M.Sc. III Semester

Total Teaching hours =50

Course PHCT 3.1: Statistical Mechanics

Unit - I **12 hrs**

Introduction to Statistical Methods

Macroscopic & Microscopic systems, Basic concepts of probability, Binomial theorem of probability , Phase space, Macrostates & microstates, constraints and accessible states, Postulates of equal a priori probability, minimum size of phase space,division of space into cells,Number of states in energy range E to E+ΔE, Random walk. Discussion of Randomwalk in 1 – D

Statistical formulation of the Mechanical problem:

Specification of a system, ensembles, classification of ensembles. statistical ensemble, basic postulates, probability calculations, behavior of density of states.

Interaction between Macroscopic systems:

Thermal, Mechanical & general interactions, Quasi-static work done by pressure, Exact & inexact differentials.

General interaction between macroscopic systems:

Dependence of density of states on external parameters, Equilibrium between interacting systems, Properties of entropy, Statistical calculation of thermodynamic quantities.

Problems.

Unit - II **13 hrs**

Statistical Thermodynamics:

Irreversibility & the attainment of equilibrium: Equilibrium conditions & constraints, Reversible & Irreversible processes.

Basic Methods & results of statistical Mechanics:

Ensemble representation: Isolated system, System in contact with heat reservoir, Simple applications of canonical distribution, Systems with specified mean energy, Calculation of mean values in a canonical ensemble, Connection with thermodynamics, ensemble used as approximations, grand canonical and other ensemble.

Simple applications of statistical mechanics:

Partitions, functions & their properties, ideal monoatomic gas(Calculation of Thermodynamic quantities), Gibb's paradox, Equipartition theorem (Proof & simple applications)

Problems.

Unit III **13 hrs**

Distribution Functions:

Maxwell – Boltzmann ,Bose – Einstein & Fermi-Dirac statistics: Identical particles & symmetry requirements ,formulation of statistical problem, the quantum distribution functions, Maxwell-Boltzmann statistics, Photon statistics, Bose-Einstein statistics, Fermi-Dirac statistics, Quantum statistics in classical limit, Quantum states of single particle ,Evaluation of partition function, Physical implications of the quantum mechanical enumeration of states.

Black Body Radiation:

Radiation emitted by a body at temperature T, Planck's law of black body radiation

Conduction Electronics in metals:

Consequences of Fermi-Dirac distribution.

Problems

Unit IV **12 hrs**

Irreversible Processes & Fluctuations:

Brownian Motion,Lengevin equation, Calculation of mean square displacement, Relation between dissipation & fluctuation force, Correlation function & the friction constant, Calculation of mean square velocity increment, velocity correlation function & mean square displacement ,Fokker-Plank equation.

Fourier analysis, Ensemble & time averages, Weiner-Khintchine relations, Nyquist's theorem & equilibrium conditions, Fluctuations & Onsager relations.

Problems

Reference Books

1. Statistical Mechanics Theory and Applications, S K Sinha, Tata McGraw-Hill, (1990).
2. Introduction to Statistical mechanics, B B Laud, Macmillan, N Delhi, (1981).
3. Statistical Mechanics by R K Pathria, Pergamon press (1972).
4. Statistical and thermal Physics F Reif, McGraw-Hill (1965).
5. Statistical Physics, L D Landau and E M Lifshitz, Pergamon press (1958).
6. Stastical Mechanics : Satya Prakash,Pragati Prakashan(6^{th} edition 2012)
7. Stastical Mechanics : B.K.Agarwal,Melvin Eisner, Second edition(2010),New Age International LTD,New Delhi.

M.Sc. III Semester

Total Teaching hours =50

Course PHCT 3.2: Mathematical Methods of Physics –II

Unit – I **12 hrs**

Integral Equations :

Linear integral equations of the first and second kind, Relation between linear differential equations and Volterra's integral equation, singular equations, solution of integral equation of second kind by method of successive substitutions and successive approximations, applications.

Unit –II **10 hrs**

Green's function:

Non- Homogeneous boundary value problems and Green's function. Symmetry of Green's function for one dimensional problems, Green's function for three dimensional case. Green's function for ∇^2 operator. Determination of green's function using a Fourier transform. Green's function in higher dimension.

Unit – III **15 hrs**

Numerical Methods: Solution of algebraic and transcendental equations:

The bisection method, The iteration method and the Newton Rapson method.

1. Interpolation : Forward backward and central differences. Newton's formulae for interpolation, Langrange's interpolation formula.
2. Least Square curves fitting procedures : Fitting a straight line, non linear curve and curve fitting by sum of exponentials
3. Numerical integration: Trapizoidal rule, Simpson's 1/3 rd rule
4. Solutions of linear equations: Guassain elimination method eigen value problem
5. Numerical solutions of differential equations: Euler method: error estimates for the Euler method and modified Eulers Method, Runge – Kutta Method.

Unit – IV **13 hrs**

Group Theory:

Groups, subgroups and classes: homomorphism & isomorphism, group representation, reducible & irreducible representation, Schur's Lemma's, Orthogonality theorem, character of a representation, Character tables, decomposing a reducible representation into irreducible representation, construction of representation, Lie groups, rotation groups SO(2) and SO(3)

Reference Books

1. Rajput B S, Mathematical Physics, Pragati Prakashan (Meerat) 1999
2. Iyengar S R K, Jain R K , Mathematical Methods, Narosa, 2006
3. Arfken And Weber, Mathematical Methods For Physicists 6th Edition, Academic Press, 2005
4. Riley K F, Hobson M P and Bence S J, Mathematical Methods for Physics and Engineering, Cup, 1997
5. Introductory Methods of Numerical analysis by S.S. Sastry (4^{th} edition) PHI 920110.
6. Numerical and Statical Methods-Sunil S. Patil, Easter Book Promotors, Belgaum.

M. Sc. III Semester

Total Teaching Hours =50

Course PHST 3.3: Condensed Matter Physics – I (Special Subject)

Unit – I **12 hrs**

Electron States:

Nearly free electron model, discontinuity at zone boundary, energy gap and Bragg reflection. Tight binding method, APW and k P method : including spin orbit interaction and neglecting spin orbit interaction of band structure calculations.

Magnetic field effects:

Hall Effect in Metals, Magnetoresistance Phenomena of ordinary magnetoresistance (OMR) and Anomalous Magnetoresistance (AMR). Current in Plane (CIP) and current perpendicular to plane (CPP) configurations. cyclotron resistance

Unit – II **12 hrs**

Fermi surface :

Extended, reduced and periodic zone schemes. Construction of Fermi surface in square lattice, Harrison construction, slope of bands at zone boundary, electron orbits, hole orbits and open orbits. Experimental methods: Electron dynamics in a magnetic field, cyclotron resonance. Quantization of orbits in a magnetic field, Landau quantization, degeneracy of Landau levels, quantization of area of orbits in k- space, de Hass-van Alphen effect, extremal orbits.

Unit – III **10 hrs**

Quantization of lattice vibrations and phonons:

Potential and kinetic energies in terms of generalized coordinates and momenta, Hamilton's equations of motion, quantization of normal modes.

Electrical Transport in Metals and Semiconductors:

Boltzmann equation, relaxation time approximation, electrical conductivity, thermal conductivity, thermoelectric effects. Calculation of relaxation time, scattering by impurities and lattice vibrations.

Unit IV **16 hrs**

Ferromagnetism :

Review of Weiss theory of ferromagnetism, its success and failure, Heisenberg exchange interaction, exchange integral, exchange energy, Ising model, Spin waves (one dimensional case only), quantization of spin waves and magnons, density of modes, thermal excitation of magnons and Bloch $T^{3/2}$ law, specific heat using spin wave theory. Ferromagnetic domains, hysteresis curve, Bloch wall, Ferromagnetism in thin films.

Anti ferromagnetism:

Characteristic property of anti ferromagnetic substance. Neutron diffraction experiment. Two sub – lattice model, molecular field theory of anti ferromagnetism, Neel's temperature, Susceptibility below and above Neel's temperature.

Ferrimagnetism:

Ferrimagnetic order, ferrites, spinel structure , cation distribution, Curie temperature and susceptibility of ferrimagnets.

Magnetostriction : Magneto-Optic Kerr Effect and Magneto-Optic Faraday Effect

Reference Books :

1. Introduction to solid state physics - C. Kittel, 5th edn., John Wiley & Sons. Inc., NewYork (1976).
2. Solid state physics by A. J. Dekker, MacMillan India Ltd. (1986).
3. Solid state physics - N. W. Ashcroft and N. D. Mermin, HRW International edn.(1976).
4. Electronic properties of materials - R. E. Hummel, 2nd edn., Springer International (1994).
5. Solid state physics - J. S. Blakemore, 2nd edn., Cambridge University Press (1985).
6. Solid State Physics: M.A. Omar.Addison-Wesley Pvt.,Ltd.,New Delhi (1993).
7. Solid State Physics : M.A.Wahab ,3rd edition , Narosa publication,New Delhi.
8. Solid State Physics : S.O.Pillai Pearson Publication

M. Sc. III Semester

Total Teaching hours =50

Course PHST 3.4 (A): Physics of Nanomaterials

Unit I: **13 hrs**

Basics of Nanoscience:

The nanoscale, historical background, quantum confinement, size dependent properties, types of nanomaterials, fullerenes, nanowires, nanotubes, thin film.

Basic Quantum Mechanics:

Wave-particle duality, Heisenberg uncertainty principle Schrödinger equation --solution of one-dimensional time-independent equation, particle in a one-dimensional box; density of states for zero-, one-, two- and three-dimensional box; particle in a coulomb potential. Tunneling of a particle through potential barrier.

Unit II: **13 hrs**

Synthesis of nanomaterials:

Physical methods mechanical --ball milling, melt mixing; evaporation --ion sputtering, laser ablation, laser pyrolysis, chemical vapour deposition, molecular beam epitaxy. Chemical methods: colloidal synthesis and capping of nanoparticles. Types of nanoparticles metals, semiconductors, graphene, carbon nano tubes etc.

Unit III: **12 hrs**

Characterization techniques:

microscopes --optical, SEM, TEM, STM, AFM; diffraction techniques -XRD, EXAFS,neutron diffraction; spectroscopes --UV-visible-IR absorption, FTIR, Photoluminescence.

Unit IV: **12 hrs**

Properties of nanomaterials:

Mechanical; Electrical --classification - metals semi-conductors, insulators, band structures; mobility, resistivity, Hall effect, magneto- resistance; Optical --optical absorption and transmission, photoluminescence, electro-luminescence, thermoluminescence; Magnetic materials - types of magnetic materials -- dia-, para-, ferro-, antiferro-; nano-magnetism.

Text books:

1. Nanotechnology: Principles and practices, S. K Kulkarni, Capital Publ. Co., New Delhi (2007)
2. Nanocrystals : Synthesis, Properties and Applications, C.N.R.Rao, P. John Thomas and G.U. Kulkarni, Springer series in Materials Science **95**, Springer-Verlag, Berlin, Heidelburg (2007).

Reference books:

1. Quantum Mechanics – Vol 1 & 2, Cohen, Tannoudji
2. The Physics and Chemistry of Solids, Stephen Elliot & S.R. Elliot
3. Solid State Physics- A.J. Dekker
4. Introduction to Nanotechnology- Charles P.Poole Jr and Franks J. Owens
5. Electronic Transport in macroscopic systems, Supriyo Datta
6. Nanotubes and Naowires- CNR Rao and A Govindaraj, RCS Publishing.
7. From Atom to Transistor- Supriyo Datta
8. Encyclopedia of Nanotechnology- Hari singh Nalwa

M.Sc III Semester
Course:PHST 3.4 (B)

Research Methodology

Total Teaching Hours=50

Unit 1: Meaning of research, objective of research, motivation in research, types of research, research approaches, significance of research, criteria of good research.
What is research problem?, Selecting the problem, necessity of defining the problem, techniques involved in defining a problem, an illustration, conclusion.

14 hrs

Unit 2: Meaning of research design, features of a good research design, important concepts relating to research design, different research design, developing a research plan.

8 hrs

Unit 3: Paper collection, usage of digital library, google search, downloading the papers from web, proof techniques.

8 hrs

Unit 4: Meaning of Interpretation, Why interpretation? , Technique of interpretation, precaution in interpretation.

8 hrs

Unit 5: Significance of report writing, different steps in writing report, layout of the research report, types of report, oral presentation, precautions for writing research report , role of computer in research.

12 hrs

References:

1. C. R. Kothari- Research Methodology, New Age International, 2009.

M.Sc. (Physics) Semester-III, Elective Paper

Total Teaching Hours=50

Paper 3.4(C): MATLAB

Unit 1: MATLAB ENVIROMENT:

Why MATLAB? – History – Its strengths – Weaknesses – Competitors – Starting MATLAB, Using MATLAB as a calculator, Quitting MATLAB, Familiar with MATLAB windows – Basic Operations – MATLAB-Data types – Rules about variable names – Predefined variables. **10 hrs**

Unit 2: PREDEFINED MATLAB FUNCTIONS and COMMANDS: Vector , Matrix , Array Addressing, Built-in functions –,Mathematical Operations ,Dealing with strings (Array of characters) , Array of array(cell) concept, Script file, Input commands, Output commands , Structure of function file ,Inline functions, Feval command, Comparison between script file and function file. **10 Hrs**

Unit III: PROGRAMMING IN MATLAB:

Conditional statements and Loop – Relational and Logical Operators , If-else statements, Switch-case statements ,LOOPING: For loop, While loop, Special commands(Break and continue), Programming examples.

Unit IV: SYMBOLIC MATHEMATICS and NUMERICAL TECHNIQUES:

Calculus,Solving Algebraic and Differential Equations,Linear Algebra,Units of Measurement, Variable-Precision Arithmetic Mathematical Modeling,Simulink and Simscape, Solutions to system of linear equations, Special Matrices **10 hrs**

Unit V: Plotting:

2D Plotting – In-built functions for plotting ,Multiple plotting with special graphics , Curve fitting, Interpolation , Basic fitting interface.

3D Plotting -Use of meshgrid function – Mesh plot – Surface plot – Plots with special graphics. **10 hrs**

Recommended Text Books:

1. Delores M. Etter, David C. Kuncicky and Holly Moore: *"Introduction to MATLAB"*, Dorling Kindersley (India) Pvt. Ltd. New Delhi, (2009).

Reference Books:

1. Brian R. Hunt, Ronald L. Lipsman and Jonathan M. Rosenberg: *"A Guide to MATLAB",* Cambridge University Press, (2008).
2. Y. Kirani Singh and B. B. Chaudhari: *"MATLAB Programming",* PHI Learning Private Ltd., New Delhi, (2010).

M.Sc. (Physics) Semester-III, Elective Paper
Course PHET 3.4 (D) : STATISTICAL INFERENCE

Total Teaching Hours : 50

Unit I : Exact Sampling distributions : Chi square variate and distribution, conditions for validity, applications of Chi square distribution. Definition of students 't' distribution. Fishers 't' distribution, properties constants of 't' distribution. Applications of 't' distribution. Definition of F statistic and distribution, applications of F test. **12hours**

Unit II: Estimation : Point estimation**,** Unbiasedness consistency , Efficient Estimators, Most Efficient Estimator , Minimum Variance – Unbiased (MVU) Estimator , Sufficiency , Neymann Factorization , Theorem , Fisher – Neyman Criterion for sufficient Estimator. Interval estimation, Confidence Intervals for large samples mean and proportion . Method of maximum Likelihood Estimation, properties of maximum Likelihood Estimators , Method of moments. **12 hours**

Unit III: Statistical Hypothesis : Recapitulation **(** Statistical Hypothesis, Simple and Composite Hypotheses, Null Hypothesis,Type-I & Type-II Errors, Level of Significance , Critical Region, Power of the Test, Steps in construction testing of Hypothesis**)** Most Powerful(MP) Test, N P Lemma (statement), Uniformly most powerful Test (UMP Test) . and problems. **10hours**

Unit IV: Sequential Probability Ratio Test (SPRT)-method**,** construction of SPRT for Normal, Binomial and Poisson distribution, Meaning and definition of OC and ASN function of SPRT(without proof) **08 hours**

Unit V: Non Parametric Methods : Advantages and Drawbacks of Non – parametric methods , Basic Distribution, Wald- Wolfowitz Run Test, Test for Randomness , Median Test , Sign Test, Mann-Whitney–Wilcoxon U- Test. **08 hours**

Books for Study:

1. Gupta S.C and Kapoor V.K:Fundamentals of Mathematical Statistics- Sultan Chand & Sons publications.
2. H. C. Saxena – Statistical Inference
3. Hogg .R.V.and Craig.A.T(1978):Introduction to Mathematical Statistics.-4/e Macmillan
4. Mukyopadhyay.P.(1996) .Mathematical Statistics.-Kolkotta Publishing House.
5. Goon AM, Gupta M.K., Das Gupta.B.(1991): Fundamentals of Statistics vol-I

Books for Reference:

a. Rohatgi.V.K.(1984):An introduction to probability theory and Mathematical statistics.
b. Murry R.Speigel (1982): Theory & Problems of Statistics,Schaum's Publishing Series.
c. P.G.Hoel (1971): Introduction to Mathematical statistics,asia publishing house.
d. Cooke, Cramer and Clake: Basic Statistical Computing, Chapman and Hall.

PHSP 3.5: Practical Solid State Physics – I

1. Structure factor calculation
2. d – spacing calculations
3. Indexing of cubic system
4. Indexing of tetragonal system
5. Specific heat of metals
6. Assigning using Fortran Programming
7. Calculation of relative integrated intensity.
8. Universal curves for ferro magnets.

(NEW EXPERIMENTS MAY BE ADDED)

Reference Books

1. X-Ray Diffraction: B.D.Cullity,Addison – Wesley,New York(1972)
2. X – Ray diffraction Procedures: H. P. Klug and L.E.Alexander,John Wiley and Sons inc . New York.
3. Interpretation of X-ray powder diffraction pattern : H.P. Lipson and
4. H.Steeple,Macmillan,London(1968)
5. Elementary Solid State Physics: M.A.Omar,Addison – Wesley Pvt. Ltd.,New Delhi (1993)
6. Elementary Solid State Physics : C.Kittle,Wiley Eastern Ltd., Bangalore (1976)
7. Introduction to Magneto chemistry : A.Earnshaw,Academic press,London (1968)

PHSP 3.6: Practical - Solid State Physics – II

1. Obtaining X – Ray pattern for given substance using X – Ray diffractometer and indexing the pattern.
2. Hall effect & hall mobility
3. Determination of e/KB
4. Four probe method
5. Determination of Curie temperature of a perromagnet
6. Hysterisis of ferro-magnetic materials
7. Comparison of observed intensities of diffraction patternfrom X – ray diffractometer with calculated intensities.
8. Size Estimation of nano crystals from the measured with of its diffraction curves by Scherrer formula.
9. Determination of elastic constants
10. Magneto resistance
11. Thermolumniscence studies of alkali halides by X – ray irradiation
12. X – Ray structure analysis of small inorganic molecules and then vibrational structure from force – field calculations.

(NEW EXPERIMENTS MAY BE ADDED)

Reference Books

1. X-Ray Diffraction : B.D.Cullity,Addison – Wesley,New York(1972)
2. X – Ray diffraction Procedures: H. P. Klug and L.E.Alexander,John Wiley and Sons inc . New York.
3. Interpretation of X-ray powder diffraction pattern : H.P. Lipson and H.Steeple, Macmillan, London(1968)
4. Elementary Solid State Physics : M.A.Omar,Addison – Wesley Pvt. Ltd., New Delhi (1993)
5. Elementary Solid State Physics : C.Kittle,Wiley Eastern Ltd., Bangalore (1976)
6. Introduction to Magneto chemistry : A.Earnshaw,Academic press,London (1968)