# Vidyasagar University
## Midnapore-721102, West Bengal

**The SYLLABUS for**
**POST-GRADUATE Programme**

**in**

# PHYSICS

Under Choice Based Credit System (CBCS)
(Semester Programme)


**[w.e.f. 2022-23]**

## *Preamble*

Physics department at Vidyasagar University has started its journey in the year 1989. The Department offers M.Sc. Physics course and Ph.D. programme. The Department is well established with eight sanctioned faculty strengths. Extramural grants from DST-FIST, CSIR, UGC-SAP and AICTE, as well as intramural grants from the University, have strengthened the Department's research and teaching learning infrastructure. The well established department is equipped with neat and clean lecture galleries, laboratory rooms with modern instruments, rich departmental library, ICT enabled seminar room, a modern computer lab and different high end research labs. The M.Sc. Physics programme offered by University is two years' in duration and is divided into four semesters. The Choice-Based Credit System (CBCS) was introduced in 2018. The courses are synchronized with the UGC model syllabus and the assigned credits are fixed on the basis of teaching hours, which in turn is linked to course content and structure. The course is designed to include classroom teaching and practical teaching in the ratio 2:1. It also emphasizes project work, students' seminars for the holistic development of the student community. Alumni of the department spans all over the national as well as some international academic institutions. The bonding between the hard-working & meritorious students and responsible & careful teachers is the recipe of the success of the department.

# COURSE STRUCTURE OF M.Sc. in PHYSICS

| SEMESTER | COURSE NO. | COURSE TITLES | | Full Marks | No. of Lectures (hours) | CREDIT (Lecture – Tutorial - Practical) |
|---|---|---|---|---|---|---|
| I | PHS 101 | PHS 101.1 | METHODS OF MATHEMATICAL PHYSICS – I | 25 | 20 | 4(3-1-0) |
| | | PHS 101.2 | CLASSICAL MECHANICS | 25 | 20 | |
| | PHS 102 | PHS 102.1 | QUANTUM MECHANICS - I | 25 | 20 | 4(3-1-0) |
| | | PHS 102.2 | CONDENSED MATTER PHYSICS– I | 25 | 20 | |
| | PHS 103 | PHS 103.1 | ELECTRODYNAMICS | 25 | 20 | 4(3-1-0) |
| | | PHS 103.2 | EXPERIMENTAL METHODS IN PHYSICS | 25 | 20 | |
| | PHS 104 | PHS 104.1 | ANALOG ELECTRONICS - I | 25 | 20 | 4(3-1-0) |
| | | PHS 104.2 | DIGITAL ELECTRONICS - I | 25 | 20 | |
| | PHS 195 | ELECTRONICS PRACTICAL –I | | 50 | 150 | 4(0-0-8) |
| | PHS 196 | COMPUTER PROGRAMMING AND NUMERICAL METHODS PRACTICAL | | 50 | 150 | 4(0-0-8) |
| | TOTAL | | | 300 | | 24 |
| II | PHS 201 | PHS 201.1 | QUANTUM MECHANICS - II | 25 | 20 | 4(3-1-0) |
| | | PHS 201.2 | METHODS OF MATHEMATICAL PHYSICS - II | 25 | 20 | |
| | PHS 202 | PHS 202.1 | CONDENSED MATTER PHYSICS- II | 25 | 20 | 4(3-1-0) |
| | | PHS 202.2 | SEMICONDUCTOR PHYSICS | 25 | 20 | |
| | PHS 203 | PHS 203.1 | ANALOG ELECTRONICS – II | 25 | 20 | 4(3-1-0) |
| | | PHS 203.2 | DIGITAL ELECTRONICS – II | 25 | 20 | |
| | *C-PHS 204* | *CONCEPTS OF PHYSICS: INVENTIONS ANS APPLICATION(CBCS)* | | 50 | 40 | 4(3-1-0) |
| | PHS 295 | ELECTRONICS PRACTICAL – II | | 50 | 150 | 4(0-0-8) |
| | PHS 296 | ADVANCE PRACTICAL – I | | 50 | 150 | 4(0-0-8) |
| | TOTAL | | | 300 | | 24 |
| III | PHS 301 | PHS 301.1 | QUANTUM MECHANICS – III | 25 | 20 | 4(3-1-0) |
| | | PHS 301.2 | STATISTICAL MECHANICS - I | 25 | 20 | |
| | PHS 302 | PHS 302.1 | MOLECULAR SPECTROSCOPY & LASER PHYSICS | 25 | 20 | 4(3-1-0) |
| | | PHS 302.2 | NUCLEAR PHYSICS – I | 25 | 20 | |
| | SPECIAL PAPER (any one) | | | | | |
| | PHS 303 | PHS 303A | ADVANCED CONDENSED MATTER PHYSICS-I | 50 | 40 | 4(3-1-0) |
| | | PHS 303B | APPLIED ELECTRONICS-I | | | 4(3-1-0) |
| | | | PHS 303B.1 APPLIED ANALOG ELECTRONICS-I | 25 | 20 | |
| | | | PHS 303B.2 APPLIED DIGITAL ELECTRONICS-I | 25 | 20 | |
| | | PHS 303C | APPLIED OPTICS AND OPTO-ELECTRONICS-I | 50 | 40 | 4(3-1-0) |
| | | PHS 303D | ASTROPHYSICS – I | | | 4(3-1-0) |
| | | | PHS 303D.1 ASTRONOMICAL METHODS | 25 | 20 | |
| | | | PHS 303D.2 STELLER STRUCTURE AND EVOLUTION | 25 | 20 | |
| | C-PHS 304 | INTRODUCTORY ASTROPHYSICS (CBCS) | | 50 | 40 | 4(3-1-0) |
| | PHS 395 | ADVANCE PRACTICAL-II | | 50 | 150 | 4(0-0-8) |
| | | SPECIAL BASED PRACTICAL | | | | |
| | PHS 396 | PHS 396A | ADVANCED CONDENSED MATTER PHYSICS-I (Practical) | 50 | 150 | 4(0-0-8) |
| | | PHS 396B | APPLIED ELECTRONICS-I (Practical) | 50 | 150 | |
| | | PHS 396C | APPLIED OPTICS AND OPTO-ELECTRONICS-I(Practical) | 50 | 150 | |
| | | PHS 396D | ASTROPHYSICS I (Practical) | 50 | 150 | |
| | TOTAL | | | 300 | | 24 |
| | PHS 401 | PHS 401.1 | QUANTUM FIELD THEORY | 25 | 20 | 4(3-1-0) |
| | | PHS 401.2 | PARTICLE PHYSICS | 25 | 20 | |
| | PHS 402 | PHS 402.1 | STATISTICAL MECHANICS - II | 25 | 20 | 4(3-1-0) |
| | | PHS 402.2 | NUCLEAR PHYSICS – II | 25 | 20 | |
| | PHS 403 | PHS 403.1 | TRANSPORT PROPERTIES AND SEMICONDUCTOR DEVICES | 25 | 20 | 4(3-1-0) |
| | | PHS 403.2 | APPLIED OPTICS | 25 | 20 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| IV | | SPECIAL PAPER (any one) | | | | | |
| | PHS 404 | PHS 404A | ADVANCED CONDENSED MATTER PHYSICS-II | | 50 | 40 | 4(3-1-0) |
| | | PHS 404B | APPLIED ELECTRONICS-II | | | | |
| | | | PHS 404B.1 | APPLIED ANALOG ELECTRONICS-II | 25 | 20 | |
| | | | PHS 404B.2 | APPLIED DIGITAL ELECTRONICS-II | 25 | 20 | |
| | | PHS 404C | APPLIED OPTICS AND OPTO-ELECTRONICS-II | | 50 | 40 | |
| | | PHS 404D | ASTROPHYSICS -II | | | | |
| | | | PHS 404D.1 | GALACTIC ASTRONOMY | 25 | 20 | |
| | | | PHS 404D.2 | EXTRA-GALACTIC ASTRONOMY AND COSMOLOGY | 25 | 20 | |
| | | SPECIAL BASED PRACTICAL | | | | | |
| | PHS 495 | PHS 495A | ADVANCED CONDENSED MATTER PHYSICS-II (practical) | | 50 | 150 | 4(0-0-8) |
| | | PHS 495B | APPLIED ELECTRONICS-II (practical) | | 50 | 150 | |
| | | PHS 495C | APPLIED OPTICS AND OPTO-ELECTRONICS-II(practical) | | 50 | 150 | |
| | | PHS 495D | COSMOLOGY AND ASTROPHYSICS II (practical) | | 50 | 150 | |
| | PHS 496 | PROJECT, SEMINAR AND GRAND VIVA | | | 50 | | 4 (0-0-8) |
| | TOTAL | | | | 300 | | 24 |
| ALL TOTAL | | | | | 1200 | | 96 |

Full Marks : 50 = END SEMESTER EXAMINATION (40) + INTERNAL ASSESSMENT (10)
25 = END SEMESTER EXAMINATION (20) + INTERNAL ASSESSMENT (5)

| Distinctive features of course content: | | | |
|---|---|---|---|
| ***Feature*** | ***Course Code*** | ***Course Wise Percentage of such courses **** | ***Programme-wise percentage of courses#*** |
| Value-added course: | PHS101 | 100 | 27.08 |
| | PHS102.1 | 100 | |
| | PHS103.1 | 100 | |
| | PHS201 | 100 | |
| | PHS301 | 100 | |
| | PHS302.2 | 100 | |
| | PHS401 | 100 | |
| | PHS402 | 100 | |
| Employability/entrepreneurship/ skill development: | PHS102.2 | 100 | 64.58 |
| | PHS103.2 | 100 | |
| | PHS104 | 100 | |
| | PHS195 | 100 | |
| | PHS196 | 100 | |
| | PHS202 | 100 | |
| | PHS203 | 100 | |
| | PHS295 | 100 | |
| | PHS296 | 100 | |
| | PHS302.1 | 100 | |
| | PHS303 | 100 | |
| | PHS395 | 100 | |
| | PHS396 | 100 | |
| | PHS403 | 100 | |
| | PHS404 | 100 | |
| | PHS495 | 100 | |
| | PHS496 | 100 | |
| Digital Content: | PHS104.2 | 100 | 29.17 |
| | PHS195 | 100 | |
| | PHS196 | 100 | |
| | PHS203.2 | 100 | |
| | PHS295 | 100 | |
| | PHS303B.2 | 100 | |
| | PHS396B | 100 | |
| | PHS404B.2 | 100 | |
| | PHS495B | 100 | |
| Ethics, gender, human values, environment & sustainability: | PHS496 | 100 | 4.17 |

*Percentage of that feature within this course

#Percentage of that feature with respect to total courses or Programme

## PROGRAMME OUTCOME

**Post Graduates (M. Sc.) students, after completion of the program, will be able to achieve**:

1. **Promotion of analytical thinking:** Physics is based on axiomatic mathematical formulation. The course serves as a platform for enhancing analytical and critical thinking within the framework of the laws of nature.
2. **Knowledge transfer:** The course aims towards teaching basic concepts and advanced topics. After completion of the course the students would get very good basic and advanced knowledge of the subject.
3. **Development of communication skills:** Students would learn how to communicate and to present topics of higher education in both English and in their Mother tongue from their experience in classroom learning and seminar presentations.
4. **Group learning:** Learning the subject through interactions with experts both in and out of the classroom. Students would also learn to work in a group.
5. **Awareness of environmental concerns:** The courses enable students to gain knowledge to work on topics that would be useful for daily life, keeping in mind the environmental concerns.
6. **Professional skill development:** Motivation of students, completion of the standard prerequisites and development of their skills to take up teaching and research in the subject as a profession.

## PROGRAMME SPECIFIC OUTCOME

The M. Sc. Physics course will cater to develop skilled scientific manpower having theoretical and experimental comprehensive knowledge of Physics. The program also induces the basic platform of higher research activities. After completion of the course, the students will be enriched on:

1. **Basic knowledge:** The M.Sc Physics programme is based on a structure and syllabus covering almost all the major fields of Physics. Basic compulsory courses such as Classical Mechanics, Quantum Mechanics, Statistical Mechanics, Electrodynamics, Mathematical Physics and several Laboratory courses strengthen the theoretical and experimental foundations of the students.

2. **Advanced knowledge:** Advanced compulsory courses such as Electronics, Condensed Matter Physics, Applied Optics, Semiconductor Devices, Molecular Spectroscopy, Nuclear Physics, Quantum Field Theory, Particle Physics enhances the knowledge of the students and provides them a broad view of the subject.

3. **Research exposure:** Students are offered several optional courses and a dissertation which give them the opportunity to learn advanced and multidisciplinary topics and work in research laboratories. From the laboratories the students get hands-on experience of high-end instruments.

4. **CBCS and interdisciplinary knowledge:** The syllabus is based on CBCS. The programme offers two courses to students from other subjects. This promotes awareness on interdisciplinary subjects.

5. **Development of Multidisciplinary skills:** The multidisciplinary skills which the students acquire from the courses will be of tremendous value to them in research areas such as Nano-Scale Physics, theoretical and experimental Condensed Matter Physics, Optoelectronics, and Electronics.

**Evaluation Methodology throughout the course curriculum :**
**Continuous Internal Assessment and End Semester Exam:**
Assignments, Review work, written tests, problem solving, presentations.

# SEMESTER- I

## Course No: PHS 101.1: Methods of Mathematical Physics

**Marks: 25 Credit: 2**
**Classes: 20**

1. Vector spaces and matrices: Vector spaces of n dimensions, inner product, Schmidt's orthogonalisation, Schwarz and Bessel inequality.

2. Hermitian and unitary matrices, eigenvectors and eigenvalues, diagonalization, unitary transformation. Cayley Hamilton theorem.

3. Complex variable: Cauchy Reimann conditions, Cauchy's integral and residue theorem, singularities, poles, branch points, contour integration. Taylor & Laurent series expansion, Principle value of an integral Riemann Surface.

4. Tensor analysis, Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. The Christoffel symbols and their transformation laws. Covariant derivative of tensors.

**Books Recommended**


1. Spiegel, M.R. (2000) Theory and Problems of Complex Variables (Schaum's outline series). McGraw-Hill Publishing Co.; Metric ed ed., United States.
2. Arfken, G.B. and Weber, H.J. (2005) Mathematical Methods for Physicists, 16th ed., Elsevier Academic Press, USA.
3. Mathews, J. and Walker, R.I. (1971) Mathematical Methods of Physics, 2nd ed., Pearson Addison-Wesley, United States.
4. Dennery, P. and Krzywicki, A. (1996) Mathematics for Physicists, 1st ed., Dover Publications Inc., United States.
5. Grewal, B.S. (1965) Higher Engineering Mathematics, 1st ed., Khanna Publisher, India.
6. Joshi, A.W. (2018) Group Theory for Physicists, 5th ed., New Age International Publishers, India.
7. Hamermesh, M. (1989) Group Theory and Its Application to Physical Problems, 1st ed., Dover Publications Inc., United States.
8. Dass, T. and Sharma, S.K. (1998) Mathematical Methods in Classical and Quantum Physics, 1st ed., Universities Press Pvt. Ltd., India.
9. Joshi, A.W. (1995) Matrices and Tensors, 3rd ed., New Age International Publishers, India.


**COURSE OUTCOME:**

- Familiar with the vector spaces and matrices
- Understand the Hermitian and unitary matrices

- Understand the Complex variable
- Know the Tensor analysis

## Course No: PHS 101.2: Classical Mechanics

**Marks: 25 Credit: 2**
**Classes: 20**

1. Recapitulation of Mechanics of System of particles, Lagrange and Hamiltonian of different systems. Lagrange & Hamiltonian for Non conservative system: Velocity dependent potential, dissipation function, charge particle is moving in an electro-magnetic field. Small Oscillations

2. Variational Principles, Hamilton's Principle from Newton's equation & D'Alemberts Principle, Lagrange's equation from Hamilton's Principle, Modified Hamilton's Principle, Hamiltons Canonical equations.

3. Gauge function for Lagrangian, Canonical Transformations, Legendre Transformation, Generating Functions, Infinitesimal Contact Transformations, Poisson Bracket, Lagrange Bracket.

4. Hamilton – Jacobi Theory, Hamilton – Jacobi equation for Hamilton's principal function, Physical significance of Hamilton's principal function, Hamilton – Jacobi equation for Hamilton's characteristic function, Physical significance of Hamilton's characteristic function Hamilton-Jacobi equation from Schrodinger equation, Action-angle variables.

**Books Recommended:**


1. Goldstein, H. (2011) Classical Mechanics, 3rd ed., Narosa Publishing Home, India.
2. Thornton, S., and Marion, J. (2003) Classical Dynamics of Particles and Systems, 5th ed., Horoloma Book Jovanovich College Publisher. UK.
3. Rana, N. C., and Joag, P. S. (1991) Classical Mechanics, 1st ed., Tata McGraw-Hill Pub. Co., India.
4. Takawale, R. G., and Puranik, P. S. (1979) Introduction to Classical Mechanics, 1st ed., Tata Mc- Graw Hill Publishing Company Limited, India.
5. Upadhyaya, J. C. (2019) Classical Mechanics, 1st ed., Himalaya Publishing House, India.
6. Morlin, D. (2008) Introduction to Classical Mechanics, 1st ed., Cambridge University Press, UK.
7. Calkin, M. G, (1996) Lagrangian and Hamiltonian Mechanics, World Scientific Publishing Co Pte Ltd, Singapore


**COURSE OUTCOME:**

**In the era of modern physics, this course in classical mechanics remained absolutely essential in the way it is designed. Firstly this course acts as the stepping stone for the**

**various branches of modern physics. e.g. the technique of action-angle variable is needed for older quantum mechanics, the Hamilton Jacobi formalism and the principle of least action paved the way to wave mechanics and the Poisson Bracket and canonical transformation leads to the justification of commutator formalisms and equation of motions. This course also provides an opportunity for students of physics to master many of the mathematical techniques.**

## Course No: PHS 102.1: Quantum Mechanics-I

**Marks: 25 Credit: 2**
**Classes: 20**

1. **Abstract formulation:** Properties of linear vector spaces. Bra-ket notation. Hermitian operators, eigenvalues and eigenvectors. Stern-Gerlach experiment. Postulates of quantum mechanics. Matrix representation, measurements, observables, and the uncertainty relations, Change of basis and unitary transformation, Position and momentum representations: Wave-functions in Position and Momentum Space. Expectation values. Ehrenfest theorem. (12)

2. **Quantum Dynamics:** Time evolution and the Schrodinger equation, Schrodinger picture, Heisenberg picture, Heisenberg equation of motion. Solution of simple harmonic oscillator by the operator method. (8)

### Books Recommended:


1. Sakurai J. J. and Napolitano J. (2020) Modern Quantum Mechanics, 3rd ed., Addison-Wesley.
2. Schiff L. I., (1969) Quantum Mechanics, 3rd ed., McGraw-Hill Book, New York.
3. Schwabl F. (2007) Quantum Mechanics, 4th ed., Springer.
4. Griffiths D. J. & Schroeter D. F. (2019) Introduction to Quantum Mechanics, 3rd ed., Cambridge Univ. Press.
5. Ghatak A. K. & Lokanathan S. Quantum Mechanics: Theory and Applications, Macmillan India Ltd..
6. Cohen- Tannoudji C., Diu B. & Laloe F. (2019) Quantum Mechanics, Vol I & II, 2nd Ed., Wiley.
7. N. Zettili N. (2009) Quantum Mechanics: Concepts and Applications, 2nd ed., Wiley India
8. Singh J., (1996) Quantum Mechanics: Fundamentals and Applications to Technology, 1st Ed., Wiley VCH.


**COURSE OUTCOME:**

**Quantum mechanics is the body of scientific laws that describe the behavior of photons, electrons and the other particles that make up the universe. It is is the branch of physics relating to the very small. This course is a substantial introduction**

**to advanced quantum mechanics and how to use it. It is specifically designed to be accessible not only to physicists but also to students and technical professionals over a wide range of applied science. At the end of the course, students will be able to learn about the abstract mathematical formulation in the language of linear vector space. Concepts such us basis change, momentum and position representations. operators and matrix representations would be introduced. Time evolution, connection to wave mechanics and Schrodinger's equation will also be discussed. Students will also learn to use operator methods for solving problems such as the harmonic oscillator in one dimension.**

## Course No: PHS 102.2: Condensed Matter Physics-1

**Marks: 25 Credit: 2**
**Classes: 20**

1. Single crystal and Polycrystal, Symmetry elements associated with Point group and Space group, Stereographic Projection, Space group representation.

2. X-ray diffraction & reciprocal lattice: Scattering of X-ray by a crystal and Derivation of Laue equation, reciprocal lattice vectors, Brillouin Zone, Atomic form factor, Structure factor and experimental diffraction methods.

3. Vibrations of monoatomic and diatomic linear lattice(qualitative), Equivalence of vibrational mode and simple harmonic oscillator, Phonons, Anharmonic crystal interactions, Debye Waller effect.

4. Energy Bands: Physical origin of the energy gap, Bloch function, essential features of Kronig penny model, effective mass, distinction of metal, insulator and semiconductor. Empty Lattice .Approximation, Tight Binding Approximation.

5. Quantum theory of dia, paramagnetism, Boltzman Transport Equation.

**Books recommended**

1. Woolfson : X ray crystallography
2. Kittel: Solid State Physics
3. Dekker: Solid State Physics.
4. Christmaan-solid state physics (academic press)
5. Warren- X-ray Diffraction

### COURSE OUTCOME:

**The course gives good idea to students related to structure and symmetry of solid. The course also gives light to the structural analysis of the materials and introduce**

**new particle phonon in solid. The course deals with Band Theory of Solid which is an important tool for material study and research.**

## Course No: PHS 103.1: Electrodynamics

**Marks: 25 Credit: 2**
**Classes: 20**

1. Radiation loss of energy by free charges of plasma: Radiation emitted by excited atoms and ions; Cyclotron or Betatron radiations; Bremsstrahlung radiation; Recombination radiation; Black body radiation; Transport of radiation.

2. Fundamental concepts about plasma: Mean free path and collision cross section; Electron and ion temperatures; Effect of magnetic field on mobility of ions and electrons; Diffusion of ions and electrons; Ambipolar diffusion.

3. Elements of Plasma Kinetic theory: Phase space; Distribution function; Boltzmann equation – Collision less and collisional; Conservation of particles, mass and charges; Vlasov Equation; Application of B-V equation to longitudinal waves.

4. Field of moving charges and radiations: Retarded potentials and Lienard Wichert potentials; Field produced by arbitrarily and uniformly moving charged particles; Radiations from an accelerated charged particle at low velocity and at high velocity; Angular distribution of radiated power; Radiation from an oscillating electric dipole; Radiation from a linear antenna; Antenna arrays.

5. Radiation in material media: Cherenkov radiation; Scattering of electromagnetic wave – Thomson, Rayleigh and resonant scattering; Polarization of scattered light; Coherence and incoherence scattered light; Dispersion and absorption of radiations; Elementary theory of dispersion – dispersions in gas, liquid and solid.

6. Relativistic electrodynamics: Lorentz transformation of space and time in 4-vector from; Transformations for charge and current densities; Transformation equations for field vectors; Covariance of Lorentz condition; Invariance of Maxwell's field equations under relativistic transformation; Covariance of Maxwell's field equations in 4-vector form and 4-tensor form; Transformation equations for magnetic field induction components; Invariants of electromagnetic fields; Covariance and transformation law of Lorentz force.

**Books Recommended:**

**Reference for journal article**


1. Cerenkov, P.A. (1937) Visible Radiation Produced by Electrons Moving in a Medium with Velocities Exceeding that of Light. Physical Review, 52, 378-381.
2. Dodig, H. (2021) Direct Derivation of Liénard–Wiechert Potentials, Maxwell's Equations and Lorentz Force from Coulomb's Law. *Mathematics, 9,* 237.


**Reference for a book as general**


1. Chakraborty, B. (2003) Principles of Plasma Mechanics, 4th ed., New Age Internationals, India.

2. Engel, V. (1994) Ionized gases, 1st ed., American Institute of Physics Melville, United States.
3. Chen, F.F. (1984) Introduction to Plasma Physics and Controlled Fusion, Volume 1: Plasma Physics, United States.
4. Goswami, S.N. (2005) Elements of Plasma Physics, 1st ed. (Reprint), New Central Book Agency (P) Ltd., India.
5. Griffiths, D.J. (1999) Introduction to Electrodynamics, 3rd ed., New Jersey, United States.
6. Jackson, J.D. (2007) Classical Electrodynamics, 3rd ed., John Wiley & Sons, Inc., United States.
7. Heald, M.A. and Marion, J.B. (1995) Classical Electromagnetic Radiation, 3rd ed., Saunders College Publishing, Harcourt Brace College Publishers, United States.
8. Panofsky, W.K.H. and Phillips, M. (2012) Classical Electricity and Magnetism, 2nd ed., Dover Publications, United States.
9. Sen, S.N. (2016) Plasma Physics: Plasma State of Matter, 11th ed. (Reprint), Pragati Prakashan, India.

**Reference for a book chapter in an edited volume**

1. Edgar, R.S. (2013) Chapter 5 Retarded Potential Theory. In Field Analysis and Potential Theory (Volume 44), 12th ed., ed. by Edgar, R.S., Springer-Verlag, Berlin, Germany.
2. Heald, M.A. and Marion, J.B. (1995) Chapter 8: Retarded Potentials and Fields and Radiation by Charged Particles, In Classical Electromagnetic Radiation, 3rd ed., ed. by Heald, M.A. and Marion, J.B. , Saunders College Publishing, Harcourt Brace College Publishers, United States, pp. 256-288.
3. Lorrain, P. and Corson, D. (2003) Chapter 14: Radiation of Electromagnetic Waves, In Electromagnetic Fields and Waves, 2nd ed., ed. by Lorrain, P. and Corson, D., CBS Publishers & Distributors Pvt. Ltd., India, pp. 595-640.
4. Miyamoto, K. (2011) Chapter 4: Velocity Space Distribution Function and Boltzmann's Equation, In Fundamentals of Plasma Physics and Controlled Fusion, 3rd ed., ed. by Miyamoto, K., National Institute of Fusion Science (NIFS), Toki, Japan, pp. 39-43.
5. Zahn, M. (1979) Chapter 9: Radiation. In Electromagnetic Field Theory: A Problem Solving Approach, 1st ed., ed. by Zahn, M., John Wiley & Sons Inc., United States, pp. 663-698.

**Reference for materials in a book**

1. Biro, T. (1992) Phase-space description of plasma waves: Linear and nonlinear theory, 1st ed., Swedish Institute of Space Physics, Umed Division, Sweden, pp. 1-7.
2. Lorrain, P. and Corson, D. (2003) Electromagnetic Fields and Waves, 2nd ed., CBS Publishers & Distributors Pvt. Ltd., India, pp. 424-436.
3. Miyamoto, K. (2011) Fundamentals of Plasma Physics and Controlled Fusion, 3rd ed., National Institute of Fusion Science (NIFS), Toki, Japan, pp. 39-43.

**COURSE OUTCOME:**

- Know the fundamental concepts about plasma, elements of plasma Kinetic theory
- Understand the loss of radiation energy by free charges of plasma systematics
- Evaluate fields and forces in Electrodynamics and Magneto-dynamics

- Know the concepts of retarded phenomena and radiation
- Radiation phenomena including scattering and dispersion in material media
- Understand the relativistic electrodynamics

## Course No: PHS 103.2: Experimental Methods in Physics

**Marks: 25 Credit: 2**
**Classes: 20**

1. Experimental techniques of Material Characterization : X-ray Diffraction (XRD), XPS, Electron microscopy: Scanning electron Microscopy, Transmission Electron Microscopy, Probe microscopy: Scanning Tunneling Microscopy, Atomic Force Microscopy, Electron Spectroscopy for Chemical Analysis (ESCA), Thermal analysis: Phase changes, crystalline and amorphous fractions – DSC Thermo-gravimetric methods – TGA, DTA, Vibrating sample magnetometer, Energy Dispersive Analysis by X-ray (EDX). Neutron scattering and neutron diffraction, NMR

2. Different optical measurements: Optical Absorption & Transmission study by UV-VIS Spectro-Photometer, Photo Luminescence (PL), FTIR, Raman spectroscopy. Electrical measurements; Studies on various Conduction Mechanisms in 2D (thin films) and Low- dimensional Systems: Arrhenius type Thermally Activated Conduction, Variable Range Hopping Conduction and Polaron Conduction.

3. Concept of Ultra High Vacuum techniques, production and measurement of low pressure, Pirani and Penning gauges, rotary and oil diffusion, Turbo, Ion, cryo-pumps; Elements of instruments, Concepts of low temperature and high temperature measurement, Sensor and transducer materials.

4. Experimental Methods of sample preparation: Semiconductor materials, composite materials, thin films, nanomaterials.

**Books recommended:**


1. Shackelford J. F, (2009) Introduction to Materials Science for Engineers, 7th ed., Pearson Prentice Hall, India

2. Callister W D (2007) Materials Science and Engineering : An Introduction", 7th ed., John Wiley & Sons, Inc., US
3. Rao V V, Ghosh T B and Chopra K L (2008) Vacuum Science and Technology, 3rd ed., Allied publishers Ltd., India
4. Bhushan B. (2004) Springer Handbook of Nanotechnology, 2nd ed. Springer, Germany
5. Kohler M. and Fritzsche W. (2004) Nanotechnology: Introduction to Nanostructuring Techniques, 2nd ed., Wiley –VcH, Germany
6. Chattopadhyay K. K. and Banerjee A. N. Introduction to Nanoscience and Nanotechnology, 1st ed., PHI, India
7. Sayer M. and Mansingh A. (2015) Measurement, Instrumentation and Experimental Design in Physics and Engineering, 1st ed., PHI, India

## COURSE OUTCOME:

**The course is typically a bridge between a physicist and a material scientist and the course is framed to enable students to understand the**

1. **expanding world of functional materials**
2. **state of the art facts and techniques involved in materials preparation**
3. **comprehensive awareness of use of different instruments for material study.**
4. **development of the various aspects of material characterization.**
5. **use of different experimental techniques, challenges and prospects materials science**

## Course No: PHS 104.1: Analog Electronics-I

**Marks: 25 Credit: 2**
**Classes: 20**

1. Operational Amplifiers: Revision of Op-amp circuits, Differential amplifier, OP-AMP architecture, Constant current sources, Input stage of an Op-Amp, OP-AMP characteristics and parameters.

2. Elements of Communication: Principle of amplitude modulation (AM) and frequency modulation (FM), AM spectrum and FM spectrum, channel band width and signal band width, side band frequency, Generation of transmitted carrier and suppressed carrier type AM signals with necessary circuits, Principles of detection of different types of modulated signals (TC and SC types), principle of generation of F.M. wave with necessary circuits, Detection of F.M. wave-Discriminators.

   Modulation techniques in some practical communication systems: Superheterodyne AM and FM radio receivers, FM stereo receiver principle, VSB AM.

3. Radio wave propagation: Ground wave, Ionospheric wave and space wave and their characteristics, reflection and refraction of radio waves in ionosphere, critical frequency, skip distance, Maximum usable frequency, fading, Secant law, duet propagation.

4. Antenna: Dipole antenna, half wave antenna, antenna with two half elements, N elements array, induction field and radiation field, radiation resistance of an antenna.

5. Radar: Radar range equation, Basic pulsed radar system-Modulators, duplexers, indicators, radar antenna, CW radar, MTI radar, FM radar, Doppler radar.

### Books Recommended:


1. Ryder, J.D. (1975) Electronics fundamental and application, 5$^{th}$ ed., PHI, India.
2. Gayakwad , R.A. (2015) Op- Amps and Linear Integrated Circuits, 4$^{th}$ ed., Pearson Education, India.

3. Roddy, D. and Coolen, J. (2008) Electronic Communications, 4th ed., Pearson Education, India
4. Chattopadhyay, D. and Rakshit, P.C. (2020) Electronics Fundamentals And Applications, 16th ed., New Age International Publishers, India
5. Millman, J. and Grable, A. (2017) Microelectronics, 2nd ed., McGraw Hill Education, India.
6. Terman, F. E. (1955) Electronic and Radio Engineering, 4th ed., McGraw-Hill Book Company Inc., Europe.

**COURSE OUTCOME:**

**At the end of the course, students will be able to**

1. **impart basic knowledge on Analog and Digital Electronics.**
2. **clarify and exemplify the previous knowledge of electronics in B.Sc. courses.**
3. **learn the basics of Op-Amp circuits and Analog communication systems.**
4. **gain knowledge on Radar, Antenna and MOSFET circuits.**

## Course No: PHS 104.2: Digital Electronics-I

**Marks: 25 Credit: 2**
**Classes: 20**

1. Review of logic gates: Combinational logic gates: Karnaugh mapping : Methods of minimization (reduction) of Product of Sum (POS) and Sum of Products (SOP) expressions of 2, 3 4and 5 variables Boolean expression, Logical implementations,
2. Sequential Circuit: Revision of Flip-Flops, Conversion of Flip-Flops.
3. Registers: Shift Register, Serial in Serial out, Parallel in Serial out, Parallel in parallel out registers, Bi-directional and Universal registers.
4. Counter: Synchronous and Asynchronous counter, modulo-Counter, decade counter, ring counter and twisted ring counter, Up/Down Counter.
5. Multivibrators: Astable and monostable (principles, Circuits and operation), Internal circuit of IC 555, Timer circuit with 555. Digital display: Seven segment display system, developing of display system for decimal, octal number system.

**Books Recommended:**

1. Jain, R. P. (2010) Modern digital electronics, 4th ed., Tata McGraw Hill, India
2. Anand Kumar, A. (2016) Fundamentals of Digital Circuits, 4th ed, PHI, India
3. Millman J. , Halkias C. C. and Parikh C. D. (2017) Integrated electronics, McGraw Hill, India
4. Sivakumar M. S. (2014) 1st ed., Fundamental of Digital Design, S. Chand & Company, India
5. Kothari D. P. and Dhillon (2015) J. S. Digital Circuits and Design 1st ed., Pearson Education India, India
6. Mano M. (2016) Digital Logic and Computer Design, 1st ed., Pearson Education India, India

7. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8th ed., Pearson New Int. Edition.

**COURSE OUTCOME:**

**At the end of the course, students will be able to**

1. **gain basic knowledge of application of Digital Logic gates.**
2. **learn the structure and use of flip flops, counters, registers etc**

## Course No: PHS 195: Electronics Practical-I

**Credit 4**
**Marks: 50**

1. To develop a LC filter (L type and π type) circuit having different cut-off frequencies and to find out frequency response characteristics.
2. To study the drain characteristics & transfer characteristics ($I_{D\ sat}$ vs $V_{gs}$ with $V_{DS}$ as parameter) of a FET/MOSFET and to find out the drain resistance, mutual conductance and amplification factor.
3. To study a transformer and to find its various parameters.
4. To construct and design a regulated power supply using Op-Amp as comparator and power transistor as pass element and to find out its ripple factor and percentage of regulation.
5. To obtain the frequency response characteristic of an inverting operational amplifier and to find out its band width.
6. To obtain the frequency response characteristic of a non-inverting operational amplifier and to find out its band width.
7. To design a J-K master – slave flip-flop and to verify its truth table.
8. To design 4 bit shift register in SISO and SIPO mode.
9. Design and study of 2 bit binary comparator.

**COURSE OUTCOME:**

**With this course, students will be able to design and fabricate various digital and analog electronic circuits, e.g. Op-Amp amplifiers, oscillator circuits.**

## Course No: PHS 196: Computer Programming and Numerical Methods

**Credit 4 Marks: 50**

Computer programming using C/Python.

1. Finite and infinite series. Finding roots using Bisection, Secant and Newton-Raphson methods.
2. Solving first and second order differential equations using Euler and Runge Kutta methods. Integration using Trapezoidal, Simpson methods.

3. Matrices: Use of arrays, Matrix Operations, Eigenvalues & Eigenvectors, Matrix Inversion, Solving Systems of Linear Equations.
4. Partial differential equations. Finite Difference method; Forward and Backward difference methods, Finite Element method. Examples:
   (i) Quantum Mechanics: Solving Schrodinger's equations in a few potentials (box, triangle, one dimensional harmonic oscillator).
   (ii) Electromagnetism: Poisson and Laplace's equation.
   (iii) Heat equation and Wave equation.
5. Use of various software packages like, Gnuplot, Origin, Mathematica.

**COURSE OUTCOME:**

**The students will get good training in computer programming with applications to various numerical methods. The programming knowledge can be used in various branches of physics. Students will also get to learn about various software packages that would be useful for research.**

# SEMESTER- II

**Course No: PHS 201.1: Quantum Mechanics-II** **Marks: 25**
**Credit: 2** **Classes: 20**

1. **Angular Momentum:** Spin 1/2 system. Rotation matrices. General commutation relations of angular momentum operators. Eigenvalues, eigenvectors. Ladder operators and their matrix representations. Orbital angular momentum. Addition of angular momenta. Clebsch-Gordan coefficients. Tensor operators and Wigner-Eckart theorem. (8)

2. **Symmetries in Quantum Mechanics:** Symmetries and conservation laws, Degeneracies, Discrete spatial translation, time translation. parity, time reversal. (4)

3. **Approximation Methods for Stationary Systems:** Time-independent perturbation theory: nondegenerate and degenerate. Stark effect, Zeeman effect. Variational and WKB methods and applications. (8)

**Books Recommended:**


1. Sakurai, J. J. and Napolitano, J. (2020) Modern Quantum Mechanics, 3rd ed., Addison-Wesley.
2. Schiff, L. I. (1969) Quantum Mechanics, 3rd ed., McGraw-Hill Book, New York.
3. Schwabl, F. (2007) Quantum Mechanics, 4th ed., Springer.
4. Griffiths D. J. & Schroeter D. F. (2019) Introduction to Quantum Mechanics, 3rd ed., Cambridge Univ. Press.
5. Ghatak, A. K. & Lokanathan, S., Quantum Mechanics: Theory and Applications, Macmillan India Ltd..
6. Cohen- Tannoudji, C., Diu, B. & Laloe, F. (2019) Quantum Mechanics, Vol I & II, 2nd Ed., Wiley.
7. N. Zettili, N. (2009) Quantum Mechanics: Concepts and Applications, 2nd ed., Wiley India
8. Singh, J. (1996) Quantum Mechanics: Fundamentals and Applications to Technology, 1st Ed., Wiley VCH.


**COURSE OUTCOME:**

**This course builds on the first part of the course Quantum Mechanics I. At the end of the course, students will be able to apply the postulates of Quantum Mechanics to rotational motion. He/She will understand the link between the angular momentum operator and the generator of rotations, the concept of spin, Pauli spin matrices. Angular momentum algebra will be introduced. Students will learn the addition of**

**angular momenta. Clebsch-Gordon coefficients and their recursion relations. They will also be able to perform calculations using angular-momentum techniques, including the Wigner-Eckart theorem. In the later part of the course the students will learn about the role played by symmetries and will learn to solve problems using approximate methods for stationary systems. Important applications such as Stark effect, Zeeman effect will be discussed. Variational and WKB methods will also be introduced.**

## Course No: PHS 201.2: Methods of Mathematical Physics - II

**Marks: 25 Credit: 2**

**Classes: 20**

1. Partial differential equations: Elliptic, parabolic and hyperbolic type equations, Lagrange's formula for 2nd order partial differential equation, Dirchlet Neumann and cauchy Boundary value problem. Greens function with applications.

2. Integral transforms: Fourier series, Fourier transforms, laplace transformation inverse laplace transform. Solution of differential equation using LT and FT. Dirac delta function and its FT.

3. Definition and nomenclature ; Examples ; Rearrangement theorem ; Cyclicgroups , Subgroups and Cosets ; Conjugate elements and class structure ; Factor groups ; Isomorphy and Homomorphy ; Direct product groups ; Symmetric groups , Cayley's theorem ; Representation of finite groups- Definition , Unitary representation , Schur's Lemma , Orthogonality theorem , Reducible and irreducible representations , Characters
   ; Regular representation ; Product representation , Character table , Examples of S_3 and C_4v ; Introduction to Lie groups and Lie algebra ; Clebsch-Gordon coefficients.
4. Integral equations. Fredholm and volterra equations of the first and second kinds. Fredholm’s theory for non-singular kernel.

**Books Recommended**


1. Arfken, G.B. and Weber, H.J. (2005) Mathematical Methods for Physicists, 16th ed., Elsevier Academic Press, USA.
2. Dennery, P. and Krzywicki, A. (1996) Mathematics for Physicists, 1st ed., Dover Publications Inc., United States.
3. Grewal, B.S. (1965) Higher Engineering Mathematics, 1st ed., Khanna Publisher, India.
4. Joshi, A.W. (2018) Group Theory for Physicists, 5th ed., New Age International Publishers, India.
5. Hamermesh, M. (1989) Group Theory and Its Application to Physical Problems, 1st ed., Dover Publications Inc., United States.
6. Dass, T. and Sharma, S.K. (1998) Mathematical Methods in Classical and Quantum Physics, 1st ed., Universities Press Pvt. Ltd., India.

**COURSE OUTCOME:**

- Familiar with the partial differential equations and Green's functions
- Understand the integral transforms
- Know the concepts of symmetry and group theory
- Understanding of the integral equations

## Course No: PHS 202.1: Condensed Matter Physics- II

**Marks: 25 Credit: 2**
**Classes: 20**

1. Superconductivity: Normal metal and alloy, Superconducting material, Resistivity: Normal metal, perfect metal, superconductor, Thermodynamics of a super conductors: Gibbs Free Energy, Entropy, Specific heat, Order of Phase Change, Resistance less circuit, Meissner Effect, Consequence of zero resistance, London Theory, Magnetic Levitation, Macroscopic Quantum Description of the Supercurrent, The Quantum Mechanical Current: Perfect Conductivity - First London Equation, Perfect Diamagnetism - Second London Equation, The Two-Fluid Model, Propagation characteristics at finite temperatures of a superconductor, Josephson Tunneling, D.C. Josephson Tunneling, A.C. Josephson Tunneling.

2. Dielectrics: Complex dielectric constant and dielectric losses, dielectric losses and relaxation time.

**Books Recommended:**


1. Kittel, C. (2012) Introduction to Solid State Physics, ed. 8, Wiley Publishers, India
2. Rose-Innes, A. C., and Rhoderick, E. H. (1969) Introduction to Superconductivity, 1st ed., Paragon Press, UK.
3. Omar, M. A. (2002) Elementary Solid State Physics- Principles & Applications, 1st ed. Pearson India.
4. David, N. University, C., and Ashcroft, N. W. (2003) Solid State Physics, 1st ed., Cengage, India
5. Annett, F. (2004) Superconductivity, Superfluids, and Condensates: 5 (Oxford Master Series in Physics,), 1st ed. OUP Oxford, UK.
6. Ibach, H., and Lüth, H (2009) Solid-State Physics: An Introduction to Principles of Materials Science, 4th ed. Springer, Germany
7. Dekker, A. J. (2000) Solid State Physics, Macmillan Student ed., Pan Macmillan, India


**COURSE OUTCOME:**

**This course is combined with the basic theory and phenomenology of superconductivity and dielectrics and their many applications in basic science and**

**technology. The course on superconductivity includes the electrical and magnetic properties of superconductors, the thermodynamics of superconductors, the origin of quantized magnetic flux and the Josephson tunneling. The dielectrics course is devoted to the study of dielectric polarization and relaxation phenomena in condensed matter. Basic theory and different experimental techniques of dielectrics are given**.

## Course No: PHS 202.2: Semiconductor Physics

**Marks: 25 Credit: 2**
**Classes: 20**

1. Electron & Hole statistics in a semiconductors: Non degenerate & degenerate semiconductor, Intrinsic semiconductor, Ionization energy calculation, Distribution function over an impurity state, N type & P type semiconductor

2. PN junction in equilibrium, Einstein Relation, Diffusion length, Derivation of diode equation, Junction capacitance, Metal Semiconductor junction.

3. Equilibrium & Non-equilibrium carriers, Photoconductivity & related device, Recombination via trap, Solar cell.

**Books recommended:**

1. Kireev: Semiconductor Physics
2. Streetman & Banerjee: Introduction to Solid State Electronics
3. Smith: Semiconductor
4. Dekker: Solid State Physics

**COURSE OUTCOME:**

**Students are enriched in semiconductor field by taking the course. Most modern Devices are based on semiconductors. Hence it is important to know the basics of Semiconductors. The students will hence understand the operation and mechanism of important semiconducting devices. The course will also provide interest to students for research in semiconducting field.**

# Course No: PHS 203.1: Analog Electronics-II

**Marks: 25 Credit: 2**
**Classes: 20**

1. (i) Network analysis : Network theorems, equivalent circuits, two-port parameters hybrid parameters, Driving point impedance and admittance, Foster's reactance theorems, properties of poles and zeros of reactance function, Topological descriptions of different commonly used networks, $\pi$ to T and T to $\pi$ conversions, reduction of a complicated network into its equivalent T and $\pi$ form.
   (ii) Filter Circuit : L filter, $\pi$ filter, iterative impedance, image impedance of a network, symmetrical network, characteristic impedance and propagation constant of a network. Methods of development of different constant-k filters like high pass, low pass, band pass and band stop filter circuits.

2. Transmission Lines: Line parameters, characteristic impedance and propagation constant of a transmission line, voltage and current equations of transmission line : Telegraphers' equations and their complete solutions, attenuation constant, phase constant, line of finite length behaving as a line of infinite length, reflection co-efficient in a line, velocity of signal in a line, voltage standing wave ratio, Input impedance of Lossless line, line at radio frequency, Origin of distortions in a transmission line, distortion less line, cable fault location telephone cable.

3. Thyristors: SCR, Triac, Diac, characteristics parameters, Thyristor rectifier & control circuits, DC Power control by SCR and AC power control by Triac.

**Books Recommended:**


1. Ryder, J. D. (2015) Networks, Lines and Fields, 2nd ed., Pearson Education, India.
2. Van Valkenburg, M.E. (2019) Network Analysis, 3rd ed., Pearson Education, India.
3. Sze, S.M. (2008) Physics of Semiconductor Devices, 3rd ed., Wiley, India.
4. Millman, J. and Halkias, C.C. (2017) Integrated Electronics, Tata McGraw Hill, India.


**COURSE OUTCOME:**

**After completion of this course, students will be able**

1. **to achieve the detail knowledge of network analysis.**
2. **to understand the operation and design of different kinds of passive filters.**
3. **to gain knowledge on transmission lines: its theory and applications.**
4. **to achieve the detail knowledge of operation and application of different kinds of thyristors like SCR, Triac, Diac etc.**

## Course No: PHS 203.2: Digital Electronics-II

**Marks: 25 Credit: 2**
**Classes: 20**

1. Combinational circuits: MUX, DeMUX, Encoder, Decoder, 4 bit comparator. ADC and DAC circuits. Code conversions : BCD to Binary converter, Binary to BCD converter.

2. Memory Unit: Construction of memory, Expansion of memory, Memory classification, Bipolar and MOS storage cells. Organization of RAM, address decoding, Registers and stack, ROM, PROM, EPROM, EEPROM, SRAM, DRAM, and FPLA. Organization and erasing schemes, Magnetic memories, Optical Memories, Semiconductor Memories.

3. The ALU: ALU organization, Integer representation, Serial and Parallel Adders, 1's and 2's complement arithmetic, Multiplication of signed binary numbers, Floating point representation, Overflow detection, Status flags.

4. Review of 8085 Microprocessor, Internal structure, Different register system, organization and assembly language. Instructions of 8085 Microprocessor, Microprocessor Programming.

**Books Recommended:**


1. Jain, R. P. (2010) Modern digital electronics, 4th ed., Tata McGraw Hill, India
2. Anand Kumar, A (2016) Fundamentals of Digital Circuits, 4th ed, PHI, India
3. Kothari, D. P. and Dhillon, J. S. (2015) Digital Circuits and Design 1st ed., Pearson Education, India.
4. Mano, M. (2016) Digital Logic and Computer Design, 1st ed., Pearson Education India, India
5. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8th ed., Pearson New Int. Edition.
6. Gaonkar, R. (2013) Microprocessor Architecture, Programming and Applications with 8085, 6th ed., Penram International Publishing, India
7. Kharate, G.K. (2010) Digital Electronics, Oxford University Press, India


**COURSE OUTCOME:**

**After completion of this course, students will be able**

1. **to understand the basic structure of 8085 microprocessor.**
2. **to learn the structure and use of different memory units.**
3. **to gain basic idea of digital communication.**

## Course No: C-PHS 204: Concepts of Physics: Inventions and applications (CBCS)

**Marks: 50 Credit: 4**
**Classes: 40**

1. Important Developments of Physical Science before 20th century: Introduction; Archimedes' principle; Concept of inertia – Galileo Galilee; Newton's laws of motion and law of gravity; Kepler's law of planetary motion; Newton's law of gravitation from Kepler's law of planetary motion; Concept of Classical Mechanics; Frame of references; Wave theory of light by Young; Dalton's atomic theory of matter; Discovery of electron; Plum pudding model of atom.

2. Progress of Physics in 20th century: Introduction; Photoelectric effect by Einstein; Experimental study of photoelectricity – Lenard's experiments; Discovery of the atomic nucleus – Rutherford alpha-particles scattering experiment; Concept of Quantum Mechanics; Radioactivity; Introduction to electronics and devices; Electromagnetic induction and its applications; Induction oven.

3. Physics of Nature: Scattering of light – Rayleigh, Thomson and Mie scattering; Tyndall effect; Blue colour of sky; Colour of Sun; Rainbow; Halo; Refraction and reflection of light; Mirage.

4. Electrical conductivity, perfect conductivity, super conductivity, Meissner effect, Magnetic levitation.

5. Electromagnetic wave: Basic idea about the generation of electromagnetic spectrum from radio frequency to $\gamma$-ray; Microwave oven.

6. Materials: Crystal and amorphous; Nano materials; Glass.

7. Development of different light sources: Incandescent bulb; Vapour lamp; Arc Lamp; Fluorescence Lamp (Tube light, CFL); Light Emitting Diode (LED); LASER – basic idea on different level laser system; Field emission.

8. Basic idea about: Optical fiber; Photo-detector; Holography; Non-linear Optics**.**

9. Medical Instrumentations: Blood pressure measurement device; Blood sugar testing device; X-ray; Ultrasonography (USG); Magneto Resonance Imaging (MRI); Photodynamical Therapy (PDT).

10. Electrical and electronic devices: Optical camera; Transistor radio, AM and FM radio, Digital Camera, Mobile, Fan, electric generator, Refrigerator.

**Books recommended:**

**Reference for journal article**

1. Kires, M. (2007) Archimedes' principle in action, Physics Education, 42, 484-487.

2. Sadaghiani, H.R. (2015) Quantum mechanics concept assessment: Development and validation study, Physical Review Special Topics – Physics Education Research, 11, 010110.

**Reference for a book as general**

1. Barnal, J.D. (2016) Itihase Bijnan, Ananda Publishers Pvt. Ltd., 1st ed., Kolkat, India. ((In Bengali)
2. Bowler, P.J. and Iwan, R.M. (2020) Making Modern Science: a Historical Survey, 2nd ed., University of Chicago Press, Chicago, United states
3. Sen, S.N. (2017) Bigyaner Itihas - The History of Science, Saibya Prakasan Bibhag, Kolkata, India. (In Bengali)
4. Dashgupta, C.R. (2004) Snatak Padartha Vigyan (Dwitiya Khanda), 3rd ed., Book Sindicate Pvt. Ltd., Kolkata, India. (In Bengali)
5. Ghatak, A. and Thyagarajan, K. (2016) Optical Electronics, 1st ed., Cembridge University Press India Pvt. Ltd, New Delhi, India.
6. Ghoshal, S.N. (2015) Nuclear Physics, Reprint 1st ed., S. Chand & Company Pvt. Ltd., India.
7. Heath, T.L. (1897) The Works of Archimedes, 1st ed., Cambridge University Press, England.
8. Rose-Innes, A.C. and Rhoderick, E.H. (1978) Introduction to Superconductivity, 2nd ed., Peragom Press, United Kingdom.
9. Tayal, D.C. (2015) Nuclear Physics, Reprint 5th ed., Himalaya Publishing House, India.
10. Khandpur, R.S. (2014) Handbook of Biomedical Instrumentation, 3rd ed., McGraw Hill Education (India) Private Limited, India.
11. Tarasov, L.V. (1986) Laser Physics and Applications, 1st ed., Mir Publishers, Moscow.
12. Banwell, C.N. and McCah, E.M. (2017) Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw - Hill Publishing Company Limited, New Delhi, India.
13. Waldman, G. (1983) Introduction to Light: The Physics of Light, Vision, and Color, 3rd ed., Prentice Hall, United States.
14. Webster, J.G. (2009) Medical Instrumentation: Application and Design, 4th ed., Wiley, United States.

**Reference for a book chapter in an edited volume**

1. Evans, R.D. (1955) Chapter 1: Charge of Atomic Nucleus, In The Atomic Nucleus, 3rd ed., ed. by Evans, R.D., Tata McGraw-Hill Publishing Company Limited, India, pp. 6-27.
2. Goldstein, H., Poole, C. and Safko, J. (2000) Chapter 1: Survey of the Elementary Principles, In Classical Mechanics, 3rd ed., ed. by Goldstein, H., Poole, C. and Safko, J., Addison Wesley, United States, pp. 1-34.
3. Levi, A.F.J. (2016) Chapter 1: Concepts in classical mechanics, In Classical Mechanics, 4th ed., ed. by Isenberg, C., IOP, United Kingdom.
4. Wong, S.S.M. (2004) Introductory Nuclear Physics, 2nd ed., WILEY-VCH Verlag Gmbl I & Co. KGaA, Weinheim, Germany, pp. 1-20.

**Reference for materials in a book**

1. Evans, R.D. (1955) The Atomic Nucleus, 3rd ed., Tata McGraw-Hill Publishing Company Limited, India, pp. 6-27.
2. Evans, R.D. (1955) The Atomic Nucleus, 3rd ed., Tata McGraw-Hill Publishing

Company Limited, India, pp. 470-510.
3. Goldstein, H., Poole, C. and Safko, J. (2000) Classical Mechanics, 3rd ed., Addison Wesley, United States, pp. 276-285.

**COURSE OUTCOME:**

- Know many important developments of Physical Science before 20$^{th}$ century
- Know the progress of Physics in 20$^{th}$ century
- Understand the physics of Nature, electrical conductivity, electromagnetic wave
- Know several materials, different light sources, applied optics, medical instrumentations, electrical and electronic devices

## Course No: PHS 295: Electronics Practical-II

**Credit: 4 Marks: 50**

1. To design a 4 bit ripple up/down counter and to develop different modulo counters from it.
2. To design 4 bit Ring counter and Twisted Ring counter.
3. Study of differential amplifier circuit using OP-amp and find out its transfer characteristics and differential mode gain.
4. Design of a window comparator using Op-amps and study its characteristics.
5. Astable and Monostable multivibrator with timer IC 555.
6. Determination of the Slew Rate (SR) of an Op-amp.
7. To design a Colpitt oscillator using transistor.
8. To design and develop FET amplifier and to find out its linearity and frequency response characteristics.
9. Band gap measurement of a Semiconductor using P-N junction.

**COURSE OUTCOME:**

**This course will help the students to design and fabricate various digital and analog electronic circuits, e.g. counters, multivibrators, oscillator circuits**.

## Course No: PHS 296: Advance Practical-I

**Credit: 4 Marks: 50**

**Group-A**

1. Linearisation LED Characteristics and finding out the quantum efficiency.
2. Determination of Plank's constant (using photo electric effect).
3. Measurement of the Hall coefficient of a given sample and calculation of its concentration.
4. Determination of refractive index using Michelson Interferometer.
5. Measurement of e/m by magnetron valve
6. Study of the characteristics of a GM tube.

7. Crystal structure determination by X-ray diffraction method.
8. To verify inverse square law using G-M counter.
9. Determination of electron temperature by single probe method.

### Group-B

1. Determination of response time of a LRD.
2. Determination of Plank’s constant (using solar cell).
3. To Study experimentally the variation of resistivity of semiconductor with temperature and hence to find out the band gap energy.
4. To estimate the separation between the two plates of a Febry-Perot interferometer.
5. Frank Hertz experiment.
6. Determination of Electron / Ion temperature by Double probe method.
7. Determination of the gamma and beta ray absorption coefficients by using a G.M. counter.
8. Determination of Curie temperature.
9. Study of nuclear counting statistics using a GM counter.
10. Characteristics of a Photo Diode.

### COURSE OUTCOME:

**This practical course structure is designed to impart the students to provide strong hands-on laboratory training in modern, currently active, areas of Physics particularly in optics, semiconductor physics and nuclear physics.**

# SEMESTER- III

## Course No: PHS 301.1: Quantum Mechanics-III

**Marks: 25 Credit: 2**
**Classes: 20**

1. **Identical particles:** Permutation Symmetry. Symmetrization postulate: symmetric and antisymmetric wave function, Pauli's exclusion Principle. Slater determinant. Two-Electron System- The Helium atom, ground state of Helium atom. (5)

2. **Approximation Methods for time-dependent perturbations:** Interaction picture. Time-dependent perturbation theory. Transition to a continuum of final states–Fermi's Golden Rule. Constant and harmonic perturbations. Sudden and adiabatic approximations. (5)

3. **Non-relativistic Scattering:** Lippmann-Schwinger Equations, Green's function method. Born approximation, S-Matrix, Optical theorem, Method of Partial Waves, Phase shifts. (5)

4. **Relativistic quantum mechanics:** Historical survey. Klein-Gordon and Dirac equations. Properties of Dirac matrices. Plane wave solutions of Dirac equation. Spin and magnetic moment of the electron, non-relativistic limits. (5)

**Books Recommended:**


1. Sakurai, J. J. and Napolitano, J. (2020) Modern Quantum Mechanics, 3rd ed., Addison-Wesley.
2. Schiff, L. I., (1969) Quantum Mechanics, 3rd ed., McGraw-Hill Book, New York.
3. Schwabl, F. (2007) Quantum Mechanics, 4th ed., Springer.
4. Griffiths, D. J. & Schroeter, D. F. (2019) Introduction to Quantum Mechanics, 3rd ed., Cambridge Univ. Press.
5. Ghatak, A. K. & Lokanathan, S. Quantum Mechanics: Theory and Applications, Macmillan India Ltd..
6. Cohen- Tannoudji, C., Diu B. & Laloe F. (2019) Quantum Mechanics, Vol I & II, 2nd Ed., Wiley.
7. N. Zettili, N. (2009) Quantum Mechanics: Concepts and Applications, 2nd ed., Wiley India
8. Singh, J., (1996) Quantum Mechanics: Fundamentals and Applications to Technology, 1st Ed., Wiley VCH.

**COURSE OUTCOME:**

**The part three of the course on Quantum Mechanics mainly focusses on developing more tools for studying applications to atomic, nuclear and solid-state physics. Students will learn about the formalism and applications of quantum mechanics to identical particles. In this context the Helium atom will be discussed. Students will be introduced to the techniques of time-dependent perturbation theory, transition to a continuum of final states and Fermi's Golden Rule. The application of time dependent formulation to quantum theory of scattering, which is widely used in nuclear and particle physics will also be discussed.**

## Course No: PHS 301.2: Statistical Mechanics - I

**Marks: 25 Credit: 2**
**Classes: 20**

1. Scope and aim of statistical mechanics. Transition from thermodynamics to statistical mechanics. Review of the ideas of phase space, phase points, Ensemble, Density of phase points. Liouville's equation and Liouville's theorem.

2. Stationary ensembles: Micro canonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuation in energy and particle. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature.

3. Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Pure and Mixed states. Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin ½ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector
4. Distribution functions. Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems.

***Books Recommended:***

1. Pathria, R.K. (2001) Statistical Mechanics, 2nd ed., Butterworth-Heinemann, Oxford, England.
2. Huang, K. (1987) Introduction to Statistical Mechanics, 2nd ed., John Wiley & Sons, Inc., United States.
3. Blundell, S.J. and Blundell, K.M. (2006) Concepts in Thermal Physics, 2nd ed., Oxford University Press, Oxford University Press, England.
4. Reif, F. (2010) Fundamentals of Statistical and Thermal Physics, 56946th ed., Sarat Book Distributors, India.

5. Kadanoff, L.P. (2000) Statistical Mechanics: Statics, Dynamics and Renormalization, 1st ed., World Scientific Publishing Co. Pvt. Ltd., India.
6. Kubo, R. (1988) Statistical Mechanics: An Advanced Course with Problems and Solutions, 17th ed., Elsevier, Netherlands.

**COURSE OUTCOME:**

- Know the concepts of phase space
- Understanding different ensembles with application to condensed matter and other branches of physics
- describe the features and examples of Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics
- Learning the Modern aspects of equilibrium and non- equilibrium statistical Physics.
- Work with various models of phase transitions and thermodynamical fluctuations.
- Describe physical quantities in quantum systems.

## Course No: PHS 302.1: Molecular Spectroscopy & Laser Physics

**Marks: 25 Credit: 2**

**Classes: 20**

1. Microwave spectroscopy: Conversation of different spectroscopic units, Basic idea about the generation of electromagnetic spectrum from radio frequency to ν-ray. Rotations of molecules, Diatomic molecular rotational spectroscopy of rigid and non-rigid diatomic molecules, Intensity of spectral lines, microwave spectroscopy of symmetric type of molecules, Stark effect.

2. Infra-red spectroscopy: Diatomic molecular vibrational spectroscopy with harmonic and anharmonic vibration, vibrational and rotational spectroscopy, anharmonic oscillation constant, rotational constant, Dissociation energy.

3. Visible and ultraviolet spectroscopy: Molecular electronic spectroscopy, Frank Condon principle, Molecular electronic vibrational-rotational spectroscopy, Born-Oppenheimer approximation, Fortrat diagram, Band head.

4. Laser: Spontaneous and stimulated emission, Laser resonator, population inversion, active and passive laser resonator, Threshold condition, saturation condition, Quality factor, Burger's law, classification of laser Three level laser and four level laser system, equation of population inversion and threshold power calculation for the laser systems. Q switching, Application of laser.

**Books Recommended**:

1. Banwell, C. N., and McCah, E. M. (2017) Fundamentals of Molecular Spectroscopy, $4^{th}$ ed., Tata McGraw - Hill Publishing Company Limited, India.
2. Aruldas, G. (2007) Molecular Structure and Spectroscopy, $2^{nd}$ ed., PHI Learning Private Limited, India.

3. Hertzberg, G. (1951) Molecular Structure and Molecular Spectra: vol. 1, Spectra of Diatomic Molecules, 2nd ed., Van Nostrand.
4. Herzberg, G. (1945) Molecular Structure and Molecular Spectra: vol. 2, Infrared and Raman Spectra of polyatomic Molecules, 16th printing ed., Van Nostrand.
5. Barrow, G. M. (1962) Molecular Spectroscopy, 1st ed. McGraw-Hill Inc.,US.
6. Ghatak, A., and Thyagarajan, K. (2007) Optical Electronics, Special ed. for sale in South Asia, Cambridge University Press India Pvt. Ltd, India.

**COURSE OUTCOME:**

**This course is combined with the basic theory and phenomenology of Laser Physics and provides an introduction to molecular spectroscopy. The course on laser physics provides an insight into the physical principles of operation of lasers, construction of laser, and their applications in different areas of science and industry. This course also covers different methods of Q-switching for the generation of ultra-short laser pulse. The course on molecular spectroscopy introduces the three key spectroscopic methods used by physicist, chemist and biochemist to analyze the molecular and electronic structure of atoms and molecules. These are Rotational, Vibrational and Electronic spectroscopy. Numerous exercises are provided to facilitate mastery of each topic**

## Course No: PHS 302.2: Nuclear Physics-I

**Marks: 25 Credit: 2**

**Classes: 20**

1. Properties of Nuclei and classification of nuclides: Recapitulation of nuclear properties and types of nuclides; Magnetic dipole moment of nuclei, nuclear magnetic moment determination – Resonance method of Rabi and colleagues; Electric multipole moment – electric quadrupole moment and nuclear shape; Mass spectrometry – basic components of mass spectroscopes and double focusing mass spectrometer of Nier and Roberts.
   Odd-even nuclei; Semi-empirical mass formula and its applications – mass parabolas for isobars.

2. $\alpha$-radiation and $\alpha$-radioactivity: Recapitulation of $\alpha$-particle spectra; Systematics of $\alpha$-decay energies; Theory of $\alpha$-decay – Gamow's theory of $\alpha$-decay, hindrance and formation factors; Energy-loss of $\alpha$-particles in matter, theoretical calculation of $\alpha$-particle range in matter and straggling of range.

3. $\beta$-radiation and $\beta$-activity: Energetics of $\beta$-decay; Nature of $\beta$-spectrum; Neutrino hypothesis and detection; Fermi's theory of $\beta$-decay and Kurie plot; Absorption of electrons in matter – ionization loss, radiation loss and range of electron; Simple ideas of parity violation in $\beta$-decay; Inverse and double $\beta$-decay.

4. $\gamma$-radiation: Passage of $\gamma$-rays through matter; $\gamma$-ray spectra and nuclear energy levels; Radiative transitions in nuclei – multipole radiations and modes of $\gamma$-ray transition; Nuclear isomerism; Nuclear resonance fluorescence; Mossbauer effect – recoil free $\gamma$-ray spectroscopy and applications of Mossbauer effect.

**Books Recommended :**

**Reference for journal article**


1. Hatsukawa, Y. (1990) Systematics of alpha decay half-lives. Physical Review C, 42, 674-682.
2. Perlman, I., Ghiorso,A. and Seaborg, G.T. (1950) Systematics of Alpha-Radioactivity. Physical Review, 77, 26-50.
3. Mattauch, J. (1936) A Double-Focusing Mass Spectrograph and the Masses of $N^{15}$ and $0^{18}$. Physical Review, 50, 617-623.
4. Nanni, L. (2019) Fermi's Theory of Beta Decay: A First Attempt at Electroweak Unification. Advanced Studies in Theoretical Physics, 13, 281-293.
5. Neyens, G. (2003) Nuclear magnetic and quadrupole moments for nuclear structure research on exotic nuclei. Reports on Progress in Physics, 66, 633-689.
6. Roy, A. (2005) Discovery of Parity Violation. Resonance, 6, 32-43.
7. Perlman, I., Ghiorso,A. and Seaborg, G.T. (1949) Relation Between Half-Life and Energy in Alpha-Decay. Physical Review, 75, 1096-1097.
8. Rabi, I.I., Millman, S. and Kusch, P. (1939) The Molecular Beam Resonance Method for Measuring Nuclear Magnetic Moments. Physical Review, 55, 526-535.
9. Santilli, R.M. (2007) The Etherino and/or the Neutrino Hypothesis. Foundations of Physics, 37, 670.
10. Silisteanu, I., Budaca, A.I. and A. O. Silisteanu, A.O. (2010) Systematics of α-Decay Half-Lives of the Heaviest Elements. Romanian Journal of Physics, 55, 1088-1110.


**Reference for a book as general**


1. Basdevant, J.L., Rich, J. and Spiro, M. (2005) Fundamentals in Nuclear Physics: From Nuclear Structure to Cosmology, 1st ed., Springer, New York, USA.
2. Blatt, J.M. and Weisskopf, V.F. (1979) Theoretical Nuclear Physics, 1st ed., Springer, Germany.
3. Cohen, B. (1974) Concepts of Nuclear Physics, 1st ed., McGraw Hill Higher Education, United States.
4. Elton, L.R.B. (1965) Introductory Nuclear Theory, 2nd ed., Sir Isaac Pitman & Sons Ltd, United Kingdom.
5. Evans, R.D. (1955) The Atomic Nucleus, 3rd ed., Tata McGraw-Hill Publishing Company Limited, India.
6. Srivastava, B.N. (25019) Basic Nuclear Physics and Cosmic Rays, 18th ed., Pragati Prakashan, India.
7. Ghoshal, S.N. (2015) Nuclear Physics, Reprint 1st ed., S. Chand & Company Pvt. Ltd., India.
8. Krane, K.S. (1987) Introductory Nuclear Physics, Rev. 3rd ed., John Wiley & Sons, United States.

9. Kaplan, I. (2002) Nuclear Physics, 19th ed., Narosa Publishing House, India.
10. Lim, Y.K. (2000) Problems and Solutions on Atomic, Nuclear and Particle Physics, 1st ed., World Scientific Publishing Co. Pte. Ltd., Singapore.
11. Segre, E.G. (1977) Nuclei and Particles: An Introduction to Nuclear and Subnuclear Physics, 2nd ed., Basic Books, United States.
12. Tayal, D.C. (2015) Nuclear Physics, Reprint 5th ed., Himalaya Publishing House, India.
13. Wong, S.S.M. (2004) Introductory Nuclear Physics, 2nd ed., WILEY-VCH Verlag Gmbl I & Co. KGaA, Weinheim, Germany.

**Reference for a book chapter in an edited volume**

1. Krane, K.S. (1987) Chapter 16: Nuclear Spin and Moments, In Introductory Nuclear Physics, Rev. 3rd ed., ed. by Krane, K.S., John Wiley & Sons, United States, pp. 602.-652.
2. Preston, M.A. and Bhaduri, R.K. (1982) Chapter 11: Alpha Radioactivity, In Structure of the Nucleus, 2nd ed., ed. by Preston, M.A. and Bhaduri, R.K., Addison-Wesley Publishing Company, Inc., United States, pp. 509-540.
3. Roy, R.R. and Nigam, B.P. (2014) Chapter 13: Beta Decay, In Nuclear Physics: Theory and Experiment, 2nd ed., New Age International Pvt. Ltd., India, pp. 496-540.

**Reference for materials in a book**

1. Krane, K.S. (1987) Introductory Nuclear Physics, Rev. 3rd ed., John Wiley & Sons, United States, pp. 193-203.
2. Preston, M.A. and Bhaduri, R.K. (1982) Structure of the Nucleus, 2nd ed., Addison-Wesley Publishing Company, Inc., United States, pp. 3-122.
3. Roy, R.R. and Nigam, B.P. (2014) Nuclear Physics: Theory and Experiment, 2nd ed., New Age International Pvt. Ltd., India, pp. 5-45.

**COURSE OUTCOME:**

- Understand the basic properties of nuclei
- Know the classification of nuclides
- Understand the three radioactive decay phenomena
- Knowledge on the interactions of alpha, beta and gamma radiations with matter
- Understanding of different nuclear spectroscopy

## Course No: PHS 303A: Advanced Condensed Matter Physics –I

**Marks: 50 Credit: 4**
**Classes: 40**

1. Optical Properties: Transverse plasma frequency & propagation of electromagnetic wave in a material, Longitudinal plasma frequency & plasmon, Electrostatic screening, Thomas Fermi dielectric function, Motts metal to insulator transition, Polariton & LST relation, Polaron.
2. Defect studies: Luminescence, Colour center, Point defects in solid, Diffusion in an ionic crystal, Ionic conductivity, Line defect.

3. Quantization of orbit in a magnetic field {Landau levels}, De Haas Van Alphen Effect, Boltzman transport equation & applied to metals to find electrical conductivity. 2D electron gas in Transverse Magnetic Field.

4. Exciton, Raman effect in crystal, Kramers Kronig relation, Ferroelectric characteristics & their classification, Polarization catastrophe, Origin of ferroelectricity, Landaus theory of ferroelectric transition.

**Books recommended:**

1. Solid State Physics: C. Kittle
2. Kireev: Semiconductor Physics
3. Solid State. Physics : Neil W. Ashcroft. N. David Mermin *(*Cengage Learning India)
4. O. Madelung – Introduction of Solid State Theory (Springer).
5. J.M. Ziman:Principles of the theory of solids
6. Solid State Physics: Mattis

**COURSE OUTCOME:**

**The course topic is Condensed Matter Physics special paper which covers large part in this field. The course enriches the student in many fields like defects in solid and introduces important new particles like Plasmon, Polariton, Polaron, Exciton. The course also includes Luminescence in solid and transport properties of metal. The course also describes the origin of Landau Levels. The course will motivate the students to do research in these fields both in Theoretical as well as Experimental Condensed Matter physics.**

## Course No: PHS 303B: Applied Electronics-I

### PHS 303B.1: Applied Analog Electronics-I

**Marks: 25 Credit: 2**
**Classes: 20**

1. Special OP- AMP Circuits & applications: Bridge amplifier circuit : advantages over single stage amplifier, instrumentation amplifiers, logarithmic amplifiers, anti-log amplifier, analog multiplier, summing integrator, chopper modulator, chopper stabilized amplifier, pulse width modulator, Regenerative comparators and their uses, pulse generator, ramp generator, square and triangular wave generator, crystal oscillator, voltage controlled oscillator (VCO). Active filters, Butterworth characteristics, first, second and higher order low pass and high pass active filters, band pass and band stop active filters.

2. Voltage regulators : Series Op-amp regulator, Current limiting, Foldback current limiter, IC regulator, precision current and voltage sources, Switching Regulators.

3. Phase Lock Loop (PLL) & applications: Operation of PLL, characteristics and parameters, Application of PLL: Frequency multiplication, tracking, FM demodulation, Order of PLL.

4. Detectors: Peak detectors, zero-crossing detectors, phase-sensitive detectors, precision rectifier.

**Books Recommended:**


1. Gayakwad , R.A. (2015) Op- Amps and Linear Integrated Circuits, 4$^{th}$ ed., Pearson Education, India.
2. Millman, J. and Halkias, C.C. (2017) Integrated Electronics, Tata McGraw Hill, India.
3. Roddy, D. and Coolen, J. (2008) Electronic Communications, 4$^{th}$ ed., Pearson Education, India
4. Gray and Meyer (2009) Analysis and Design of Analog Integrated Circuits, 5$^{th}$ ed., Wiley, India.
5. Soclof, S. (2004) Design and Applications of Analog Integrated Circuits, PHI, India.


**COURSE OUTCOME:**

**To develop the concepts of electronics in order to strengthen the understanding of electronic devices those are the part of our surrounding technologies.**

**After completion of this course, students will be able to**

1. **achieve detail knowledge of application oriented Op-Amp circuits.**
2. **understand details inside the linear and switched mode regulated power supplies.**
3. **know the components, operation and use of phase locked loop.**

## PHS 303B.2: Applied Digital Electronics-I

**Marks: 25 Credit: 2**
**Classes: 20**

1. Digital Logic families: DTL, TTL, ECL, MOS, CMOS logic circuits, their advantages, disadvantages and comparison : Speed of operation, Power dissipation, Figure of merit, Fan-in and Fan-out.

2. Different memory systems : Memory organization and addressing, Sequential Memory : Charge coupled devices (CCD), Unit cell of SRAM and DRAM, Ratioed and Ratio-less shift registers, Special Memory units: MRAM, RRAM, PAL, FPLA. .

3. Specialized Communication Systems: Mobile Communication – Concepts of cell and frequency reuse, Hands-off technique, Description of cellular communication

standards; Computer communication: LAN, WAN, Computer topology, TCP/IP Protocol, Circuit message and packet switched networks; Design and examples of ARPANET, ISDN, Medium access techniques – TDMA, FDMA, CDMA, ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol.

**Books Recommended:**


1. Jain, R. P. (2010) Modern digital electronics, 4th ed., Tata McGraw Hill, India
2. Anand Kumar, A. (2016) Fundamentals of Digital Circuits, 4th ed, PHI, India
3. Kothari, D. P. and Dhillon, J. S. (2015) Digital Circuits and Design 1st ed., Pearson Education India, India
4. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8th ed., Pearson New Int. Edition.
5. Roddy, D. and Coolen, J. (2000) Electronic Communications, 4th ed., Prentice Hall of India, India
6. Taub, H. and Schilling, D. (2017) Digital Integrated Electronics, McGraw Hill Education, India
7. Taub, H., Schilling, D. and Saha, S. (2017) Principles of Communication System, 4th ed., McGraw Hill Education, India


**COURSE OUTCOME:**

**To develop the concepts of electronics in order to strengthen the understanding of electronic devices those are the part of our surrounding technologies.**

1. **to get details of different logic families like DTL, TTL, ECL, MOS, CMOS, etc.**
2. **to understand the in-depth knowledge of different memory units.**
3. **to gain basic knowledge of advanced communication systems like mobile & computer communication**

## Course No: PHS 303C: Applied Optics and Opto-electronics – I

**Marks: 50 Credit: 4**
**Classes: 40**

1. **Optical Sources :** Principle of operation of LED , and Semiconductor junction Laser , Internal and External quantum efficiencies of LED , Different efficiencies of Semiconductor junction Laser , Equations relating the light intensity of LED and Semiconductor Laser with applied current, Quantum well laser , Principle of operation of quantum well Laser .

2. **Optical detector :** PiN detector , Quantum efficiency of PiN detector, Avalanche photo detector, Equations relating the applied light intensity with received photo current of a PiN detector and that of a Avalanche photo detector , Dark current of a photo detector, Shot noise, Signal to noise ratio of a photo detector, Photo conductor and its principle of operation, Photo transistor and its principle of operation .

3. **Optical fiber communication :** Types of optical fiber , Propagation of electromagnetic radiation through 3-dimensional cylindrical step index optical fiber and through graded index optical fiber, Concept of TEM modes in cylindrical fiber. Dispersion in optical fiber; multi path dispersion , material dispersion, and wave guide dispersion, Derivation of the expressions of dispersions, concepts of dispersion free fiber and dispersion compensated fiber, maximum bit rate in optical fiber, Power budget equation and Time budget equation, Wavelength division multiplexing and demultiplexing.

**Books Recommended:**


1. Ghatak, A., and Thyagarajan, K. (2007) Optical Electronics, Special ed. for sale in South Asia, Cambridge University Press India Pvt. Ltd, India.
2. Bhattacharya, P. (1996) Semiconductor optoelectronic devices, 2$^{nd}$ ed., Prentice Hall publication, India.
3. Yariv, A. (1984) Optical Electronics, 3$^{rd}$ ed., Holt McDougal.
4. Tarasov, L. V. Laser Physics and Applications, Mir Publishers, USSR
5. Pipker, J. (2003) Semiconductor Optoelectronic Devices: Introduction to Physics and Simulation, 1$^{st}$ ed., Academic Press, USA
6. Bhattacharya, P. (2017) Semiconductor Optoelectronic Devices, end ed., Pearson, India.
7. Rosencher, E., and Vinter, B (2002) Optoelectronics, 1$^{st}$ ed., Cambridge, University Press.
8. Mukhopadhyay, S. (2000) Optical computation and parallel processing, 1$^{st}$ ed., Classique Books Publisher, India.
9. Ghosh, P. and Mukhopadhyay, S. (2004) Some digital approaches in optical computation, Premier Books publication, India.


**COURSE OUTCOME:**

**The course is important to train the students in important topic i.e applied optics and optoelectronics. The students will be enriched to do research in important fields like Fiber Optics, Optoelctronics, and Semiconductor laser.**

## Course No: PHS 303D: Astrophysics – I

## PHS 303D.1: Astronomical Methods

**Marks: 25 Credit: 2**
**Classes: 20**

1. **Introduction:** Mass, length and time scale in Astrophysics. Apparent and absolute magnitude.
2. **Units and Measurements**: Electromagnetic Spectrum - Measuring stellar characteristics (temperature, distance, luminosity, mass, size).

3. **Sky Coordinates and Motions**: Earth Rotation - Sky coordinates – seasons - phases of the Moon - the Moon's orbit and eclipses – time keeping (sidereal vs synodic period); Planetary motions - Kepler's Laws.
4. **Radiation Processes in Astrophysics:** Concepts of Radiative Transfer – special relativity – Maxwell’s equations – Wave equation – retarded potentials – radiation field – Poynting vector – radiation from accelerated charge – bremsstrahlung – Thomson and Compton scattering – synchrotron radiation – thermal and non-thermal distribution of radiating particles – non-thermal synchrotron radiation – self-absorption – synchrotron and Compton cooling – Inverse Compton catastrophe and brightness temperature limit – propagation effects: dispersion, faraday rotation, depolarization – Atomic and molecular spectra – fine structure and hyperfine transition.

## PHS 303D.2: Steller Structure and Evolution

**Marks: 25 Credit: 2**
**Classes: 20**

1. **Sun as a star :** Solar Parameters, Solar Photosphere, Solar Cycle, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Basics of Solar Magnetohydrodynamics. Helioseismology, Solar Nucleosynthesis.
2. **Equations of stellar structure :** Fundamental equations – Hydrostatic equilibrium – Mass distribution – Luminosity distribution – Radiation transport - Convective transport – Condition for convection – Adiabatic temperature gradient – Secondary equations
3. **Modeling and evolution :** Approach to solutions - Sun - Main-sequence stars – Spectral types – Convective regions - Hertzsprung–Russell diagram – Color-magnitude diagram – Effective temperature and radius - Giants and supergiants - Evolution of single stars – Solar evolution – Massive stars – Gamma-ray bursts – Globular clusters – Open clusters – Variable stars - Scaling laws – Matter density – Pressure – Temperature – Luminosity – Mass dependence – H-R diagram comparison – Homology transformations
4. **Compact stars :** White dwarfs – Mass-radius relation – Stability – Sirius B – Chandrasekhar mass limit - Neutron stars – Radius of a neutron star – Equations of state and structure – Evidence for neutron stars – Maximum mass - Black holes – Event horizon (Schwarzschild radius) – Angular momentum – -Static Black Holes (Schwarzschild and Reissner - Nordstrom) - Rotating Black Holes – Kerr Metric (derivation not required) - Event Horizon - Extraction of energy by Penrose process - Kerr-Neumann Metric (no derivation) - No hair theorem - Cosmic Censorship Hypothesis. Innermost stable orbit – Broad, distorted iron line – Planck length – Particle acceleration – Evaporation – Existence of black holes

**Books Recommended:**

1. Carroll, B.W. and Ostlie, D.A. (2006) An Introduction to Modern Astrophysics, 2nd ed., Cambridge University Press, England.
2. Shu, F. (1981) The Physical Universe: An Introduction to Astronomy, 1st ed., University Science Books, USA.
3. Harwit, M. (2000) Astrophysical Concepts, 3rd ed., Springer, New York, United

States.
4. Padmanabhan, T. (2006) Invitation to Astrophysics, Latest Edition, 3rd ed., World Scientific Publishing Co. Pvt. Ltd., India.
5. Padmanabhan, T. (2000) Theoretical Astrophysics (Volume I-III), 1st ed., Cambridge University Press, England.
6. Longair, M.S. (1992) High Energy Astrophysics (Volume 1-2), 2nd ed., Cambridge University Press, England.
7. Sparke, L.S. and Gallaghar, J.S. (2015) Galaxies in the Universe: An Introduction, 2nd ed., Cambridge University Press, England.
8. Prialnik, D. (2013) An Introduction to the Theory of Stellar Structure and Evolution, Latest Edition, 2nd ed., Cambridge University Press, England.
9. Schneider, S. and Arny, T.T. (2021) Pathways to Astronomy, 6th ed., McGraw-Hill Science Engineering, United States.
10. Chandrasekhar, S. (1989) Stellar Structure and Stellar Atmospheres (Volume 1), 1st ed., The University of Chicago Press, United States.
11. Abhyankar, K.D. (2001) Astrophysics: Stars and Galaxies, 1st ed., Universities press (India) Limited., India.
12. Menzel, D.H., Bhatnagar, P.L. and Sen, H.K. (1963) Stellar Interiors, Chapman & Hall, 1st ed., United Kingdom.

**COURSE OUTCOME:**

- Introduce the basics of astrophysics
- Know the astronomical units and measurements
- Understand the radiation emission processes in astrophysics
- Understand the solar system and solar energy generation
- Acquainted with the modeling and evolution of stars including Sun
- Familiar with different stars and their motion
- Know about the black holes

## Course No: C-PHS 304: Introductory Astrophysics (CBCS)

**Marks: 50 Credit: 4**
**Classes: 40**

**1. Our Planet, our Universe:**
Introduction to astronomy; Our motion in the Universe; The night sky; Astronomical objects – constellations, planets, moon, asteroids, comets, meteorites and other objects; Basic concepts in astronomy such as astronomical distances, latitude and longitude; Celestial sphere – celestial coordinate systems; Dwarf planets; Formation of our solar system; Sun-Moon-Earth configurations – Moon phases, Solar and Lunar eclipses; Rotation of Earth – Latitude and Longitude.

**2. Astronomical Tools:**
Light as a tool to probe the Universe; Properties of light; The wave particle nature of light; Atoms and spectroscopy; The thermal spectrum; Stellar classification –

Hertzsprung-Russell diagram; Composition of a star's outer layers and its surface temperature; The Inverse square law; Telescopes to learn about astrophysical phenomena.

**3. The Sun:**

Introduction to our solar system; Formation of our solar system; Basic parameters of Sun; Structure of Sun; Origin of solar energy; Solar constant; Nuclear fusion; Solar time; Solar cycle; Solar activity; Solar wind; Solar missions; Main-Sequence lifetime.

**4. Evolution of Stars:**

Post-main-sequence evolution of a Sun-like star; Planetary nebulae; White dwarfs; Neutron Stars; Difference between stars; brown dwarfs and giant planets; Supernova explosions; Neutron stars and black holes; Color-magnitude diagrams; Binary star systems.

**5. Galaxy and Cosmos:**

Populations of stars and star clusters; Galaxy types and the formation and interaction of galaxies; The Milky Way; Active galactic nuclei; The rotation of our galaxy; Dark matter; The expansion of the Universe and the Big Bang Theory.

**Books Recommended :**

**Reference for journal article**


1. Hathaway, D.H. (2010) The Solar Cycle. *Living Reviews in Solar Physics*. 7, 1-65.
2. Narang, S., Gupta, M., and Anubha Singh Gaur, A.S. (2016) The Study of Present Solar Cycle 24 – Future Aspects. Research Journal of Physical Sciences, 4, 5-10.


**Reference for a book as general**


1. Abhyankar, K.D. (2001) Astrophysics: Stars and Galaxies, 1st ed., Universities press (India) Limited., India.
2. Bennett, J.O. and Donahue, M.O. (2016) The Cosmic Perspective, 8th ed., Pearson Education, Inc., United Kingdom.
3. Bowers, R. and Deeming, T. (1984) Astrophysics I : Stars (Volume 1), 1st ed., Jones and Bartlett Publishers, Inc. , United States.
4. Bowers, R. and Deeming, T. (1984) Astrophysics II: Interstellar Matter and Galaxies (Volume 2), 1st ed., Jones and Bartlett Publishers, Inc. , United States.
5. Chandrasekhar, S. (1989) Stellar Structure and Stellar Atmospheres (Volume 1), 1st ed., The University of Chicago Press, United States.
6. Chen, C.J. (2011) Physics of Solar Energy, 1st ed., John Wiley & Sons, Inc., United States.
7. Elkins-Tanton, L.T. (2006) The Solar System: Asteroids, Meteorites, and Comets, 1st ed., Chelsea House Publishers, USA.
8. Krisna Swamy, K.S. (1996) Astrophysics: A Modern Perspective, 1st ed., New Age International Private Limited, India.
9. Menzel, D.H., Bhatnagar, P.L. and Sen, H.K. (1963) Stellar Interiors, Chapman & Hall, 1st ed., United Kingdom.
10. Raychaudhuri, A.K., Banerji, S. and Banerjee, A. (1992) General Relativity, Astrophysics, and Cosmology, 1st ed., Springer-Verlag, Germany.
11. Schneider, S. and Arny, T.T. (2021) Pathways to Astronomy, 6th ed., McGraw-Hill Science Engineering, United States.

12. Schwarzschild, M. (1958) Structure and Evolution of the starts, Princeton University Press, 1st ed., United States.
13. Srinivasan, U. (2003) Hello Stars, 2nd ed., National Council for S & T Communication, India.
14. Larson, D.B. (1984) The Universe of Motion (Volume III), 3rd ed., North Pacific Publishers, Washington, United States.
15. Svalgaard L: (2013) Solar activity – past, present, future. Journal of Space Weather and Space Climate, 3, A24-p1-A24-p8.

**Reference for a book chapter in an edited volume**

1. Chen, C.J. (2011) Chapter 3: Origin of Solar Energy, In Physics of Solar Energy, 1st ed., John Wiley & Sons, Inc., United States, pp. 67-76.
2. Chen, C.J. (2011) Chapter 4: Tracking Sunlight, In Physics of Solar Energy, 1st ed., John Wiley & Sons, Inc., United States, pp. 77-104.
3. Srinivasan, U. (2003) Chapter 1: The Night Sky, In Hello Stars, 2nd ed., ed. by Sehgal, N.K., National Council for S & T Communication, India, pp. 1-5.
4. Srinivasan, U. (2003) Chapter 5: Stars, Constellations and Festivals, In Hello Stars, 2nd ed., ed. by Sehgal, N.K., National Council for S & T Communication, India, pp. 34-36.

**Reference for materials in a book**

1. Chen, C.J. (2011) Physics of Solar Energy, 1st ed., John Wiley & Sons, Inc., United States, pp. 1-4.
2. Larson, D.B. (1984) The Universe of Motion (Volume III), 3rd ed., North Pacific Publishers, Washington, United States, pp. 15-54.
3. Elkins-Tanton, L.T. (2006) The Solar System: Asteroids, Meteorites, and Comets, 1st ed., Chelsea House Publishers, USA, pp. 35-60.
4. Srinivasan, U. (2003) Hello Stars, 2nd ed., National Council for S & T Communication, India, pp. 1-43.

**COURSE OUTCOME:**

- Introduce the basic concepts of astrophysics
- Understand the fundamental concept of our planet and universe
- Know the details of stars, galaxy and other celestial objects
- Knowledge on different parameters for astrophysical measurements
- Details of the sun, solar system and related phenomena
- Evolution of universe and stars
- Know the galaxy and cosmos

## Course No: PHS 395: Advance Practical-II (Practical)

**Marks: 50 Credit: 4**

**Group-A**

1. Determination of LDR conductivity with input LED power.
2. Determination of Plank's constant (using solar cell).

3. To Study experimentally the variation of resistivity of semiconductor with temperature and hence to find out the band gap energy.
4. To estimate the separation between the two plates of a Fabry-Perot interferometer.
5. Frank Hertz experiment.
6. Determination of Electron / Ion temperature by Double probe method.
7. Determination of the gamma and beta ray absorption coefficients by using a G.M. counter.
8. Determination of Curie temperature.
9. Study of nuclear counting statistics using GM counter.
10. Characteristics of a Photo Diode.

**Group-B**

1. Linearisation LED Characteristics and finding out the quantum efficiency.
2. Determination of Plank's constant (using photo electric effect).
3. Measurement of the Hall coefficient of a given sample and calculation of its concentration.
4. Determination of refractive index using Michelson Interferometer.
5. Measurement of e/m by magnetron valve
6. Study of the characteristics of a GM tube.
7. Crystal structure determination by X-ray diffraction method.
8. To verify inverse square law using G-M counter.
9. Determination of electron temperature by single probe method.

**COURSE OUTCOME:**

**This practical course structure is designed to impart the students to provide strong hands- on laboratory training in modern, currently active, areas of Physics particularly in optics, semiconductor physics and nuclear physics.**

## Course No: PHS 396A: Advanced Condensed Matter Physics-I (Practical) Marks: 50 Credit: 4

**Group-A**

1. Study of Hall effect with variation of temperature.
2. Determination of Lande g-factor for the given sample using electron spin resonance spectrometer.
3. Determination of barrier potential and doping profile of transistor junctions
4. Determination of ionic conductivity of the given sample.
5. Study of Hysteresis loop of magnetic materials by using Hysteresis Tracer.
6. Study of characteristics of the given solar cell
7. Study of Diac & Triac characteristics with application

**Group-B**

1. Study of magneto resistance of the given material
2. Determination of carrier life time in Photoconductor

3. Measurement of magnetic susceptibility and Bohr magneton number of given sample by Gouy method.
4. Absorption/Transmission spectra of thin films by using UV/VIS spectro photometer.
5. Dielectric measurement of polycrystalline ferroelectric sample.
6. Study of Thermo luminescence in a crystal.
7. Study of UJT &SCR characteristics with application.

**COURSE OUTCOME:**

**This practical course structure is designed to impart the students to provide strong hands- on laboratory training especially in the advance field of Condensed Matter Physics. This will help them immensely for research in condensed matter physics as well as experimental research in Condensed Matter Physics.**

**Course No: PHS 396B: Applied Electronics-I (Practical)**

**Marks: 50**
**Credit: 4**

1. Design, Construction and performance testing of a Logarithmic amplifier using μA 741, diode and matched transistors.
2. Design, Construction and performance testing of an antilog amplifier using μA 741 and matched transistors.
3. Design of an IC Power Amplifier and its linearity, frequency response, efficiency, and distortion calculation.
4. Design of a Precision adjustable voltage regulator using μA 741 and series pass transistor and a transistor as current limiter and its performance comparison with LM78XX series fixed regulators.
5. Design and study of Multiplexer: formation, cascading and equation solving.
6. Design and study of De-multiplexer: formation, cascading and equation solving.
7. Design of an Active high pass/Low pass second order Butterworth filter.
8. Design an active band pass filter using single stage μA 741 Op-amp.
9. Design and study of an active phase sifter.
10. Frequency to Voltage converter circuit design.
11. Design and study of a Voltage Controlled Oscillator (VCO)/Voltage to Frequency converter.
12. Design of BCD addition and subtraction using Full Adder IC
13. Shift registers: PISO, SISO, PIPO, SIPO.

**COURSE OUTCOME:**

**This course will help the students to**

**(i)** **design and fabricate various advanced digital and analog electronic circuits, e.g. Mux, DeMUX, registers, voltage regulators, active filters etc.**

**(ii)** **design and conduct various electronics experiments.**

**The experiments will help the students to understand the application of the theories in practical field.**

## Course No: PHS 396C: Applied optics and opto-electronics-I (Practical)

**Marks: 50 Credit: 4**

**Group A:**

1) To set up a Mach Zehnder Interferometer by Laser to measure the Phase difference of two light beams.
2) To set up a Mach Zehnder Interferometer ( MZI) experiment with single mode fibers and Laser to measure phase modulation.
3) To set up an experiment for measuring displacement by optical fiber sensor.
4) To measure attenuation and splice/ connector loss by using OTDR.
5) To set-up an experiment for measuring temperature by optical fiber sensor.
6) To study interference of light by single mode fiber.
7) To study the spectral response of a photo detector using optical fiber link.

**Group B :**

1) To measure the $V_{\Pi}$ voltage of an Electrooptic modulator.
2) To Use magneto-optic modulator for verifying Faraday effect.
3) To generate optical Manchester coded data.
4) Verification of optical cross gain modulation by SOA.
5) Use of Heterodyne detector for measuring phase and intensity of an optical signal.
6) Measurement of threshold current of a Semiconductor Junction Laser from its Light intensity vs. Current density curve.
7) Use of OP AMP for using LED as linear modulator .

**COURSE OUTCOME:**

**This practical course structure is designed to impart the students to provide strong hands- on laboratory training especially in the advance field of Optoelectronics. This will help them immensely for research in Semiconductor Laser and .Fiber Optics.**

## Course No: PHS 396D : Astrophysics I (PRACTICAL)

**Marks: 50, Credit: 4**

1. Identification of following objects with naked eyes or a binocular.
   a) Mercury, b) Venus, c) Mars, d) Jupiter e) Saturn, f) North Pole, f) The Big Dipper (Ursa Major) g) The Little Dipper (Ursa Minor), h) Betelgeuse and i) Cassiopeia.
2. Study of movement of Moon between rise to set time.

3. Study of movement of a planet in sky between rise to set of the planet .
4. Identify Sun spots with a solar-filter or a mirror.
5. Different Fitting techniques (linear and non-linear, fits to data with experimental errors, evaluating goodness of fit, etc) and error analysis.
6. Study of Light curve of astronomical sourecs in different energy band.
7. Study of power spectrum of different astronomical sources.
8. Correlation, anti-correlation and time-delay between signals from two two different wavelengths.
9. RGB image from an astronomical source.

**COURSE OUTCOME:**

**The course is meant to give knowledge of Astronomy and Astrophysics to the interested students. Various astronomical methods are introduced along with different units used in astronomy and their measurement. Sky co-ordinate and motion is introduced in details. Different radiation processes in astrophysics is described. Stellar structure and evolution is studied to understand formation and evolution of different stellar systems. Practical experiments are aimed to give students good idea about night sky and various hands on experiments.**

# SEMESTER- IV

## Course No: PHS 401.1: Quantum Field Theory

**Marks: 25 Credit: 2**
**Classes: 20**

1. **Classical field theory:** From discrete to continuous systems. Natural units, Four-Vectors and Minkowski Space, Lorentz Transformations. Lagrangian and Hamiltonian formulation. Euler-Lagrange equations, Symmetries and Noether's theorem. (4)

2. **Canonical Quantization:** Klein-Gordon (scalar) field, Dirac field and electromagnetic field. Two point functions causality and propagators. (6)

3. **Interacting fields:** Examples of interacting field theories. Perturbation theory, Wick's theorem, Correlation functions, Feynman rules and diagrams. LSZ reduction, S-Matrix and cross-section. Tree-level processes in QED. Ultraviolet divergences and introduction to renormalization. (10)

**Books Recommended:**


1. Peskin, M. E. & Schroeder, D. V. (1995) An Introduction to Quantum Field Theory, 1st Ed., Westview Press Inc.
2. Srednicki, M. (2007) Quantum Field Theory 1st Ed., Cambridge University Press
3. Ryder, L. H. (1996) Quantum Field Theory, 2nd Ed., Cambridge University Press
4. Ramond, P. (1997) Field Theory, 2nd Ed., Westview Press Inc.
5. F. Mandl & Shaw G. (2010) Quantum Field Theory, 2nd Ed., John Wiley & Sons Inc.
6. Das, A. (2020) Lectures on Quantum Field Theory, 2nd Ed., World Scientific
7. Pal, P & Lahiri A. (2005) A First book of Quantum Field Theory, 2nd Ed., Alpha Science International Ltd.
8. Roman, P. (1969) Introduction to Quantum Field Theory, 1st Ed., John Wiley
9. Weinberg, S. (2005) The Quantum Theory of Fields, Volume 1: Foundations, 2nd Ed., Oxford University Press, India
10. Weinberg, S. (2005) The Quantum Theory of Fields, Volume 2: Applications, 2nd Ed., Oxford University Press, India


**COURSE OUTCOME:**

**At the end of the course, students will be able to understand Quantum field theory so that he/she can use these in various branches of physics as per his/her requirement. He/she can understand relativistic effects in quantum mechanics and the need for quantum field theory. The course will discuss the Lorentz covariant form of Lagrangian and Hamiltonian for scalar, vector fields, electromagnetic fields and their**

**second quantisation. Students can understand the symmetries and the implications of Noether's Theorem in conserved currents and charges. He/she can understand the interaction picture, S-matrix, and Wick's Theorem. The origin of Feynman diagrams and application of Feynman rules to derive the amplitudes for elementary processes in QED will also be discussed.**

## Course no: PHS 401.2: Particle Physics

**Marks: 25 Credit: 2 Classes: 20**

1. Elementary particles: Review of the fundamental classification of elementary particles and study of their different properties. Conservation Laws, (2)

2. Isospin, Hypercharge and Quark Model: Review of Lie Groups, representations of SU(2), SU(3), Isospin, Gell-mann and Nishijima SU(3) Quark model, wavefunctions of mesons and baryons, the need for color quantum number. Charm and other flavors. (8)

3. Discrete symmetries: Parity, charge conjugation, time reversal, CPT theorem, intrinsic parity and charge conjugation of pions. Multi-photon states. Parity non-conservation, G-Parity, Tau-theta puzzle. Neutral K-meson system and CP violation. (6)

4. Electroweak theory: Spontaneous symmetry breaking, Higgs mechanism. Basics of electroweak theory and Standard Model. (4)

**Books Recommended:**

1. Halzen, F. & Martin, A. D. (2008) Quarks & Leptons: An introductory Course In Modern Particle Physics, John Wiley (India)
2. Pal, P. B. (2014) An Introductory Course of Particle Physics, 1st Ed., CRC Press
3. Griffiths, D. (2008) Introduction to Elementary Particles, 2nd Ed., Wiley-VCH
4. Gasiorowicz, S. (1966) Elementary Particle Physics, 1st Ed., John Wiley & Sons Inc.
5. Perkins, D. H. (2014) An Introduction to High Energy Physics, 2nd Ed., Cambridge University Press
6. Cheng, T. P. & Ling-Fong, Li ( 1984) Gauge Theory of Elementary Particle Physics, 1st Ed., Oxford University Press.

**COURSE OUTCOME:**

**The aim and objective of the course on Particle Physics is to introduce the M.Sc. students to the invariance principles and conservation laws, hadron-hadron interactions, relativistic kinematics, static quark model of hadrons and weak interactions, so that they grasp the basics of fundamental particles in proper perspective. At the end of the course, the student will be able to understand overview of particle spectrum, their interaction and major historical and latest developments, various invariance principles and symmetry properties in particle physics, basic rules of Feynman diagrams and the quark**

**model for hadrons. Students will also learn about the basics of electroweak theory.**

## Course No: PHS 402.1: Statistical Mechanics-II

**Marks: 25 Credit: 2 Classes : 20**

1. **Ideal quantum systems**:

   (i) Properties of ideal Bose gas: Bose-Einstein condensation: Transition in liquid He-4, Superfluidity in He-4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids.

   (ii) Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism. White dwarf.

2. **Interacting systems**:

   (i) Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian.

   (ii) Exact solution of one-dimensional Ising system. Bragg-William approximation (Mean field theory).
   (iii) Introduction to 2D XY model and Kosterlitz-Thouless Transition

3. **Phase transition**: General remarks. Phase transition and critical phenomena. Critical indices. Landau's order parameter theory of phase transition.
4. **Fluctuations:** Thermodynamic fluctuations. Spatial correlations in a fluid. Brownian motion: Einstein-Smoluchowski's theory.

**Books Recommended:**


1. Pathria, R.K. (2001) Statistical Mechanics, 2nd ed., Butterworth-Heinemann, Oxford, England.
2. Huang, K. (1987) Introduction to Statistical Mechanics, 2nd ed., John Wiley & Sons, Inc., United States.
3. Blundell, S.J. and Blundell, K.M. (2006) Concepts in Thermal Physics, 2nd ed., Oxford University Press, Oxford University Press, England.
4. Reif, F. (2010) Fundamentals of Statistical and Thermal Physics, 56946th ed., Sarat Book Distributors, India.
5. Kadanoff, L.P. (2000) Statistical Mechanics: Statics, Dynamics and Renormalization, 1st ed., World Scientific Publishing Co. Pvt. Ltd., India.
6. Kubo, R. (1988) Statistical Mechanics: An Advanced Course with Problems and Solutions, 17th ed., Elsevier, Netherlands.
7. Ma, S.K. (1985) Statistical Mechanics, World Scientific Publishing Co. Pvt. Ltd., United Kingdom.
8. Ishihara, A. (1971) Statistical Physics, 1st ed., Elsevier, Netherlands.


**COURSE OUTCOME:**

- Familiar with the ideal quantum distributions
- Know the applications to interacting systems and evaluation of phase transitions

- Understand different quantum statistics for explanation of B.E. condensation, Black body radiations, Pauli paramagnetism, Landau diamagnetism and electron gas systems for thermionic and photoelectric emission.
- Use and develop mean field theory for first and second order phase transitions in one and two dimensional Ising model

## Course No: PHS 402.2: Nuclear Physics-II

**Marks: 25 Credit: 2**

**Classes: 20**

1. Nuclear reactions: Introduction to classification of nuclear reactions, reaction channels and conservation laws in nuclear reactions; Nuclear reaction kinematics – mass and energy balance in nuclear reactions; Nuclear reaction mechanisms – compound, direct and pre-equilibrium reaction mechanisms; Compound nuclear model; Basic ideas on continuum theory; Nuclear resonance – resonance cross-sections and Breit-Wigner one level formula.

2. Nuclear forces and two-nucleon problem: Recapitulation of nuclear forces; Deuteron – ground and excited states of deuteron, wave equation for deuteron and its solution, and normalization of deuteron wave function; Neutron-proton (n-p) scattering at low energies – partial wave method, energy limits, phase shift, scattering cross-section, scattering length and nature of wave functions; Proton-proton (p-p) scattering at low energies – partial wave method, phase shift and effect of nuclear forces; Basic concept on neutron-neutron (n-n) scattering.

3. Nuclear models: Liquid drop model; Fermi gas model; Nuclear shell structure – evidence for existing of magic numbers and experimental evidences for shell effect; Single particle states in nuclei – square-well, harmonic oscillator and spin-orbit coupling potentials; Single particle shell model; Collective model of Bohr and Mottelson.

4. Neutron Physics: Classification and sources of neutrons; Neutron monochromators – mechanical velocity selector, time of flight velocity selector and crystal spectrometer; Thermal neutrons – energy distribution and diffusion of thermal neutrons; Elements of neutron optics.

5. Reactor physics: Reactor materials – fuels, moderators, reflectors and coolants; Slowing down of neutrons in matter – energy loss in moderator, scattering angles, average energy loss per collision, transport mean free path, scattering cross-section, average logarithmic energy decrement, slowing-down power, moderating ratio and slowing down time.

6. Nuclear fission and fusion: Energetics of fission process; Deformation of compound nucleus in terms of liquid drop model; Bohr-Wheeler theory of nuclear fission; Fertile and fissile materials; Nuclear fusion and thermonuclear reactions; Basic concept on nucleosynthesis.

## Books Recommended:

### Reference for journal article


1. Haidenbauer, J. (2004) The Nucleon-Nucleon Interaction. Brazilian Journal of Physics, 34, 845-849.
2. Klein, A.G. and *S* A Werner, S.A. (1983) Neutron optics. Reports on Progress in Physics, 46, 259-335.
3. Machleidt, R. and Slaus, I. (2001) The nucleon-nucleon interaction. Journal of Physics G: Nuclear and Particle Physics, 27, R69.
4. Naghdi, M. (2014) Nucleon-nucleon interaction: A typical/concise review. Physics of Particles and. Nuclei, 45, 924-971.
5. Nico, J.S. and Snow, W.M. (2005) Fundamental Neutron Physics. Annual Review of Nuclear and Particle Science, 55:27–69.


### Reference for a book as general


1. Basdevant, J.L., Rich, J. and Spiro, M. (2005) Fundamentals in Nuclear Physics: From Nuclear Structure to Cosmology, 1st ed., Springer, New York, USA.
2. Blatt, J.M. and Weisskopf, V.F. (1979) Theoretical Nuclear Physics, 1st ed., Springer, Germany.
3. Cohen, B. (1974) Concepts of Nuclear Physics, 1st ed., McGraw Hill Higher Education, United States.
4. Elton, L.R.B. (1965) Introductory Nuclear Theory, 2nd ed., Sir Isaac Pitman & Sons Ltd, United Kingdom.
5. Evans, R.D. (1955) The Atomic Nucleus, 3rd ed., Tata McGraw-Hill Publishing Company Limited, India.
6. Ghoshal, S.N. (2015) Nuclear Physics, Reprint 1st ed., S. Chand & Company Pvt. Ltd., India.
7. Krane, K.S. (1987) Introductory Nuclear Physics, Rev. 3rd ed., John Wiley & Sons, United States.
8. Kaplan, I. (2002) Nuclear Physics, 19th ed., Narosa Publishing House, India.
9. Lim, Y.K. (2000) Problems and Solutions on Atomic, Nuclear and Particle Physics, 1st ed., World Scientific Publishing Co. Pte. Ltd., Singapore.
10. Roy, R.R. and Nigam, B.P. (2014) Nuclear Physics: Theory and Experiment, 2nd ed., New Age International Pvt. Ltd., India.
11. Segre, E.G. (1977) Nuclei and Particles: An Introduction to Nuclear and Subnuclear Physics, 2nd ed., Basic Books, United States.
12. Srivastava, B.N. (25019) Basic Nuclear Physics and Cosmic Rays, 18th ed., Pragati Prakashan, India.
13. Tayal, D.C. (2015) Nuclear Physics, Reprint 5th ed., Himalaya Publishing House, India.
14. Wong, S.S.M. (2004) Introductory Nuclear Physics, 2nd ed., WILEY-VCH Verlag Gmbl I & Co. KGaA, Weinheim, Germany.


### Reference for a book chapter in an edited volume


1. Basdevant, J.L., Rich, J. and Spiro, M. (2005) Chapter 3: Nuclear reactions, In Fundamentals in Nuclear Physics: From Nuclear Structure to Cosmology, 1st ed., ed. by Jean-Louis Basdevant, J.L., Rich, J. and Spiro, M., Springer, New York, USA, pp. 107-174.
2. Krane, K.S. (1987) Chapter 4: The Force Between Nucleons, In Introductory Nuclear Physics, Rev. 3rd ed., ed. by Krane, K.S., John Wiley & Sons, United States, pp. 80-

115.
3. Preston, M.A. and Bhaduri, R.K. (1982) Chapter 7: Single-Particle Model, In Structure of the Nucleus, 2nd ed., ed. by Preston, M.A. and Bhaduri, R.K., Addison-Wesley Publishing Company, Inc., United States, pp. 217-243.

**Reference for materials in a book**

1. Basdevant, J.L., Rich, J. and Spiro, M. (2005) Fundamentals in Nuclear Physics: From Nuclear Structure to Cosmology, 1st ed., Springer, New York, USA, pp. 67-89.
2. Preston, M.A. and Bhaduri, R.K. (1982) Structure of the Nucleus, 2nd ed., Addison-Wesley Publishing Company, Inc., United States, pp. 123-169.

**COURSE OUTCOME:**

- Understand the nuclear forces and two-nucleon problem
- Know the nuclear reactions and their classification
- Understand various nuclear models
- Understanding of neutron physics and reactor physics
- Know the applications of nuclear physics are nuclear power generation
- Know the nuclear fission and fusion

## Course No: PHS 403.1: Transport Properties and Semiconductor Devices

**Marks: 25** **Credit: 2**
**Classes: 20**

1. Boltzman transport equation applied to a non degenerate semiconductor, Electrical conductivity, Hall effect & Thermoelectric effect in semiconductor, Quantum Hall effect.

2. Light Emitting Junction, Semiconductor laser diode, Calculation of threshold current density for lasing from a pn diode , Hetero junction based laser. AlGaAs and GaAs based quantum well, Tunnel Diode.

3. Four- layer pnpn device, Derivation of channel conductance and drain current for FET and MOSFET, Gunn Effect Oscillator, Derivation of transport coefficient, injection ratio and current gain of a transistor.

4. Transducer & sensors: Photo-transducer : Photo diodes and photo-transistors, thermistor, photo-electric transducer, photo- conductors.

**Books Recommended:**

1. Kireev: Semiconductor Physics
2. S.M. Sze : Physics of semiconductor devices
3. Streatman & Banerjee: Introduction to solid state electronics

**COURSE OUTCOME:**

**Most of the devices are based on semiconductors. The course discusses in details the transport properties and various semiconductor devices along with their operation mechanism. The course describes extensively many important devices like Gunn Diode, FET, MOSFET, Semiconductor Laser. The course also includes important topic like Quantum Hall Effect, Thermoelectric effect in Semiconductors. The course will encourage the students to do researches in Semiconducting devices which is an important topic of Applied Physics**.

## Course No: PHS 403.2: Applied Optics

**Marks: 25 Credit: 2**
**Classes: 20**

1. Fiber optics: Different types (single and multi mode) of step index and graded index optical fiber, ray path in graded index optical fiber, Multipath broadening, Modal analysis of Electromagnetic waves in planer waveguide. Application of fiber in digital communication.

2. Holography: Coherent light and application of coherent light in holography. Recording and reconstruction of wave front.

3. Non-linear Optics: Non-linearity of medium, second and higher harmonic generation, phase matching condition, frequency addition and frequency subtraction, self focusing and self defocusing, Pokels & Kerr type of nonlinear materials, Examples of Organic and inorganic nonlinear materials. Photo dynamical therapy.

4. Photonics Information Processing: Optical logic operations, Optical arithmetic operation with binary, optoelectronic logic gates, all optical logic gates, tristate logic system and tristate AND & OR gate.

5. Photosensors, different types of photo-detector, Graphene and graphene based photodetectors, photo sensitivity, photoresponsivity.

**Books Recommended:**


1. Ghatak, A., and Thyagarajan, K. (2007) Optical Electronics, Special ed. for sale in South Asia, Cambridge University Press India Pvt. Ltd, India.
2. Bhattacharya, P. (1996) Semiconductor optoelectronic devices, 2nd ed., Prentice Hall publication, India.
3. Yariv, A. (1984) Optical Electronics, 3rd ed., Holt McDougal.
4. Tarasov, L. V. Laser Physics and Applications, Mir Publishers, USSR
5. Pipker, J. (2003) Semiconductor Optoelectronic Devices: Introduction to Physics and Simulation, 1st ed., Academic Press, USA

6. Bhattacharya, P. (2017) Semiconductor Optoelectronic Devices, end ed., Pearson, India.
7. Rosencher, E., and Vinter, B (2002) Optoelectronics, 1st ed., Cambridge, University Press.
8. Mukhopadhyay, S. (2000) Optical computation and parallel processing, 1st ed., Classique Books Publisher, India.
9. Ghosh, P. and Mukhopadhyay, S. (2004) Some digital approaches in optical computation, Premier Books publication, India.

**COURSE OUTCOME:**

**The course is an introduction to the fundamentals of optoelectronics and principles of the optoelectronic devices operation. This course helps students prepare them for advanced study and research in semiconductor optics and optoelectronic devices. Topics include optical waveguides, optical logic operations, nonlinear optics an introduction to different types of detectors, and holography. The course also covers the basic optical and electro-optical properties of semiconductors and low-dimensional semiconductor structures.**

## Course No: PHS 404A: Advanced Condensed Matter Physics – II

**Marks: 50 Credit: 4**
**Classes: 40**

1. Magnetism : Pauli's Spin Paramagnetism, Exchange interaction, Ferromagnetic, anti-ferromagnetic and Ferri-magnetic order, molecular fields, Domain theory, Bloch wall, spin waves, magnons, magnetic resonance, principle and application of NMR, EPR, ESR.

2. Superconductivity: Review of experimental results, electron-phonon interaction, Cooper pair, BCS theory, energy gap, transition temperature, Ginzburg Landau theory, Coherence length, Flux quantization, Critical Current density, DC/AC Josephson effect, SQUID, superconducting devices, recent advances on high Tc superconductors. Vortices and quantization.

**Books Recommended:**

1. Magnetism in Condensed Matter: Stephen Bludell
2. Theory of Superconductivity, J. Robert Schrieffer,
3. Introduction to Superconductivity, 2nd Edition, by Michael Tinkham
4. Superconductivity, Superfluids, and Condensates (Oxford Master Series in Physics, 5) 1st Edition by James F. Annett.
5. Solid State. Physics : Neil W. Ashcroft. N. David Mermin (Cengage Learning India)

**COURSE OUTCOME:**

**The course topic is Solid State Physics special paper which covers large part in this field The course enriches the student in many field like Magnetism, Superconductivity which are two important branches of Physics. The course will motivate the students to do research in these fields both in Theoretical as well as Experimental Condensed Matter physics.**

## Course No: PHS 404B: Applied Electronics –II

**Marks: 50 Classes: 40**

## PHS 404B.1: Applied Analog Electronics –II

**Marks: 25 Credit: 2**
**Classes: 20**

1. B/W Television: Working principle, TV camera- Image Orthicon, Vidicon, Plumbicon ; B/W TV Picture tube, scanning and deflection, synchronization, Details of composite video signal, Transmitting and Receiving systems, Vestigial Side Band (VSB) transmission, Television standards, Advantages of Negative modulation, Different kinds of TV antenna, Block diagram of B/W TV receiver and Transmitter. Colour TV standards : NTSC, PAL SECAM, colour television principles, Colour subcarrier, transmission format of intensity and colour signal. Colour difference signals, Reproduction of colour signals at the receiver, Colour TV picture tubes: Delta Gun, PIL and Trinitron,

2. Wave Guides: Wave guides coaxial, rectangular and cylindrical; Different modes of propagation of em signal through wave guides, resonators.

3. Instrumentations: Digital voltmeter: different types, Digital ammeter and ohmmeters.

**Books Recommended**

1. Gulati, R.R. (2014) Monochrome and Color Television, 3rd ed., New Age International Publishers, India
2. Dhake, A. M. (2017) Television and Video Engineering, 2nd ed., McGraw Hill Education, India.
3. Roddy, D. and Coolen, J. (2008) Electronic Communications, 4th ed., Pearson Education, India.
4. Helfrick, A.D. and Cooper, W.D. (2015) - Modern Electronic Instrumentation & Measurement Techniques, 1st ed., Pearson Education, India.
5. Carlson, A. B., Crilly, P.B., and Rutledge, J.C. (2001) Communication Systems, 4th ed., McGraw Hill Higher Education, India
6. Kennedy, G., Davis, B., and Prasanna, S.R.M. (2011) Electronic Communication Systems, 5th ed., McGraw Hill Education, India.

**COURSE OUTCOME:**

**To develop the relevant knowledge of electronics in order to deepen the understanding of modern electronic communication devices those are associated with our social life.**

**After completion of this course, students will be able to**

1. **gain in-depth knowledge of monochrome and colour television principle.**
2. **know the details of signal propagation through wave guide.**
3. **understand the principle behind instrumentation for different measurements**.

## PHS 404B.2: Applied Digital Electronics –II

**Marks: 25 Credit: 2**
**Classes: 20**

1. Digital communication: Signal sampling, Sampling Theorem, Nyquest rate, aliasing effect, sample and hold systems, Quantization process and error calculation.

2. Pulse modulation and demodulation techniques: PAM, TDM-PAM, PWM, PPM, Pulse code modulation (PCM) - modulation and demodulation, Differential PCM, Delta Modulation.

3. Digital modulation techniques : ASK, FSK, PSK, DPSK, QPSK, MSK principle, modulation and demodulation techniques.

4. Microprocessor and their applications: Architecture of 8 bit (8085) and 16 bit (8086) microprocessors; addressing modes and assembly language programming of 8085 and 8086. Interfacing concepts memory and I/O interfacing; Interrupts and interrupt controllers; microprocessor based data acquisition (DAS) system, comparison of different microprocessors. Microprocessor programming.

**Books Recommended**


1. Gaonkar, R. S. (2013) Microprocessor Architecture, Programming and Applications with 8085, 2nd ed., Penram International Publishing, India
2. Roddy, D. and Coolen, J. (2000) Electronic Communications, 4th ed., Prentice Hall of India, India
3. Taub, H., Schilling, D. and Saha, S. (2017) Principles of Communication System, 4th ed., McGraw Hill Education, India


**COURSE OUTCOME:**

**To develop the relevant knowledge of electronics in order to deepen the understanding of modern electronic communication devices those are associated with**

**our social life.**

**After completion of this course, students will be able**

1. **to get details of digital communication including different digital modulation techniques.**
2. **to develop knowledge on 8085 and 8086 microprocessors with programming**

## Course No: PHS 404C: Applied Optics and Opto-electronics – II

**Marks: 50** **Credit: 4**
**Classes: 40**

1. Optical modulators: Electro-optic modulators and Pockels effect, Phase modulation and Amplitude modulations in Electro-optic modulator, Optical Kerr effect, Modulation of light using optical Kerr effect, Self focusing, self defocussing, Optical switches using Kerr effect, Optical Faraday effect.

2. Optical amplifiers : Semiconductor Optical Amplifier ( SOA) and its principle of operation, Self phase modulation, cross phase modulation , Cross gain modulation and wavelength conversion of SOA, EDFA and its principle of operation.
3. Photonic measurements: Homodyne and Heterodyne detectors for phase and intensity measurements, OTDR.
4. Optical encoding: Intensity encoding, frequency encoding, polarization encoding, RZ, NRZ, Manchester line encoding, Method of obtaining Manchester coded data, probability error and bit error rate.
5. Optical devices: principle of operation of Liquid Crystal Display; Charge Coupled Devices; Fiber optic displacement, current and temperature sensors.

**Books Recommended:**


1. Bhattacharya, P. (1996) Semiconductor optoelectronic devices, 2nd ed., Prentice Hall publication, India.
2. Yariv, A. (1984) Optical Electronics, 3rd ed., Holt McDougal.
3. Pipker, J. (2003) Semiconductor Optoelectronic Devices: Introduction to Physics and Simulation, 1st ed., Academic Press, USA
4. Bhattacharya, P. (2017) Semiconductor Optoelectronic Devices, end ed., Pearson, India.
5. Rosencher, E., and Vinter, B (2002) Optoelectronics, 1st ed., Cambridge, University Press.
6. Mukhopadhyay, S. (2000) Optical computation and parallel processing, 1st ed., Classique Books Publisher, India.
7. Chen, R.H. (2011) Liquid Crystal Displays: Fundamental Physics and Technology, 1st ed., Wiley, India.

**COURSE OUTCOME:**

**The course is important to train the students in important topic i.e applied optics and optoelectronics. The students will be enriched to do research in important fields like Fiber Optics, Optoelectronics, Semiconductor laser.**

## Course No: PHS 404D : Astrophysics II

**Marks: 50 Credit: 4 Classes: 40**

### PHS 404D.1: Galactic Astronomy

**Marks: 25 Credit: 2 Classes: 20**

1. **The Milky Way**: Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way. (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus.
2. **Milkyway in different wavelengths**: Optical, IR, radio and X-rays.
3. **Interstellar Medium**: Density, Contents, different models, extinction.
4. **Galactic Plane Surveys:** Log N – Log S Plot.
5. **Telescopes and Detectors:** Principle of Optical, Infrared, Radio, X-rays, Gamma-rays, Neutrinos and Cosmic Ray Astronomy; Gravitational Radiation; Detection of Dark Matter and Dark Energy - Astronomy from Space; Imaging – Focal Plane Imagers, PSF and Deconvolution, Interferometry- Photometry, Spectroscopy, Polarimetry, Astrometry; Solar Telescopes; Surveys, Astronomical Databases, Virtual Observatory. Names of most Popular Telescopes in different Wave Bands – TMT, Giant Meter Wave Radio Telescope (GMRT) - Square Killometer Array (SKA), Astrosat.

### PHS 404D.2: Extra-galactic Astronomy and Cosmology

**Marks: 25 Credit: 2 Classes: 20**

1. **Galaxies:** Hubble's Classification of Galaxies, Galaxy Morphology, Contents and Dimensions – Collisionless Stellar Dynamics – Relaxation Time, Dynamical Friction, Violent Relaxation – Galactic Potential and Orbits – Spiral Density Wave and Lindblad Resonance – Rotation Curves – Tully-Fisher Relation – Central Black Holes and Fundamental Plane Relationship– Mass and Luminosity Function – Press Schechter Formalism – Star Formation History and Chemical evolution – Active Galaxies and Activity Duty Cycle – Galaxies at High Redshift - Evidence of Dark matter. Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo), Gas and Dust in the Galaxy, Spiral Arms.
2. **Cluster of Galaxies:** Properties, Classification, Virial Theorem
3. **Cosmology**: Introduction - Cosmological Principles - Weyl Postulates - Robertson-Walker Metric (derivation is not required) – Cosmological Parameters - Static Universe - Expanding Universe - Open and Closed Universe - Cosmological Red Shift -

Hubble's Law - Olber's Paradox – Big Bang, Early Universe (Thermal History and Nucleosynthesis), Cosmic Microwave Background Radiation, Event Horizon, Particle Horizon and some problems of Standard Cosmology.

**Books Recommended:**


1. Carroll, B.W. and Ostlie, D.A. (2006) An Introduction to Modern Astrophysics, 2nd ed., Cambridge University Press, England.
2. Shu, F. (1981) The Physical Universe: An Introduction to Astronomy, 1st ed., University Science Books, USA.
3. Harwit, M. (2000) Astrophysical Concepts, 3rd ed., Springer, New York, United States.
4. Padmanabhan, T. (2006) Invitation to Astrophysics, Latest Edition, 3rd ed., World Scientific Publishing Co. Pvt. Ltd., India.
5. Padmanabhan, T. (2000) Theoretical Astrophysics (Volume I-III), 1st ed., Cambridge University Press, England.
6. Longair, M.S. (1992) High Energy Astrophysics (Volume 1-2), 2nd ed., Cambridge University Press, England.
7. Sparke, L.S. and Gallaghar, J.S. (2015) Galaxies in the Universe: An Introduction, 2nd ed., Cambridge University Press, England.
8. Prialnik, D. (2013) An Introduction to the Theory of Stellar Structure and Evolution, Latest Edition, 2nd ed., Cambridge University Press, England.
9. Schneider, S. and Arny, T.T. (2021) Pathways to Astronomy, 6th ed., McGraw-Hill Science Engineering, United States.
10. Chandrasekhar, S. (1989) Stellar Structure and Stellar Atmospheres (Volume 1), 1st ed., The University of Chicago Press, United States.
11. Abhyankar, K.D. (2001) Astrophysics: Stars and Galaxies, 1st ed., Universities press (India) Limited., India.
12. Menzel, D.H., Bhatnagar, P.L. and Sen, H.K. (1963) Stellar Interiors, Chapman & Hall, 1st ed., United Kingdom.


**COURSE OUTCOME :**

- Understand the structure and properties of the Milky Way
- Know the Milky Way in different wavelengths
- Acquainted with the interstellar medium
- Know the Log N – Log S Plot in galactic plane surveys
- Familiar with the telescopes and astronomical detectors
- Introduce the Galaxies and their classifications
- Understand the cluster of Galaxies
- Acquainted with the cosmology

## Course No: PHS 495A: Advanced Condensed Matter Physics -II (Practical)

**Credit: 4** **Marks: 50**

**Group-A**

1. Study of magneto resistance of the given material.
2. Determination of carrier life time in Photoconductor.
3. Measurement of magnetic susceptibility and Bohr magneton number of given sample by Gouy method.
4. Absorption/Transmission spectra of thin films by using UV/VIS spectrophotometer.
5. Dielectric measurement of polycrystalline ferroelectric sample.
6. Study of Thermo luminescence in a crystal.
7. Study of UJT & SCR characteristics with application

**Group-B**

1. Study of Hall effect with variation of temperature.
2. Determination of Lande g-factor for the given sample using electron spin resonance spectrometer.
3. Determination of barrier potential and doping profile of transistor junctions
4. Determination of ionic conductivity of the given sample.
5. Study of Hysteresis loop of magnetic materials by using Hysteresis Tracer.
6. Study of characteristics of the given solar cell
7. Study of Diac & Triac characteristics with application

**COURSE OUTCOME:**

**This practical course structure is designed to impart the students to provide strong hands- on laboratory training specially in the advance field of Condensed Matter Physics. This will help them immensely for research in condensed matter physics as well as experimental research in Condensed Matter Physics**.

## Course No: PHS 495B: Applied Electronics –II (Practical)

**Credit: 4** **Marks: 50**

1. Design of a Schmitt trigger circuit using μA 741.
2. DSB-TC and DSB-SC generation using analog multiplier IC MC 1495 or MC1496.
3. Design and performance study of a VCO IC (NE 566).
4. Design and performance study of a PLL IC (NE 565).
5. Design a FM demodulator using PLL.
6. Study of Pulse Amplitude Modulation transmission and reception.
7. 8085 Microprocessor programming.
8. Study of Pulse Width Modulation using 555 Timer IC.
9. Study of Pulse Code Modulation transmission and reception.
10. To study the input stage of an Op-amp using discrete components and find out the differential mode gain.
11. PSIPCE study the input stage of an Op-amp using discrete components and find out

the differential mode gain.

12. Study of D.A.C & A.D.C.

**COURSE OUTCOME:**

**This course will help the students to**

**(i) design and fabricate various advanced digital and analog electronic circuits, e.g. modulator circuits, PLL circuits, Microprocessor programming, etc.**

**(ii) design and conduct various electronics experiments.**

**The experiments will help the students to understand the application of the theories in practical field.**

## Course No: PHS 495C: Applied optics and Opto-electronics-II (Practical)

**Credit: 4 Marks: 50**

**Group A :**

1) To measure the $V_{\Pi}$ voltage of an Electro-optic modulator.
2) To use magneto-optic modulator for verifying Faraday effect.
3) To generate optical Manchester coded data.
4) Verification of optical cross gain modulation by SOA.
5) Use of Heterodyne detector for measuring phase and intensity of an optical signal.
6) Measurement of threshold current of a Semiconductor Junction Laser from its Light intensity vs. Current density curve.
7) Use of OP AMP for using LED as linear modulator .

**Group B :**

1. To set up a Mach Zehnder Interferometer by Laser to measure the Phase difference of two light beams.
2. To set up a Mach Zehnder Interferometer ( MZI) experiment with single mode fibers and Laser to measure phase modulation.
3. To set up an experiment for measuring displacement by optical fiber sensor.
4. To measure attenuation and splice/ connector loss by using OTDR.
5. To set-up an experiment for measuring temperature by optical fiber sensor.
6. To study interference of light by single mode fiber.
7. To study the spectral response of a photo detector using optical fiber link.

**COURSE OUTCOME:**

**This practical course structure is designed to impart the students to provide strong hands- on laboratory training specially in the advance field of Optoelectronics. This will help them immensely for research in Semiconductor Laser and Fiber Optics.**

## Course No: PHS 495D : Cosmology and Astrophysics II (PRACTICAL)

**Marks: 50, Credit: 4**

1. With a small telescope, identify following objects :
   a) Moons of Mars, b) storm in Jupiter, c) rings and moons of Saturn, d) Orion nebula, e) Andromeda galaxy
2. Radio Astronomy with AIPS: Load of a image in aips, Measurement of rms of a given image.
3. Radio Astronomy with AIPS: Measurement of flux density of a point and extended source.
4. Polar alignment of an optical telescope.
5. Detection of variation of solar radiation using two component radio interferometer.
6. Study of solar flares on Very Low Frequency signals using a standard transmitter signal.
7. Deflection of radio signal from Sun using a small radio antenna.
8. Variation of radio signal towards Galactic plane using a small radio antenna.
9. CCD characterization.
10. Estimation of atmospheric extinction in different colours (filters)
11. Measurement of period of a binary star system
12. Distance determination to Cepheid variables based on their light curves
13. Classification of stars based on their spectra
14. Use of spectral classification in deriving distances to stars.

## COURSE OUTCOME:

1. **The course is meant to give advance knowledge of Astronomy and Astrophysics to the interested students.**
2. **Galactic and Extra-galactic Astronomy is introduced in details alongwith brief introduction of cosmology.**
3. **Practical experiments are aimed to give students good idea about night sky and various advance hands on experiments.**

## Course No: PHS 496: PROJECT, SEMINAR AND GRAND VIVA

**Credit: 4 Marks: 50**

### GUIDE LINE FOR THE COURSE :

Students have to perform the following duties :

1. Identify an area for research where the knowledge base can be potentially augmented.
2. Understand the shortcoming/lacunae in state of existing knowledge through literature review.
3. Propose / design a possible solution to the problem.
4. Collaborate with other researchers and institutes around to facilitate the proposed solution.

5. Present the entire work in the form of dissertation.
6. Defend the work through a presentation and a viva exam to a panel of evaluators.

**COURSE OUTCOME:**

**Students are expected to come up with a comprehensive project work in subjects of physics. The students have to perform a research project during their last two semesters on wide range of modern-day topics under the guidance of any of the faculty members of Physics department and the exam will be held at the end of fourth semester. This gives an ideal atmosphere for converting class room learning to cutting-edge research applications. The project topics should be chosen so as to inculcate culture of independent research. At the end of the course each student have to present a thesis.**

**Each student has to present a seminar on a topic of their own choice in the final semester. There is a good interacting session in the seminar. Thus seminar gives a good training to student and gives encouragement to be a participant of National and International Seminar**.