

1.Solid State Physics, A.J. Dekker (MacMillan, 1958)
2.Introduction to Solid State Physics, C. Kittel(Wiley Eastern, 1977).
3.Materials science and engineering-V Raghavan, (pHI, 2015)

Books for Reference:

1.“Elements of Materials Science”, L.H. Van Vlack (Addison Wesley)
2.“Physics of Thin Films”, K.L.Chopra
3.“Thin Films”, O.S.Heavens
4.“Multiple Beam Interferometry”, Tolansky
5.“Transmission Electron Microscopy”, Thomas
6.“The Physics of Quasicrystals”, Ed. Steinhardt and Ostulond
7.“Handbook of Nanostructured Materials and Nanotechnology”, Ed. Harisingh Nalwa

DSE

PHY10E603 **Credits: 4**

QUANTUM FIELD THEORY **T-P: 4-0**

	Course Outcome	**Cognitive level**
CO1	Illustrate the canonical quantization of electromagnetic and Schrodinger field. electron-photon interaction at a more fundamental level.	Understand
CO2	Substantiate the necessity of quantization for studying the behavior of identical many particle system, like atoms, molecules, nuclei.	Apply
CO3	Describe the canonical quantization of photon field	Apply
CO4	Calculate the Feynman propagator for any field	Analyse
CO5	Describe all types of interactions as current-current interactions	Analyse

Unit I: Classical Field Theory (14 hours)

Harmonic oscillator, The linear chain- classical treatment, the linear chain – quantum treatment, classical field theory, Hamiltonian formalism, Functional derivatives, Canonical quantization of nonrelativistic fields, Lagrangian and Hamiltonian for the Schroedinger field, Quantization of fermions and bosons, Normalization of Fock states.

Unit II: Canonical quantization of Klein Gordon field (10 hours)

The neutral Klein – Gordon field Commutation relation for creation and annihilation operators, Charged Klein – Gordon field, Invariant commutation relations, Scalar Feyman propagator,

Unit III: Canonical quantization of photon field (12 hours)

Maxwells equations, Larangian density for the Maxwell field, Electromagnetic field in the Lorentz gauge, Canonical quantization of the Lorentz gauge – Gupta-Bleuler method, Canonical quantization in the Coulomb gauge.

Unit IV: Canonical quantization of spin ½ fields (12 hours)

Lagrangian and Hamiltonian densities for the Dirac field, Canonical quantization of the Dirac field, Plane wave expansion of the field operator, Feyman propagator for the Dirac field.

Unit V: Interacting quantum fields and Quantum Electrodynamics (12 hours)

The interaction picture, Time evolution operator, Scattering matrix, Wick's theorem, Feynman rules for QED, Moller scattering and Compton scattering.

Text Book

Greiner and Reinhardt, Field Quantization, Spinger-Verlag -1996.

Reference Books

13. Lewis H. Ryder, Quantum Field theory, Cambridge University Press - 1995.
14. Pierre Ramond, Field Theory – A modern primer, Bengamin – 1996.
15. Itzyskon and Zuber, Quantum Field theory, McGraw Hill – 1989.
16. Karson Huang, Quantum Field theory, Wiley

Pattern of Question Paper for Core and Elective courses in M.Sc. Physics w.e.f. 2024

Reg. No: **Code:** **Name:**

1^{st} / 2^{nd} / 3^{rd} / 4^{th} Semester M.Sc. Degree Examination – w.e.f 2024,

CCSS – M.Sc. Programme

Code: (e.g. PHY01C501:) Subject (e.g. CLASSICAL MECHANICS AND CHAOS)

Time : 3 hours Total Marks = 50

Section A

(8 Short questions each answerable within 7 minutes)

(Answer **ANY EIGHT** questions, each carry 2 Marks)

Question Numbers 1 to 10 Total Marks 8 x 2= 16

Section B

(3 essay questions each answerable within 20 minutes)

(Answer **ANY THREE** questions, each carry 6 Marks)

Question Numbers 11 to 15 Total Marks 3 x 6= 18

Section C

(4 problems answerable each within 16 minutes)

(Answer **ANY FOUR** questions, each carry 4 Marks)

Question numbers 16 to 22 Total marks 4x4 = 16 marks