Goa University

P.O. Goa University, Taleigao Plateau, Goa 403 206 India

M. Sc. Physics Syllabus for Choice-Based Credit System

(from the academic year 2016-2017)

The Department of Physics offers a full-time two-year (four semester) Master's programme in Physics.

The programme aims at imparting postgraduate education in Physics and preparing those who have studied up to the Bachelor's level, additional exposure of a sufficiently high level to enable them to pursue careers in Physics and embark on Ph.D. programmes of study.

The prerequisites of the M.Sc. programme in Physics are a B.Sc. degree in Physics with 6 units as first preference and B.Sc. with 3 units of Physics as second preference.

The Choice Based Credit System applies to the M.Sc. programme. A total of 80 credits must be earned by a student for the award of the Master's degree. Of these, 60 credits pertain to Core areas of Physics while the final 20 credits which are earned in the final (4^{th}) semester are designated as Optional courses. These optional courses may also be chosen from courses offered by other Departments. The experimental component of the Core courses comprises 20 credits. Normally, each course has one hour of tutorial each week to help understanding of the theory and its application.

The two-year programme has four semesters. In the 1^{st}, 2^{nd} and 3^{rd} semesters only Core courses necessary for the essential Physics postgraduate formation are run. The 4^{th} semester is reserved for only Optional courses which are considered additional but desirable. There are a total of ten 4-credit Optional courses and a Dissertation equivalent to 8 credits in this semester. Students may choose any combination such that 20 credits are offered in this last semester of their programme. One of the courses – Neutron Physics – requires students to visit a nuclear establishment as part of the course.

The tables starting on the next page list the courses under the programme. The recommended semester-wise distribution of the courses is also given. Description of each of the courses is given in subsequent pages.

List of Courses and Course Structure

Course Code	Course Title	Number of credit	Weekly Class Distribution [L-T-P]@
Semester I			
PHC-100*	BRIDGE COURSE ON MATHEMATICAL METHODS	2	[2-1-0
PHC-101	MATHEMATICAL PHYSICS	5	[4-1-0]
PHC-102	CLASSICAL MECHANICS	5	[4-1-0]
PHC-103	ELECTROMAGNETIC THEORY	5	[4-1-0]
PHC-104	ELECTRONICS PRACTICALS	3	[0-0-3]
PHC-105# or PHC-110	COMPUTER PROGRAMMING WITH C	2	[0-0-2]
	COMPUTER PROGRAMMING IN FORTRAN 95	2	[0-0-2]

* Not included for the calculation of GPA, but should be completed successfully.
@ [Lecture-Tutorials-Practical]
# Either PHC-105 or PHC-110 will be offered

Course Code	Course Title	Number of credit	Weekly Class Distribution [L-T-P]
Semester II			
PHC-106	QUANTUM MECHANICS – I	5	[4-1-0]
PHC-107	BASIC ELECTRONICS	5	[4-1-0]
PHC-108	STATISTICAL MECHANICS	5	[4-1-0]
PHC-109	GENERAL PHYSICS PRACTICALS	5	[0-0-5]
PHO-301	SUMMER FELLOWSHIPS*	1	

* Optional extra credit.

Course Code	Course Title	Number of credit	Weekly Class Distribution [L-T-P]
Semester III			
PHC-201	QUANTUM MECHANICS - II	5	[4-1-0]
PHC-202	NUCLEAR PHYSICS	4	[3-1-0]
PHC-203	SOLID STATE PHYSICS	5	[4-1-0]
PHC-204	SOLID STATE PHYSICS PRACTICALS	4	[0-0-4]
PHC-205	PHYSICS SEMINARS	2	[0-0-1]

Course Code	Course Title	Number of credit	Weekly Class Distribution [L-T-P]
Semester IV*			
PHO-302	NEUTRON PHYSICS	4	[3-1-0]
PHO-303	SUPERCONDUCTIVITY AND SUPERFLUIDITY	4	[3-1-0]
PHO-304	X-RAY SPECTROSCOPY	4	[3-1-0]
PHC-305	ELECTRONICS PRACTICALS-II	4	[0-0-4]
PHC-306	SEMICONDUCTOR PHYSICS	4	[3-1-0]
PHO-307	PROJECTS	8	[0-0-8]
PHO-308	ACOUSTICS AND NOISE CONTROL	4	[3-1-0]
PHO-309	PHYSICS OF NON-CONVENTIONAL ENERGY SOURCES	4	[3-1-0]
PHO-310	NUMERICAL METHODS AND FORTRAN PARALLEL PROGRAMING USING OPEN MP	4	[2-0-2]
PHO-311	PHASE TRANSITIONS AND CRITICAL PHENOMENA	4	[3-1-0]
PHO-312	SPECTROSCOPIC TECHNIQUES IN CONDENSED MATTER PHYSICS	4	[3-1-0]

* Students to register for a total of 20 credits.

PHC 101: MATHEMATICAL PHYSICS

1. Ordinary Differential Equations [**4L+4T]**

Second order homogeneous and inhomogeneous equation, Wronskian, General Solutions, Ordinary and Singular points, Series Solutions.

2. Special Functions **[10L+5T]**

Legendre's equation, Generating function for the Legendre Polynomial, Roddgues's Formula, Recurrence Relations, Spherical Harmonies, Bessel Equation, Generating Function, Recurrence Relations, Spherical Bessel Function, Hermite Equation, Generating Function, Recurrence Relations

3. Functions of Complex Variable **[10L+5T]**

Limits, Continuity, Analyticity of Functions of a Complex Variable, Taylor and Laurent Series, Isolated and Essential Singuladties, Branch Cuts, Cauchy Formula, Contour Integration, Application of Residue Theorem, Analytical Continuation, Asymptotic Series and Methods of Steepest Descent

4. Linear Vector Spaces **[6L+4T]**

Linear Operators, Matrices, Coordinate Transformations, Eigenvalue Problems, Diagonalization of Matrices, Infinite Dimensional Spaces, Elements of Group Theory.

5. Integral Transforms **[3L+2T]**

Fourier Series, Fourier Transforms, Laplace Transforms, Applications of Integral Transforms.

6. Boundary Value and Initial Value Problems **[10L+5T]**

Fourier Series in two and three Variables, Coupled Pendulums, Vibrating String in one Dimension, Heat Conduction, Wave Equation, Introduction to Green Function Method.

Text Books/References

1. Mathematical Methods for Physics, Arfken, Academic Press, London (1994).
2. Mathematical Methods for Physics, J. Mathew and R. L. Walker, Benjamin Publishers (1973).
3. Complex Variables and Applications, James W. Brown and Ruei. V. Churchill 6th Edition (international) , McGraw - Hill (1996).
4. Applied Mathematics for Engineers and Physicists, 3rd Edition, L. A. Pipes, Mcgraw-Hill (1971).
5. Special Functions for Scientists and Engineers, W. W. Bell, D. Van Nostrand Company Ltd.
6. Mathematical Methods for Physics and Engineering, K. F. Riley, P. Hobson and S. J. Bence.

PHC 102: CLASSICAL MECHANICS

1. Newton's Laws of Motion **[5L+1T]**

Mechanics of a single particle, Mechanics of a system particles, Constraints and their classification, Principle of virtual work, D'Alembert's principle.

2. Lagrangian Formulation **[10L+3T]**

Degrees of Freedom, Generalized Coordinates, Calculus of variations, Hamilton's principle, Euler-Lagrange's equations of motion, Application to non-holonomics systems, Advantages of a variation principle formulation, Conservation theorems and symmetry properties.

3. Rigid Body Dynamics **[5L+1T]**

Eulerian angles, Inertia tensor, Angular momentum of rigid body. Free motion of rigid body, Motion of symmetric top.

4. Hamilton's equation of motion **[9L+3T]**

Legendre transformation and the Hamilton equations of motion, cyclic coordinates and conservation theorems, Routh's procedure and oscillation about steady motion, Derivation of Hamilton's equations from a variational principle, Principle of least action.

5. Canonical Transformations **[10L+3T]**

Equations of canonical transformations, Examples of canonical transformations, Poisson brackets and other canonical invariants, Equations of motion, Infinitesimal canonical transformation theorems in Poisson bracket formulation, Angular momentum, Poisson brackets relations, Lagrange brackets.

6. Hamilton - Jacobi Theory **[5L+ 1T]**

H-J equation for Hamilton's principal function, Harmonic oscillator problems, H -J equation for characteristic function, Action angle, Kepler's problem.

7. Two-body Central Force Problem **[10L+3T]**

Equations of motion and first integrals, Classification of orbits, virial theorem, Differential equation and integrable power law potentials, Kepler's problem.

8. Small Oscillations **[5L+1T]**

Simple Harmonic Oscillations, Damped Oscillations, Forced Oscillations without and with damping, Coupled Oscillations.

Text Books / Reference

1. Classical Mechanics, N. C. Rana, and P. S. Joag, Tata Mcgraw-Hill (1991)
2. Classical Mechanics, H. Goldstein, McMillan, Bombay (1998)
3. Classical Mechanics, J. C. Upadhyaya, Himalaya, Publishing House, Mumbai (1991)
4. Classical Mechanics, P. V. Panat, Alpha Science International Ltd (2004)

PHC 103: ELECTROMAGNETIC THEORY

1. Maxwells Equations **[7L+1T]**

Displacement current, Maxwell's equations, Vector and Scalar potentials, Gauge transformation, Lorentz and Coulomb gauge, Poynting's theorem, Conservation of energy and momentum for charged particles and fields.

2. Electromagnetic Waves **[12L+3T]**

Plane electromagnetic waves and their propagation in non-conducting and conducting media, Frequency dispersion in conductors, Dielectrics and plasma.

3. Electromagnetic Radiation **[12L+ 3T]**

Retarded Potentials, Fields and radiation by localized dipole, Lienerd Weichert potentials, Power radiated by an accelerated charge.

4. Physics of Plasmas **[9L+2T]**

Electrical neutrality in a plasma, Particle orbits and drift motion in a plasma, Magnetic mirrors, The hydro-magnetic equations, The pinch effect, Plasma oscillations and wave motion, Reflection from a plasma (ionosphere).

5. Wave Guides **[9L+2T]**

Propagation of Waves between conduction planes, Wave guides in arbitrary cross-section, Wave -guides in Rectangular Cross-section, Coaxial Wave guide, Resonant Cavities, Dielectric wave guides.

6. Relativistic Electrodynamics **[10L+2T]**

Lorentz transformation as four dimensional orthogonal transformation, Lorentz matrix, four vectors in mechanics and electrodynamics, Lorentz covariance of Maxwell equations, field tensor, transformation of fields, field due to a point charge in uniform motion, relativistic Lagrangian formulation of classical mechanics and electrodynamics.

Text Books / References:

1. J.B.Marion, Classical Electromagnetic Radiation, Academic Press, New York (1980).
2. J.R.Reitz and F.J.Milford, Foundations of Electromagnetic theory, Addison – Welsey, Reading (1960).
3. B.B. Laud, Electromagneties, Wiley Eastern Ltd. , New Delhi (1983).
4. S.P.Puri, Classical Electrodynamics, Tata Mcgraw-FEII Publishing Co. Ltd., New Delhi (1997).
5. David J. Griffiths, Introduction to Electrodynamics, Prentice - Hall of India Pvt. Ltd., New Delhi (1995).
6. J.D. Jackson, Classical Electrodynamics, Wiley, New York (1995).

PHC 100: BRIDGE COURSE ON MATHEMATICAL METHODS

1. Preliminary Calculus

Differentiation from first principles; products; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz' theorem; special points of a function; theorems of differentiation.

Integration from first principles; the inverse of differentiation; integration by inspection; sinusoidal functions; logarithmic integration; integration using partial fractions; substitution method; integration by parts; reduction formulae; infinite improper integrals; plane polar coordinates; integral inequalities; applications of integration.

2. Series and Limits

Series; Summation of series (arithmetic, geometric); convergence of infinite series; Operations with series; Power series; Taylor series; Evaluation of limits.

3. Partial Differentiation

Definition of partial derivative; the total differential and total derivative; Exact and inexact differentials; Useful theorems of partial differentiation; the chain rule; Change of variables; Taylor's theorem for many variable functions; Stationary values of many variable functions; Stationary variables under constraints; Thermodynamic relations; Differentiation of integrals.

4. Vector Algebra

Scalars and vectors; Addition and subtraction of vectors; Multiplication by a scalar; Basis vectors and components; Magnitude of a vector; Multiplication of vectors; Equation of lines and planes; Using vectors to find distances; Reciprocal vectors.

5. Ordinary differential equations

Linear equations with constant coefficients; Linear equations with variable coefficients; General ordinary differential equations.

Text Books / References:

1. Mathematical Methods for Physics and engineering, K.F. Riley , M.P. Hobson and S.J. Bence, Cambridge University Press, Cambridge UK (Reprint 2002)

PHC 104: ELECTRONICS PRACTICALS

(Minimum 10 Experiments)

1. Operational Amplifier parameters
2. Series voltage regulator using transistors
3. Constant Current Supply
4. Schmitt trigger circuit and its use as zero crossing detector and squaring circuit (2 experiments)
5. J.K. flip-flop counter: Scale of 16 and 10 using IC
6. Adder and Subtracter Circuits (2 experiments)
7. Oscillators: Design and Construction of Wien bridge
8. Oscillators: Design and Construction of phase shift oscillators
9. Multivibrators : Design and Construction of Monostable (2 experiments)
10. Multivibrators : Design and Construction of Astable (2 experiments)
11. Design and Construction of DC differential amplifier using op-amps
12. Design and Construction of Function generator
13. Design and construction of Negative non linear resistor (Chua circuit)

PHC 105 : COMPUTER PROGRAMMING WITH C

1. Introductory Concepts **[6L]**

Introduction to computers, Introduction to Linux OS, Linux basics, Introduction to C, Writing a C Program, Compiling and Executing the Program, Error Diagnostics, Some simple C Programs, Desirable Program Characteristics.

2. C Fundamentals **[4L]**

The C character Set, Identifiers and Keywords, Data types, Constants, variable and Arrays, Declarations, Expressions, Statements, Symbolic Constants

3. Operators and Expressions **[4L]**

Arithmetic Operators, Unary Operators, Relational Logical Operators, Assignment Operators, the Conditional Operators, Library Functions.

4. Data Input and Output **[4L]**

Preliminaries, Single character input and output, entering Input data, writing output data, Opening and closing data file, format statements.

5. Control Statements **[4L]**

Preliminaries, Branching statements, Looping statements, nested control structure, switch, break, continue, go to statements.

6. Functions **[4L]**

Defining functions, accessing functions, Passing arguments to a function.

7. Arrays **[4L]**

Defining an array, processing an array, passing arrays to functions, multidimensional arrays.

Text Books / Reference

1. Programming with C, Byron Gottfried, Tata Mcgraw-Hill (1996).

PHC 110: COMPUTER PROGRAMMING IN FORTRAN 95

1. Introductory Concepts **[1T+1L]**

Introduction to computers, Introduction to Linux OS, Linux basics, Introduction to FORTRAN, Writing a FORTRAN Program, Compiling and Executing the Program, Error diagnostics, Some simple FORTRAN Programs, Desirable Program Characteristics.

2. Numerical Constants and Variables **[1T+1L]**

Constants, Scalar variables, declaring variable names, implicit declaration and named constants.

3. Arithmetic Expressions **[1T+1L]**

Arithmetic operations and modes of expressions, Integer Expressions, Real expressions, Precedence of Operations in expressions, Assignment statements, defining variables, Intrinsic functions.

4. Input-output statements **[1T+1L]**

List directed input statements, list directed output statements.

5. Conditional statements **[1T+1L]**

Relational Operators, the Block IF construct.

6. Implementing Loops in Programs **[1T+1L]**

The block DO loop, rules to be followed in writing DO loops.

7. Functions and Subroutines **[1T+2L]**

Introduction, function subprograms, syntax rules for function subprograms, generic functions, subroutines.

8. Defining and manipulating arrays **[1T+1L]**

Arrays variables, use of multiple subscripts, do type notation for Input/Output statements, Initializing arrays, use of arrays in Do loops, whole array operations.

9. Elementary format specifications **[1T+1L]**

Format description for numerical data, read statements, Format description for print statements, multi-record format, generalized Input/Output statements.

Text Books / Reference

1. Computer Programming in FORTRAN 90 and 95 by V. Rajaraman, Prentice-Hall of India, New Delhi 1999.
2. Fortran 95, by Martin Counihan, UCL Press Limited University College London (1996).
3. Fortran 95/2003: for Scientists and Engineers , Stephen Chapman, McGraw-Hill (2007).

PHC 106: QUANTUM MECHANICS – I

1. Schrodinger's Equation and Hermitian operators [12L+4T]

(a) Time -dependent Schrodinger equation, continuity equation, expectation values, Ehrenfest's theorems, time-independent Schrodinger equation and stationary states.

(b) Hermitian operators, eigenvalues and eigenstates of Hermitian operators, momentum eigenfunctions, orthogonality and completeness of wave functions, Computability and compatibility of observables, parity operation.

2. Exactly Solvable Problems [12L+4T]

(a) One-dimensional square-well problem, bound states, One dimensional potential step and potential barrier, Scattering states, linear harmonic oscillator.

(b) Spherically symmetric potential, orbital angular momentum operator L, eigenvalues and eigenfunctions of L', Spherical harmonics, hydrogen atom problem.

3. Vector space formulation of quantum mechanics [10L+4T]

Dirac Notation, representation of states and observables, bra and ket vectors, linear operators, relation with wave mechanics, algebra of hermitian operators, matrix representation, unitary operators, Schrodinger and Heisenberg representations, linear harmonic oscillator problem by operator method.

4. Angular Momentum theory [14L+6T]

Angular momentum and rotation, Rotational Symmetry and conservation of angular momentum, Treatment of general angular momentum by operator method, eigenvalues and eigenvectors, Eigen values and eigenfunctions of L^2 and Lz operators, ladder operators L+ and L-, spin angular momentum, algebra of Pauli matrices, Pauli representation of angular momentum operators.

Addition of two angular momenta, spin-orbit interaction, Clebsch Gordon coefficients,. Central forces with an example of hydrogen atom. motion of electron in a magnetic field

Text Books / References

1. Ajoy Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Macmillan India Ltd, Delhi (1999)
2. P. M. Mathew and K. Venkatesan, Quantum Mechanics, Tata McGraw-IEII
3. Quantum Mechanics by L.I.Schiff
4. Modern Quantum mechanics by J.J.Sakurai
5. Quantum Physics by R. Eisberg and R.Resnick
6. Introduction to Quantum Mechanics by by David J.Griffiths
7. Introductory Quantum mechanics by Granier, Springer Publication.
8. Introductory Quantum Mechanics, Li boff, 4th Edition, Pearson Education Ltd.

PHC 107: BASIC ELECTRONICS

1. Network Analysis and Synthesis [15L+5T]

Superposition theorem, Maximum power transfer theorem, T and π networks, Lattice Network, Symmetric Network, Network in the frequency domain, transform impedance, Network functions for the one port and two port, poles and zeros of network function, Positive real functions, Hurwitz polynomials, Synthesis of one port networks, Foster and Cauer forms.

2. Small Signal Amplifiers [12L+ 5T]

Transistor h - parameters, Graphical determination of h - parameters, Small signal model of BJT (analysis of multistage amplifiers) and FET Amplifiers and analysis, Transistor amplifier with Re unbypasssed, High Ri amplifier circuits, Miller's Theorem and Bootstrapped CC amplifier.

3. Power Amplifiers [10L+ 2T]

Large signal amplifiers, Class of operation, Harmonic distortion, class A amplifier with resistive and transformer coupled load, Power efficiency calculations, class B amplifiers, crossover distortion, Complementary symmetry amplifiers.

4. Communication Electronics [10L+7T]

(a) Fundamentals of amplitude, frequency & phase modulation, Simple circuits for amplitude modulation and Demodulation, Digital PCM and Demodulation, Fundamentals of optical communication. (b) Definition of microwave, characteristic features, application of microwaves Microwave Oscillators: Klystron, reflex klystron, magnetron, Gun diode, Cavity resonators, standing wave detectors.

Text Books / References

1.Network, Lines and Fields, J. D. Ryder, Prentice-Hall of India Pvt. Ltd., New Delhi (1995)

2.Electronics Fundamentals and Applications, J. D, Ryder, Prentice-Hall of India Pvt. Ltd., New Delhi (1983)

3. Network Synthesis, Van Valkenburg, Prentice -Hall of India Pvt. Ltd., New Delhi (1984)

4. Integrated Electronics, Analog and Digital Circuits and Systems, J.Millman and C.C. Halkias, McGraw-Hill Book Co. Tokyo (1997)

5. Fundamentals of Electronics Communications, Kennedy, Tata McGraw-Hill Book Co. New Delhi (1996)

6. Electronic Communication, Shrader, McGraw-Hill International (1997)

7. Electronic Communication, D.Ruddy, J.Coolen, Prentice -Hall of India Pvt. Ltd. , New Delhi (1997)

8. Electronic Communications, Modulation & Transmission, Robert J. Schoenbeck.

9. Theory & Problems in Circuit Analysis, TSKV. Iyer.

10. Network Analysis, Van Valkenburg, Practice Hall of India Pvt.Ltd. New Delhi.

11. Microwave devices and circuit – Samuel Y. Liao, PHI

12. Microwave –K.C. Gupta, Wiley Eastern Ltd.

13. Microwave Engineering – Sanjeeva Gupta and others, Khanna Publishers.

14. Microwave circuit and passive devices – M.L. Sisodia and G.S. Raghuvanshi, Wiley Eastern Ltd.

PHC 108: STATISTICAL MECHANICS

1. Kinetic Theory and Equilibrium state of Dilute Gas [11L+2T]

Formulation of problem, binary collisions, Boltzmann transport equation, Boltzmann's H theorem, Maxwell-Boltzmann distribution, Method of the most probable distribution, analysis of the H theorem, recurrence and reversal paradoxes, Validity of the Boltzmann transport equation.

2. Classical Statistical Mechanics [10L+3T]

Review of laws of thermodynamics, Entropy, Thermodynamic Potentials, Postulate of Classical Statistical Mechanics, Microcanonical ensemble, derivation of thermodynamics, equipartition theorem, Classical ideal gas, Gibbs paradox.

3. Canonical and Grand Canonical Ensembles [8L+2T]

Canonical ensemble, energy fluctuations in canonical ensemble, grand canonical ensemble, density fluctuations in grand canonical ensembles, equivalence of canonical and grand canonical ensembles, behaviour of W(N), meaning of Maxwell construction.

4. Quantum Statistical Mechanics [5L+1T]

Postulates of quantum statistical mechanics, density matrix, ensembles in quantum mechanics, third law of thermodynamics, ideal gases in microcanonical and grand canonical ensembles, foundations of statistical mechanics.

5. Ideal Fermi Gas [6L+2T]

Equation of state of Ideal Fermi Gas, theory of white dwarfs, Landau diamagnetism, DeHass-Van Alphen effect, Pauli paramagnetism.

6. Ideal Bose Gas [6L+2T]

Photons, phonons, Bose-Einstein condensation.

7. The Ising Model [10L+1T]

Definition of the Ising model, Equivalence of the Ising model to other models, Spontaneous magnetization, The one dimensional Ising model, Formulation of the two dimensional ising model, The Onsager solution.

8. Critical Phenomena [4L+1T]

The order parameter, the correlation function and the fluctuation dissipation theorem, critical exponents.

Text Books and References

1. Statistical Mechanics, Kerson Huang, John Wiley and Sons New Delhi 2000.
2. Fundamentals of Statistical Mechanics, B. B. Laud, New Age International Ltd. New Delhi 1998.
3. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill International 1985.
4. Statistical Mechanics L. D. Landau and E. M. Lifshitz, Pergamon Press 1969.
5. Statistical Physics, R. P. Feynmann, The Benjamin Cummings Publishing Co 1981.
6. Introduction to Statistical Physics, S. K. Sinha, Narosa Publishing House, New Delhi 2007.
7. Statistical Physics, Tony Guenault, New Age International Ltd. New Delhi 2007.

PHC 109: GENERAL PHYSICS PRACTICALS

Minimum of 12 experiments

Short Lecture Course on – Theory of errors, Treatment of Errors of observation, Least squares fitting and Data analysis.

The experiments on the following topics are to be performed with emphasis on the estimation and calculation of errors

1. Types of Statistical Distributions
2. Forbidden Energy gap of a Germanium/Silicon and a light emitting diode
3. Analysis of Sodium Spectrum – Quantum defect and Effective quantum number
4. Michelson Interferometer / Fabry-Perot Interferometer
5. Determination of Stephan's Constant
6. Zeeman's effect
7. Frank Hertz Experiment
8. Statistical Distribution of radioactive decay
9. Verification of Inverse Square Law using GM counter
10. Linear Absorption Coefficient of Aluminium using GM counter
11. Debye Relaxation
12. Thermal diffusivity of Brass
13. Calibration of Lock-in Amplifier
14. Mutual inductance lock-in amplifier
15. X-ray Emission
16. Strain Gauge
17. Ultrasonic Interferometer
18. Thermometry – measurement of thermoemf of Iron-Copper (Fe-Cu) thermocouple as a function of temperature.
19. Measurement of low resistance using lock-in amplifier
20. Tracking of first order and second order transition by measurement of resistance of shape memory alloy and Ni metal
21. Percolation threshold and temperature dependence of resistance in composites
22. Dynamics of non linear system – Feigenbaum circuit

Text Books and References

1. Errors of Observations and Their Treatment, J.Topping, Chapman and Hall (1972).

PHO-301 : SUMMER FELLOWSHIPS

Students are to be encouraged to attend summer fellowships offered by various national laboratories, institutes and universities during the summer months of May and June each year between Parts I and II. The learning cum experience gained at such places will be required to be written up as a report and presented. These will be assessed by the D.C. and awarded a grade. Such fellowships may be considered to be equivalent to ONE credit. This extra credit will be in addition to the 80 credits that are necessary for the award of a Master's degree in Physics.

PHC 201: QUANTUM MECHANICS II

1. Identical Particles [6L+2T]

Symmetrization postulate, connection between spin and statistics, Pauli exclusion principle, wave function for fermions and bosons. Examples : Helium atom, Scattering of identical particles.

2. Perturbation Theory [12L+4T]

Time-independent perturbation theory, non-degenerate and degenerate cases, applications to simple problems, time dependent perturbation theory, Golden rule for transition probability, application to simple problems.

3. Variational method [6L+4T]

Upper bounds on the ground state and excited state energies, applications to simple problems.

4. Scattering Theory [12L+4T]

Schrodinger equation for a free particle in three dimensions, expansion of plane waves in spherical harmonics, scattering by a potential, scattering amplitude and cross-sections, Born approximation, scattering by Yukawa and Coulomb potentials, concept of phase shifts, calculation of phase shifts from potentials, partial wave expansion of scattering amplitude, optic& theorem.

5. Relativistic Wave Equations [14L +5T]

A. Klein-Gordon equation, Plane wave solution, charge and current densities, hydrogen atom.

B. Dirac equation, algebra of Dirac matrices, covariance of Dirac equation, plane wave solutions, equation in an electromagnetic field,

C. Properties of Dirac electron

D. The spin of the Dirac particle, Magnetic dipole moment of electron, Velocity operator, Expectation value of the velocity.

E. Parity, Charge conjugation and time reversal operations, Parity operation, Charge conjugation, a time reversal operation.

F. Feynmann's theory of Positrons

Text Books and References

1. A.K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Macmillan India Ltd., Delhi (1999)
2. P.M.Mathew and K. Venkatesan, Quantum Mechanics, Tata McGraw-l-fill
3. L.I. Schiff, Quantum Mechanics, (3rd Edition) McGraw-Hill (1 968)
4. V. K. Thankappan, Wiley Eastern Ltd. (1985).
5. V. Devanathan, Narosa Publishing House (2006).

PHC 202: NUCLEAR PHYSICS

1. Basic Properties of Nuclei **[6L +2T]**

Nuclear mass, charge and radius, Nuclear spin, Parity Statistics, magnetic and electric quadrupole moments.

2. Nuclear Models **[9L +3T]**

a) Liquid Drop model, Weizsacker's mass formula, mass parabolas.

b) Nuclear shell model. Energy levels in a three dimensional harmonic oscillator well potential,

spin orbit interaction, prediction of magic numbers, ground state spins and parities, magnetic moments, Schmidt lines, Nuclear quadrupole moment.

c) Collective Model, Bohr-Mottelson theory of surface vibrations and rotations of nuclei, Excitation spectra of deformed nuclei, Niisson model.

3. Nuclear Transformations **[9L +3T]**

a) Alpha decay, Barrier penetration problem. Gamow's theory of Alpha decay, Geiger-Nuttal law, Alpha spectra and nuclear energy level.

b) Gama transitions, multipole radiations, Quantum theory of the transition probability, selection rules, Angular correlation, Calculations of transition rates and comparison with experiments, internal conversion

c) Beta Decay, Experiments in beta spectra, neutrino hypothesis, Fermi's theory of beta decay, Kurie plots, ft values, Allowed and forbidden transitions, selection rules, electron capture, parity violation in beta decay, experimental verification, measurement of neutrino helicit.

4. Two-Body Problem **[9L +3T]**

Properties of deuteron Theory of the ground state of deuteron, Magnetic moment and electric quadrupole moment of deuteron, tensor force, theory of nucleon-nucleon scattering at low energy, phase shift and scattering length , effective range theory, experimental determination of low energy parameters, nature of nuclear forces, Wigner, Heisenberg and Majorana exchange forces, Mason theory of nuclear force.

5. Nuclear Reactions **[3L +1T]**

Cross-sections, principles of detailed balance, Bohrs theory of compound nucleus, resonances and Breit-Wigner Single level formulation, optical model, Direct reaction, Nuclear fission.

6. Elementary Particles **[6L +2T]**

Classification of elementary particles, Baryons, Mesons and Leptons, Strong , weak and electromagnetic interactions, Isobaric spin, strangeness and parity, elementary particles reactions and decays, Resonances, Eightfold way, Quark model.

Text/ Reference Books

1. Introduction to Nuclear Physics, H. Enge, Addison-Wesley (1 974)
2. Experimental Nuclear Physics, E. Segre, John Wiley (1 960)
3. Nuclear Physics, V. Devanathan.

PHC 203: SOLID STATE PHYSICS

1. Crystal structure and Crystal Binding [11L+4T]

Crystals-Lattice, Bravais lattice, primitive unit cell, seven crystal systems, fourteen Bravais lattices, definitions of directions, coordinates and planes,

Simple crystal structures: NaCl, CsCl, diamond, hexagonal close-packed structure, cubic ZnS structure.

Reciprocal Lattice-Diffraction of waves by crystals, Bragg law, Scattered wave amplitude -Fourier analysis, reciprocal lattice vectors, diffraction conditions, Laue equations, Brillouin zones, Geometric structure factor, Atomic Structure factor

Point Defects General Thermodynamic Features, Color centres, Line Defects: Dislocations.

Crystals of inert gases-Van der Waals-London interaction, repulsive interaction, equilibrium lattice constants, cohesive energy, Ionic Crystals-Electrostatic or Madelung Energy, evaluation of Madelung constant, covalent crystals, bonding in metals, and Hydrogen bonds.

2. Free Electron Theory and Energy Bands in solids [17L+3T]

Free electron theory-Sommerfield model, Electrical conductivity, Experimental electrical resistivity of metals, Heat capacity of electron gas, Experimental heat capacity, Thermal conductivity of metals, motion in magnetic fields Cyclotron frequency, Hall effect, AC conductivity.

Energy Spectra in atoms, molecules and solids, Energy Bands in Solids; the Bloch Theorem, Band symmetry in k-space; Brillouin Zones, Number of states in the band, The nearly free electron model, The energy gap and the Bragg reflection, Tight binding model, Metals, insulators and semiconductors, density of states, The Fermi surface, Velocity of Bloch electron, Electron dynamics in an electric field, The dynamical effective mass, Physical origin of effective mass, The hole, Electrical conductivity, Electron dynamics in a magnetic field; cyclotron resonance and Hall effect, Experimental methods of determination of band structure, Limit of band theory; metal-insulator transition.

3. Thermal Properties [8L+2T]

Vibrations of a one -dimensional monatomic lattice, first Brillouin zone, group velocity, long wavelength limit, derivation of force constant from experiment. Vibrations of a one dimensional diatomic lattice. Quantization of elastic waves, phonon momentum, Inelastic scattering by Phonons.

Phonon Heat capacity, Planck distribution, normal mode enumeration, density of states in one dimension, density of states in three dimensions Debye model for density of states, Debye T' law, Einstein model of the density of states, Thermal conductivity- Thermal resistivity of phonon gas, Umklapp process.

4. Optical and Dielectric Properties [8L+2T]

Optical reflectance, Excitons, Raman effect in crystals.

Macroscopic electric field, local electric field at atom, dielectric constant and polarizability, Structural Phase transitions, Ferroelectric Crystals and Displacive transition.

5. Magnetic Properties **[8L+2T]**

Langevin Diamagnetism Equation, Quantum Theory of Diamagnetism, Paramagnetism, Quantum Theory of Paramagnetism, Paramagnetic Susceptibility of Conduction electrons,

Ferromagnetic Order, Magnon, Ferrimagnetic Order, Antiferromagnetism, Ferromagnetic Domain.

6. Superconductivity **[8L+2T]**

Experimental surve- Occurrence of Superconductivity, Destruction of superconductivity by magnetic fields, Meissner effect, Heat capacity, Energy gap, microwave and infrared properties, Isotope Effect.

Theoretical Survey-Thermodynamics of the transition, London equation, Coherence length, BCS theory, Flux quantization, Type II superconductors, Tunneling, Josephson effects High Tc superconductivity.

Text / Reference Books

1. Elementary Solid State Physics; Principles and Applications, M. A. Omar Addison Wesley (2000).

2. Introduction to Solid State Physics, C. Kittel, 7th Edition, John Wiley & Son, Inc. New York (1997).

3. Solid State Physics, Niel W. Ashcroft, N. David Mermin, Harcourt Asia Pte Ltd. (2001).

4. Solid State Physics, G. Bums, Academic press, Inc. London (1985).

5. Solid State Physics, A. J. Dekker, McMillan, India (1985).

6. Solid State Physics, J. S. Blakemore, W. B. Sauders, Philadelphia (1969).

PHC 204: SOLID STATE PHYSICS PRACTICALS

1. X-Ray Diffraction : XRD of Cubic Material; Powder Pattern and its qualitative and quantitative analysis.
2. Determination of Resistivity and Band Gap of a Semiconductor by Four Probe Method
3. Measurement of Thermoelectric Power
4. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Material by Gouy's Method
5. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Liquid by Quinke's Method
6. Study of Hysteresis of a Ferrite and determination of Curic / Ne'el temperature of a Ring made up of a Ferrite Material.
7. Determination of Lande's Splitting Factor, g, in an organic radical . ESR Spectrum
8. Study of Elastic behaviour of solids using a composite piezoelectric oscillator
9. Determination of Transition Temperature of a Ferroelectric Material Dielectric Constant
10. Measurement of Activation Energy of F-Centres in Alkali Halide Crystals Thermoluminescence
11. Determination of a Hall Coefficient and Nature of a Semiconductor and Mobility of Charge Carriers
12. Frequency dependence of Dielectric constant
13. Energy band gap of material by UV reflectance.
14. IR spectra of material and its analysis.
15. Temperature variation of resistivity of semiconductor material and determination of activation energy.
16. Raman effect – demonstration applied to a particular material.

A minimum of 12 experiments are expected to be done by the students.

PHC 205: PHYSICS SEMINARS

This 2 Credit course will consist of 15 weeks of seminars delivered by students, each giving 2 talks of duration 40 minutes each including time for questions and answers. Preparation for each talk will be done in consultation and guidance by a faculty member who would be designated for each student and who will help the student in preparing a synopsis of the talk. Assessment will be done by designated faculty members during the talks. A record will be kept of each talk.

PHO 302: NEUTRON PHYSICS

1. Interaction of Neutrons with Matter
Interaction of neutrons with matter, cross-section and variation with neutron energy. Neutron flux. Maxwellian distribution. Fissile and fertile materials. Chain reaction and neutron life cycle. Fermi four factor formula $k_{eff.}$

2. Neutron Diffusion
Diffusion theory approximation, derivation of diffusion equation. Neutron balance and critical equation. Boundary conditions and extrapolation distance. Diffusion length and its measurement.

3. Slowing down of Neutrons
Slowing down length, lethargy, slowing down in a mixture. Moderations. Slowing down models.

4. Calculation of Critical Size of Reactors
Critical equation. One group model, four factor formula and calculation of parameters. Critical size of sphere and cylinder. Effect of reflector.

5. Power Operation
Reactor kinetics, mean neutron lifetime. The "In-Hour" equation and stable reactor period. Reactivity changes due to temperature. Fission product poisoning . Fuel burn-up. Measurement or reactor power and period.

6. Reactor Types and Economics
Descriptions of MAGNOX, CANDU, fast reactor. Calculation of total generation cost. Comparison with economics of oil **fired** plant. Influence of economics on nuclear plant design.

7. Radiological Protection
Units of radiation and radioactivity. Concept and derivation of safe working levels. Monitoring instruments and methods.

8. Reactor Fuels and Materials
Uranium resources and requirements. Isotope separation. (one method). Fuel reprocessing. Storage and disposal of nuclear waste – consideration of different methods.

9. Nuclear Policy:
Elements of India's Nuclear Policy. Examples of Policy of other countries.

Text/ Reference Books

1. Nuclear Reactor Engineering by S. Glasstone and A. Sesonske. (Van Nostrand Reinhold Co.).
2. Fundamentals of Nuclear Reactor Physics by E. E. Lewis (Elsevier) (2008).
3. Safe Handling of Radioisotopes (Safety Series no. 1) (1958).
4. Atomic Energy Waste. Editor E. Glueckauf, (Butterworths).

PHO 303: SUPERCONDUCTIVITY AND SUPERFLUIDITY

SUPERCONDUCTIVITY: [40]

1. Basic Experimental Aspects [3L+1T]

Introduction, Conduction in metals, Zero-resistivity, Meissner-Ochsenfeld effect, Perfect diamagnetism, Type-I and type-II superconductors, Application of low and high temperature superconductors.

2. Superconducting Materials [6L+2T]

Classical Superconductors: Elemental superconductors, superconducting compounds and alloys, A15 compounds, Chevrel phase compounds and their crystal structure, experimental studies on these materials, Phase diagrams.

High-temperature Superconductors: La-Ba-Cu-0 systems, Y-Ba-Cu-0 systems, Bi-Sr-Ca-Cu-0 systems, Ti-Sr-Ca-Cu-0 systems, superconductivity in rare-earth and actinide compounds, organic superconductors, MgB_2 and Iron Arsenide systems, their crystal structure, experimental studies on these materials, Phase diagrams.

3. Theoretical Aspects [22L+6T]

Phenomenological theories: Thermodynamics of superconducting transition, expressions for critical temperature T_c, critical field H_C London's theory, Pippard non-local theory, Ginzburg-Landau Theory.

Microscopic theory: BCS theory, the electron-phonon interaction, the Cooper pair formation, BCS ground state, Consequences of the BCS theory and comparison with experimental results, Coherence of the BCS ground state and the Meissner-Ochsenfeld effect.

Possible Mechanisms of high T_C Superconductors: Hubbard-Model, the Resonance valence Bond (RVB) model, Spin fluctuation model.

SUPERFLUIDITY: [20]

1. Superfluid Helium-4 [5L+2T]

Introduction, Classical and quantum fluids, the macroscopic wave function, Superfluid properties of He II, Flow quantization and vortices, the momentum distribution, quasiparticle excitations.

2. Superfluid Helium-3 [5L+2T]

Introduction, The Fermi liquid normal state of ^{3}He, the pairing interaction in liquid ^{3}He, Superfluid phases of ^{3}He.

3. Bose-Einstein Condensates [5L+1T]

Introduction, Bose-Einstein Statistics, Bose-Einstein condensation, BEC in ultra-cold atomic gases.

Text/ Reference Books

1. James F. Annett, "Superconductivity, Superfluids and Condensates", Oxford Series in Condensed Matter Physics.
2. J.B. Ketterson and S.N. Song, Superconductivity, Cambridge Univ. Press (1999).
3. M. Tinkham, Introduction to Superconductivity, McGraw Hill (1996).
4. C. Kittel, "Introduction to Solid State Physics", Wiley
5. H. Ibach and H. Luth, " Solid State Physics", Springer

PHO-304: X-RAY SPECTROSCOPY

1. Production of X-rays **[10L+2T]**

Early history and the X-ray tube, Synchrotron Radiation – Properties, Radiated Power, Spectral and angular distribution, Polarization, pulsed time structure, brightness and emittance, Undulator radiation, Wiggler radiation.

2. Scattering of X-Rays **[12L+3T]**

Thomson and Rayleigh (Coherent) Scattering, Incoherent (Compton) Scattering, X-ray Diffraction and powder analysis techniques, Scattering from liquids and glasses (introduction), Small angle scattering.

3. Photoelectron Spectroscopy **[10L+2T]**

Photoelectric Effect, Quantum Theory of the Photoelectric Effect, Born Approximation, Shake-up Structure, Experimental Systems, Auger Effect and its Relation to ESCA and X-Ray Spectra, Basic Theory of the Auger, Effect, Detection of Auger Electrons, X-Ray Line Width, Satellites, Low-Energy Satellites, Fluorescence, Measurement of Fluorescence Yield, Autoionization and Internal Conversions.

4. Chemical Shifts in Emission Spectra **[5L+1T]**

Chemical Shifts of Emission Lines, Level Shift, X-Ray Line Shift, Appearance Potential Spectroscopy, Resonance X-Ray Emission Spectroscopy, Width and Fine Structure of Emission Lines, Anisotropic X-Ray Emission Lines, Nuclear Finite-Size Effects.

5. Absorption Spectra **[12L+3T]**

Absorption Edge, Transition rate, X-Ray Absorption Near Edge Structure (XANES), Chemical Shifts of Absorption Edges, Extended X-Ray Absorption Fine Structure, History of EXAFS, Basic Theory of EXAFS, EXAFS Experiment, Beamline and optics, Detectors, Data acquisition, treatment and analysis.

Text/ Reference Books

1. X-ray Spectrometry : Recent Technological Advances, Edited by K.Tsuji, J.Injuk and R.V.Grieken John Wiley & Sons Ltd. England 2004
2. X-ray Spectroscopy : An Introduction, Bipin Kumar Agarwal Springer –Verlag, 1991
3. X-ray Spectroscopy, L.V. Azaroff McGraw-Hill, New York, 1974
4. X-Rays in Theory and Experiment, Arthur H. Compton and Samuel K. Allison D Van Nostrand Company Inc. 1947
5. Elements of X-ray Diffraction, B.D.Cullity Addision Wesley Publishing Company Inc.
6. Introduction to XAFS, Grant Bunker, Cambridge University Press, 2010.
7. Elements of Modern X-ray Physics, Jens Als-Nielsen and Des Mc Morrow, 2nd Edition, Wiley 2011.

PHO 305: ELECTRONICS PRACTICALS-II

1. Study of R-S, D/T, J-K Flip-Flops.
2. Study of counters: Ripple, Mode 3, Mode 5, Mod 7, Mod 9, Mod 12 counters.
3. Study of Shift Register.
4. Study of Binary weighted and R-2R D/A Converter.
5. Study of Random Access Memory (RAM) Read Only Memory. (ROM)
6. Study of A/D Converter.
7. Experiment with Microprocessor
8. Convert BCD in to HEXADECIMPL
9. Design and construction Analog Multiplexer
10. Design and construction of Sample and Hold Circuits
11. Full adder and subtractor
12. Solving of Differential Equation by analog computation using OPAMPS
13. Design and construction of Amplitude modulation and Demodulation Circuit.
14. Design and construction of frequency modulation and demodulation Circuit.
15. Design and construction of variable voltage (0-25V; 1Amp) Regulated power Supply.
16. Design and construction of low voltage SMS power supply.

Any **eight** experiments to be completed

PHO 306: SEMICONDUCTOR PHYSICS

1. Electrons in Solids **[10L]**

Schrodinger equation for electrons; the free electron problem. filling of electronics states: statistics. Cubic lattices, Diamond and zinc blende structures. Metal, Semiconductors and insulators; Fermi levels in metals and semiconductors.

2. Electrons in Semiconductors **[10L]**

Electrons in a periodic potential, Bandstructures of Ge, Si and GaAs, Mobile carriers: Intrinsic carriers, intrinsic concentration doping: Donors and acceptors; carriers in doped semiconductors.

3. Carrier Dynamics in Semiconductors **[20L]**

Scattering in semiconductors; Velocity-electric field relations, Very high field transport: breakdown phenamena, Carrier transport by diffusion; Transport by drift and diffusion, Einstein relation, Charge injection and quasi-Femi levels; Charge generation recombination; Optical processes in semiconductors, Nonradiative Recombination, Continuity equation: diffusion length.

4. Junctions in Semiconductors : P-N Diodes **[20L]**

Unbiased P-N junction., P-N junction under bias., The real diode : consequences of defect, High voltage effects in diodes, Modulation and Switching : AC response.

Text/ Reference Books

1. Semiconductor Devices : basic Principles, Jasprit Singh. (John Wiley & Sons, New York, 2004).
2. Physics of Semiconductors and Their Heterostructures Jasprit Singh (McGraw -Hill, New, York, 1993).
3. Introduction to Semiconductor Materials and Devices , M.S. Tyagi (John Wiley & Sons, New York, 2000).
4, Physics of Semiconductor Devices S. M. Sze (John Wiley & Sons, New York, 1981).
6. Solid State Electronic Devices, B. G. Streetman and S. Banerjee (Prentice Hall, Englewood Cliffe, NJ 1999).

PHO 307: PROJECTS

This 8-Credit project is to be carried out over semesters 3 and 4 on experimental or theoretical studies that are done by a student in consultation and guidance of a faculty member. The work may be done either in the Physics Department or in a designated laboratory with the permission of the D.C. A comprehensive report is to be written and presentation made to the D.C. in the fourth semester. The assessment is as per the appropriate ordinance of Goa University.

PHO 308 ACOUSTICS AND NOISE CONTROL

(Faculty wide optional paper for M. Sc. Final year)

1. Fundamentals & History of Acoustics; Human Perception & Response to Sound *(12 Lectures)*

Introduction to Acoustics; Brief History of Acoustics; Frequency, Wavelength, Simple harmonic motion & Superposition of waves; Sound waves; Acoustical properties; Levels; Source Characterization; Human hearing mechanisms; Pitch, Loudness, Intelligibility & Annoyance; Other Effects (Precedence Effect, Perception of Echoes and Direction, Binaural Sound)

2. Acoustics of Rooms for Speech, Music & Worship *(16 Lectures)*

Energy Build-up in a Room; Room Impulse Response; Subjective & Objective Room Acoustical Parameters for Music; Speech-Intelligibility Tests & Metrics; Rooms for Speech Intelligibility; Speech Privacy Calculations; Speech Reduction Rating & Privacy; Open-Plan Ceilings & private offices; Masking Sound; Acoustical Characterization of a Worship Space, Church Acoustics; Temple Acoustics; Mosque Acoustics; Acoustics of other Worship Spaces; Sound Reinforcement & Electro-acoustics.

Assignment: *Conservation & Restoration of Acoustical Heritage in traditional worship spaces.*

3. Ultrasonics: Biological & Medical Acoustics *(16 Lectures)*

Ultrasonics (Relaxation processes, Cavitation, Phonons, Transducers, Transducers Arrays, Ultrasound Imaging); Forest & Ocean Bioacoustics (Optimized Communication; Insects; Land Vertebrates; Birds; Bats; Aquatic Animals; Generalities; Quantitative System Analysis**;** Hearing in Cetaceans; Echolocation Signals; Odontocete Acoustic Communication; Acoustic Signals of Mysticetes); Medical Acoustics (Basic Physics of Ultrasound Propagation in Tissue; Methods of Medical Ultrasound Examination; High-Intensity Focused Ultrasound (HIFU) in Surgery; Thrombolysis; Lower-Frequency Therapies)

Assignments: *Effects of Noise Emission on Aquatic & Forest animals; Symposium on Ultrasound safety.*

4. Environmental Noise: Sources, Effects, & Control *(16 Lectures)*

Environmental Noise: Characterization, Prediction, Assessment & Control (Specification & measurement of sound isolation, Design of partitions & barriers, Railroad noise, Aircraft and Airport noise, Industrial Noise, Building site noise), Noise in buildings & communities (criteria, isolation of air-borne & structure-borne noise in buildings, community noise ordinances); Effects of Noise on People (Sleep disturbance due to transportation noise exposure; Effects of infrasound, low-frequency noise & ultrasound on people; Auditory hazards of impulse & impact noise; Noise induced annoyance & stress; Effect of Noise on Behaviour & Work Efficiency; Hearing protectors; Hearing conservation programs; Rating measures, descriptors, criteria & procedures for determining human response to noise);

Assignment: *Noise from entertainment sources and other leisure activities* ***(****Noise from Pubs and clubs – code of practice, outdoor music events – guidance on control, noise*

from water sport activities; motor sports; relevant codes of practice) 26

References:

1. Springer Handbook of Acoustics, Rossing, 2007
2. Architectural Acoustics, M. Long, 1st Ed., 2005
3. The Master Handbook of Acoustics, Everest, 4th Ed., 2000
4. Worship, Acoustics & Architecture, Cirillo & Martellotta, 2006
5. Acoustics of Worship Spaces, Lubman & Wetherill, 1985
6. Engineering Noise Control, C. Hansen, 4rd Ed. 2009
7. Fundamentals of Acoustics, Bruneau, 2006
8. The Science and Applications of Acoustics, Daniel Raichel, 2000
9. Fundamentals of Acoustics, Kinsler et al., 4th Ed, 2000
10. Handbook of Noise and Vibration Control - Crocker, 2007
11. Noise and Vibration Control Engineering - Principles and Applications, Ver & Beranek, 2nd Ed. 2006
12. Acoustical designing in Architecture, Knudsen, Harris, 1988

PHO 309 PHYSICS OF NON- CONVENTIONAL ENERGY SOURCES

(Faculty-wide Physics course for students of the Faculty of Natural Science – 4 credits)

An Introduction to Energy Sources (2L)

Renewable and non-renewable energy sources, energy consumption Global and National scenarios, Prospects of non-conventional Energy Sources- scope and potential.

Solar radiations (6L)

Extra terrestrial radiation, Spectral distribution of solar radiation, Solar constant, Measurement of solar radiations, Solar radiation geometry, Flux on a plane surface, Latitude, Declination angle, Surface azimuth angle, Hour angle, Zenith angle, Solar altitude angle, expression for angle between incident beam and the normal to a plane surface

Solar energy (8L)

Solar thermal power and it's conversion, Solar collectors, Flat plate, Performance analysis of flat plate collector, Solar concentrating collectors, Types of concentrating collectors, Thermodynamic limits to concentration, Cylindrical collectors, Thermal analysis of solar collectors, Tracking CPC and solar swing . Solar thermal energy storage, Different systems, solar pond.

Applications: Water heating, Space heating & cooling, Solar distillation, solar pumping, solar cooking, Greenhouses, Solar power plants.

Solar photovoltaic system (4L)

Photovoltaic effect, Efficiency of solar cells, Semiconductor materials for solar cells, Solar photovoltaic system, Standards of solar photovoltaic system, Applications of PV system, PV hybrid system.

Wind Energy (6L)

Principle of wind energy conversion; Betz model, wind mills- horizontal axis and vertical axis, horizontal axis wind turbines, their components. Vertical axis- Magnus effect, Madaras & Darrieus turbine. Analysis of aerodynamic forces acting on wind mill blades and estimation of power output.

Energy from Biomass (5L)

Photosynthesis, Bio gas production Aerobic and anaerobic bio-conversion process, Raw materials, Properties of bio gas, Producer gas, Biomass conversion technologies, Biogas generation plants, classification, advantages and disadvantages, Fuel properties of bio gas, utilization of biogas.

Geothermal Energy (5L)

Structure of earth's interior, geothermal sites, geothermal resources, Principle of working, Estimation and nature of geothermal energy, Types of geothermal stations, advanced concepts, Problems associated with geothermal conversion.

Energy from the ocean (5L)
Principle of ocean thermal energy conversion, systems like open cycle, closed cycle, Hybrid cycle, Energy from tides, basic principle of tidal power, single basin and double basin tidal power plants, advantages, limitation and scope of tidal energy. Wave energy conversion machines, power plants based on ocean energy advantages and disadvantages of wave energy.

Fuel Cells (5L)
Introduction, Design principle and operation of fuel cell, Types of fuel cells, conversion efficiency of fuel cell, application of fuel cells. Efficiency of fuel cells, operating characteristics of fuel cells, Advantages and future potential of fuel cells.

Hydrogen Energy (5L)
Properties of hydrogen as a source of renewable energy, Hydrogen Production methods, Hydrogen storage, hydrogen transportation, utilization of hydrogen gas as a fuel, hydrogen as alternative fuel for vehicles. Development of hydrogen cartridge.

Books
1. Bansal Keemann, Meliss," Renewable energy sources and conversion technology", Tata Mc Graw Hill.
2. Kothari D.P., “Renewable energy resources and emerging technologies”, Prentice Hall of India Pvt. Ltd.
3. Rai G.D, "Non-Conventional energy Sources", Khanna Publishers.
4. Ashok V. Desai, "Nonconventional Energy", New Age International Publishers Ltd.

REFERENCES:
1. Renewable Energy Sources / Twidell & Weir
2. Solar Energy / Sukhatme
3. Solar Power Engineering / B.S. Magal Frank Kreith & J.F. Kreith
4. Principles of Solar Energy / Frank Krieth & John F Kreider
5. Non-Conventional Energy Systems / K Mittal / Wheeler
6. Renewable Energy Technologies / Ramesh & Kumar / Narosa
7. Energy Technology – S Rao and B B Parulakar

PHO 310: NUMERICAL METHODS AND FORTRAN PARALLEL PROGRAMING USING OPEN MP

1. Computations and basics of open MP **[12T+15L]**

Introduction to scientific computations and FORTRAN parallel Programing using Open MP.

2. Introduction to numerical methods **[1T+2L]**

Round-off and truncation errors.

3. Solving nonlinear algebraic equations **[2T+4L]**

Bisection method; Regula Falsi method Newton-Raphson and Secant methods.

4. Solving systems of linear algebraic equations **[2T+4L]**

Gaussian elimination method; Gaussian elimination with pivoting, LU Decomposition method, Inverse matrix algebra. Eigenvalues and eigenvectors.

5. Cuver fitting and interpolation **[2T+4L]**

Linear least-squares regression; Linearized nonlinear regression models. Interpolation techniques.

6. Numerical integration and differentiation **[2T+4L]**

Trapezoidal and Simpson's rules, Gauss quadrature Multiple integrals. Finite differences, difference formulas Differentiation using Lagrange polynomials.

7. Ordinary differential equations **[2T+4L]**

Euler's Method, Modified Euler's method. Runge-Kutta methods Multiple-step methods; Predictor-corrector methods. Systems of first-order equations

Text/ Reference Books

1. Computer Programming in FORTRAN 90 and 95 by V. Rajaraman, Prentice-Hall of India, New Delhi 1999.
2. Fortran 95, by Martin Counihan, UCL Press Limited University College London (1996).
3. Fortran 95/2003: for Scientists and Engineers , Stephen Chapman, McGraw-Hill (2007).
4. Numerical Methods for Scientific and Engineering computation by Jain M. Wiley Eastern Limited (1995).
5. FORTRAN 77 and numerical methods by Xavier, C New Delhi New Age International 2003
6. Numerical Recipes in C by Press, William H. New Delhi Cambridge University Press 2005
7. Open MP user guide at http://openmp.org/wp/resources/#Tutorials

PHO-311 PHASE TRANSITIONS AND CRITICAL PHENOMENA

1. Phenomenology of phase transitions **[5L+1T]**

The role of symmetry and the onset of order, Switching of the degree of order, Example of atomic site ordering, Ferroelectric phase transitions, How to observe a phase transition, Order of a phase transition, General aspects of the thermodynamics of a phase transition, Seeds of a theoretical model, Examples.

2. Magnetic phase transitions **[5L+1T]**

Macroscopic and microscopic views of magnetism, Non-interacting atoms in a magnetic field: paramagnetism, Interacting atoms in a magnetic field: ferromagnetism, Critical exponents revisited, Successes and failures of the mean-field model.

3. Landau theory **[12L+2T]**

Introduction, Quantification of the free energy, Results for second-order phase transitions, Field-dependence of the order parameter at the transition temperature, Taking account of spatial variations, Validity of Landau theory, Ferromagnetism, the mean-field approximation, and Landau theory, First-order phase transitions, the case when the free energy is allowed to have odd-order terms, Tricritical phase transitions. Examples like phase transitions and elastic strain, ferroelectric phase transition, superfluid Mott insulator phase transition.

4.The role of symmetry **[12L+2T]**

Introduction to Symmetry, Point group symmetry operations, Space group symmetry operations, Groups and their representations, Symmetry of the order parameter, Symmetry of the spontaneous strain, Group-subgroup relationships across phase transitions.

5. Soft modes and displacive phase transitions **[4L+1T]**

Displacive phase transitions, Phenomenology of the soft mode model of displacive phase transitions, Lattice dynamics theory of the soft mode, Lattice dynamical theory of the low-temperature phase, Phase transitions, soft modes, and structure flexibility: the Rigid Unit Mode model.

6. Order-disorder phase transitions **[4L+1T]**

Order–disorder phenomenology, Mean-field theory of order–disorder phase transitions: the Bragg–Williams model, Computational methods, Beyond Bragg–Williams theory: the Cluster Variation Method.

7. Critical point phenomena **[4L+1T]**

The Widom scaling hypothesis: relationships between critical exponents, Introduction to the renormalization group, deriving the Widom scaling hypothesis, a sketched example: the 1D Ising model.

8. Reconstructive Phase transitions **[4L+1T]**

Introduction and definition, Examples, Thermodynamics of reconstructive Phase transitions

Text/ Reference Books

1. Binney, J. J., N. J. Dowrick, A. J. Fisher, and M. E. J. Newman (1992) The theory of critical phenomena: An introduction to the renormalisation group. Oxford: Clarendon Press
2. Blundell, S. (2001) Magnetism in condensed matter. Oxford: Oxford University Press
3. Burns, G. and A. M. Glazer (2013) Space groups for solid state scientists, third edition. Waltham: Academic Press
4. Dove, M. T. (2003) Structure and dynamics. Oxford: Oxford University Press.
5. Goldenfeld, N. (1992) Lectures on phase transitions and the renormalisation group. Reading, MA: Addison-Wesley
6. Muller, U. (2013) Symmetry relationships between crystal structures. Oxford: Oxford University Press
7. Nishimori, H. and G. Ortiz (2011) Elements of phase transitions and critical phenomena. Oxford: Oxford University Press
8. Salje, E. K. H. (1993) Phase transitions in ferroelastic and co-elastic crystals, student edition. Cambridge: Cambridge University Press
9. Tol´edano, J.-C. and P. Tol´edano (1987) The Landau theory of phase transitions. Singapore: World Scientific
10. Yeomans, J. M. (1992) Statistical mechanics of phase transitions. Oxford: Clarendon Press
11. Statistical Physics, Kerson Huang, Chapman and Hall/CRC

PHO-312 SPECTROSCOPIC TECHNIQUES IN CONDENSED MATTER PHYSICS

OPTICAL SPECTROSCOPY

1. Introduction **[6L+1T]**

Electromagnetic radiation, Energy quantisation, light-matter interaction, Absorption and Emission of radiation, Line width and its broadening mechanisms, natural and Doppler broadening, Optical measurements: noise statistics, photon detectors and cameras, UV-VIS spectroscopy, Instrumentation.

2. Luminescence Spectroscopy **[6L+1T]**

Optical absorption: Free carrier absorption-optical transition between bands-direct, and indirect-excitons, principles of luminescence, Frank-Condon principle, types of luminescence, instrumentation, excitation and emission spectra, decay mechanism, Fluorescence, Phosphorescence, lifetime measurements, luminescence in different types of phosphors, sensitized luminescence, thermo luminescence and methods of analysis, models for luminescence, Phosphors for different applications.

ATOMIC AND MOLECULAR SPECTROSCOPY

1. Electronic spectroscopy **[7L+1T]**

One-electron and two-electron atoms: spectrum of hydrogen, helium and alkali atoms; Many electron atoms: central field approximation, Thomas-Fermi model, Slater determinant, HarteeFock and self-consistent field methods, Hund's rule, L-S and j-j coupling, Equivalent and non-equivalent electrons, Spectroscopic terms, Lande interval rule; Interaction with Electromagnetic fields: Zeeman, Paschen Back and Stark effects, electronic spin resonance.

Hyperfine structure and isotope shift, selection rules; Lamb shift, Spontaneous and stimulated emissions, Einstein coefficients, Introduction to lasers and laser spectroscopy.

2. Molecular Spectroscopy **[7L+1T]**

Types of Molecules, Microwave spectroscopy, Rotation of molecules, rotational spectra, diatomic and polyatomic molecules, Infrared spectroscopy,: the vibrating diatomic molecule – simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator – CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry,

Raman spectroscopy: pure rotational and vibrational spectra, techniques and instrumentation, the influence of rotation on the spectra of linear molecules – Electronic spectra of diatomic molecules – Born-Oppenheimer approximation, vibrational coarse structure – progressions. Intensity of vibrational transitions – the Franck-Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions – the Fortrat diagram.

X-RAY SPECTROSCOPY

1. X-rays [**3L+1T]**

waves and photons, Generation of X-rays, X-ray tubes, Rotating anode, Synchrotron radiation from circular arc, Undulator and Wiggler radiation.

2. X-ray Scattering **[4L+1T]**

One electron scattering, Scattering from an atom, Scattering from a crystal, Scattering from liquids and glasses, Small angle scattering

3. X-ray Absorption [3L+1T]

X-ray absorption fine structure spectroscopy, X-ray photoelectron spectroscopy, X-ray fluorescence spectroscopy.

4. X-rays and magnetism [2L]

Resonant X-ray magnetic scattering, X-ray magnetic circular dichroism.

NUCLEAR SPECTROSCOPY

1. Nuclear Magnetic Resonance [7L+1T]

Principles, Classical treatment of NMR (Bloch equations), experimental methods, Chemical shift, Knight shift in metals, spin-lattice relaxation, Applications

2. Mossbauer Spectroscopy [6L+1T]

Principles, The Debye-Waller Factor, Mossbauer Sources and Experimental Apparatus, Isomer Shifts, Electric quadrupole interaction, Magnetic Dipole Interaction, Quadratic Doppler effect, Results of Mossbauer spectroscopy.

Text/ Reference Books

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