



# UNIVERSITY OF CALICUT

## Scheme and Syllabus for M.Sc. (Physics) Programme(CSS) for affiliated colleges w.e.f. 2012 admissions

The duration of the M.Sc (Physics) programme shall be 2 years, split into 4 semesters. Each course in a semester has 4 credits (4C) and Practicals having 2 credits (2C). The total credits for the entire programme is 80. The scheme and syllabus of the programme, consisting of sections (a) *Courses in various semesters* (b) *Constitution of clusters* (c) *The Credits and Hours* (d) *Grading and Evaluation* (e) *Detailed syllabus* (f) *Model question papers* are as follows:

### A) COURSES IN VARIOUS SEMESTERS

#### Semester -I (16C)

- (PHY1C01) Classical Mechanics (4C)
- (PHY1C02) Mathematical Physics - I (4C)
- (PHY1C03) Electrodynamics and Plasma Physics (4C)
- (PHY1C04) Electronics (4C)
- (PHY1P01) General Physics Practical -I
- (PHY1P02) Electronics Practical -I

#### Semester -II (22C)

- (PHY2C05) Quantum Mechanics -I (4C)
- (PHY2C06) Mathematical Physics -II (4C)
- (PHY2C07) Statistical Mechanics (4C)
- (PHY2C08) Computational Physics (4C)
- (PHY2P03) General Physics Practical -II (3C)
- (PHY2P04) Electronics Practical -II (3C)

External Practical Exam. for PHY1P01 & PHY2P03, PHY1P02 & PHY2P04

#### Semester -III (16C)

- (PHY3C09) Quantum Mechanics -II (4C)
- (PHY3C10) Nuclear and Particle Physics (4C)
- (PHY3C11) Solid State Physics (4C)
- Elective -I (4C)
- (PHY4Pr) Project
- (PHY3P05) Modern Physics Practical -I

#### Semester -IV (26C)

- (PHY4C12) Spectroscopy (4C)
- Elective -II (4C)
- Elective -III (4C)
- (PHY4Pr1) Project (4C)
- (PHY4P06) Modern Physics Practical -II (3C)
- (PHY4P07) Computational Physics Practical (3C)
- Viva Voce (Comprehensive) (4C)

External Practical Exam. for PHY3P05 & PHY4P06, PHY4P07 and Comprehensive Viva Voce.

## B) CONSTITUTION OF CLUSTERS

### Elective -I Cluster:

(PHY3E01) Plasma Physics  
 (PHY3E02) Foundations of Quantum Mechanics  
 (PHY3E03) Radiation Physics  
 (PHY3E04) Computer Software and Applications  
 (PHY3E05) Fluid Dynamics  
 (PHY3E06) Digital Signal Processing  
 (PHY3E07) Experimental techniques

### Elective -II Cluster:

(PHY4E08) Advanced Nuclear Physics  
 (PHY4E09) Astrophysics  
 (PHY4E10) Advanced Statistical Mechanics  
 (PHY4E11) Materials Science  
 (PHY4E12) Electronic Instrumentation  
 (PHY4E13) Lasers and Fibre Optics  
 (PHY4E14) Communication Electronics

### Elective -III Cluster:

(PHY4E15) Quantum Field Theory  
 (PHY4E16) Chaos and Nonlinear Physics  
 (PHY4E17) Advanced Condensed Matter Physics  
 (PHY4E18) Modern Optics  
 (PHY4E19) Physics of Semiconductors  
 (PHY4E20) Microprocessors and Applications

## C) THE CREDITS AND HOURS PER WEEK

The credits and hours proposed for various courses in different semesters are as given under.

Semester	No. of Theory Papers	Practicals	Theory		Practical		Project		Seminar	Viva Cred.	Total Hrs	Total Cred
			Hrs	Cred	Hrs	Cred	Hrs	Cred	Hrs			
I	4	1. Gen. Phy 2. Electronics	16	16	8	0	0	0	1	0	25	16
II	4	1. Gen. Phy 2. Electronics	16	16	8	6	0	0	1	0	25	22
III	4	1. Mod. Phy	16	16	4	0	4	0	1	0	25	16
IV	3	1. Mod. Phy. 2. Comp. Phy.	12	12	8	6	4	4	1	4	25	26
<b>Total Credits for the Programme</b>												<b>80</b>

## D) GRADING AND EVALUATION

- (1) Accumulated minimum credit required for successful completion of the course shall be 80.
- (2) A project work of 4 credit is compulsory and it should be done in III & IV semesters. Also a comprehensive Viva Voce may be conducted by external examiners at the end of IV Semester and carries 4 credits.
- (3) Evaluation and Grading (as done in B.Sc CCSS):  
 All grading starting from the evaluation of papers is done on 5 point scale (A, B, C, D, E) and SGPA and

CGPA – between 0 to 4 and in two decimal points. An overall letter grade (Cumulative Grade) for the whole programme shall be awarded to the student based on the value of CGPA using a 7-point scale given below.

#### Overall Grade in a Programme

CGPA	Overall Letter Grade
3.80 to 4.00	A+
3.50 to 3.79	A
3.00 to 3.49	B+
2.50 to 2.99	B
2.00 to 2.49	C+
1.50 to 1.99	C
1.00 to 1.49	D

(4) Weightage of Internal and External valuation:

The evaluation scheme for each course shall contain two parts (1) internal evaluation (2) external evaluation. Its weightages are as follows:

Evaluation	Weightage
Internal	1 (or 25%)
External	3 (or 75%)

Both internal and external evaluation will be carried out using Direct Grading System

(5) Internal evaluation (must be transparent and fair):

**Theory:**

- Tests- wt = 2 (at least 2 tests with 50% Problems)
- Tutorial on assignments and Exercises-wt =1
- Seminars and Viva Voce- wt =1
- Attendance - wt =1

**Practical:**

- Tests - wt=2
- Lab. skill/quality of their results- wt =1
- Viva Voce- wt =1

**Project:**

- Monthly progress - wt =2
- Regularity and attendance -wt =1
- Seminar and Viva Voce- wt =1

(6) External evaluation:

- Theory:** Every semester

#### Pattern of question Papers

Division	Type	No. of Questions	Weightage	Total Weightage
Part A	Short Answer	12 (No Choice)	1	12
Part B	Essay	2 out of 4	6	12
Part C	Problems	4 out of 6	3	12
Total weightage for a question paper				36

Answer to each question may be evaluated based on

- Idea/knowledge – wt =1
- Logic/steps – wt =1
- Analytic skill – wt =1
- Correctness – wt =1

b) **Practicals:** At the end of II and IV semesters.

c) **Project:** End of IV semester. Its evaluation is based on:

- Presentation – wt =3

- (b) Project Report – wt =2
- (c) Project Viva – wt =1
- d) **Comprehensive Viva-Voce** at the end of IV semester.

(7) Theory papers must contain at least 4 lectures plus 1 Tutorial. Project is equivalent to one theory papers (6 hours) and one practical (8 hours).

(8) Directions for question paper setters:

Part A: Set each questions to be answered in 5 minutes duration and should extract the critical knowledge acquired by the candidate in the subject.

Part B: 30 minutes answerable questions each. May be asked as a single question or parts. Derivation type questions can be also asked.

Part C: 15 minutes answerable questions each and as far as possible avoid numerical type questions.

## **E) DETAILED SYLLABUS**

### **SEMESTER - I**

### **PHY1C01 : CLASSICAL MECHANICS (4C)**

#### **1. Lagrangian and Hamiltonian Formulation:**

Constraints and Generalized coordinates, D'Alemberts principle and Lagrange's equation, Velocity dependent potentials, Simple applications, Hamilton's Principle, Lagrange's equation from Hamilton's principle, Kepler problem, Scattering in a central force field, Transformation to lab coordinates, Legendre Transformation, Hamilton's canonical equations, Principle of least action, Canonical transformations, examples, Enough exercises (14 hours)

Text : Goldstein, Sections 1.3 – 1.6, 2.1 – 2.3, 3.10, 3.11, 8.1, 8.5, 8.6, 9.1, 9.2

#### **2. The classical background of quantum mechanics:**

Equations of canonical transformations, Examples, Poisson brackets and other canonical invariants, Equation of motion in Poisson bracket form, Angular momentum Poisson brackets, Hamilton-Jacobi equation, Hamilton's principal and characteristic function, H-J equation for the linear harmonic oscillator, Separation of variables, Action-angle variables, H-J formulation of the Kepler problem, H-J equation and the Schrödinger equation, Enough exercises. (15 hours)

Text : Goldstein, Sections 9.1, 9.2, 9.4 - 9.6, 10.1 – 10.5, 10.7, 10.8

#### **3. The Kinematics and Dynamics of Rigid Bodies:**

Space-fixed and body-fixed systems of coordinates, Description of rigid body motion in terms of direction cosines and Euler angles, Infinitesimal rotation, Rate of change of a vector, Centrifugal and Coriolis forces, Moment of inertia tensor, Euler's equation of motion, Forcefree motion of a rigid body, Enough exercises. (13 hours)

Text : Goldstein, Sections 4.1, 4.4, 4.8 – 4.10

#### **4. Small Oscillations:**

Formulation of the problem, Eigen value equation, Eigenvectors and Eigenvalues, Orthogonality, Principal axis transformation, Frequencies of free vibrations, Normal coordinates, Free vibrations of a linear tri atomic molecule, Enough exercises. (8 hours)

Text : Goldstein, Sections 6.1 – 6.4

#### **5. Nonlinear Equations and Chaos:**

Introduction, Singular points of trajectories, Nonlinear oscillations, Limitcycles, Chaos : Logistic map, Definitions, Fixed points, Period doubling, Universality, Enough exercises. (12 hours)

Text : Bhatia, Sections 10.1, 10.2, 10.3, 10.4, 10.5, 10.51

Text Books :

1. Goldstein "Classical Mechanics" (Addison Wesley)
2. V.B.Bhatia : "Classical Mechanics" (Narosa Publications, 1997)

Reference :

1. Michael Tabor : "Chaos and Integrability in Nonlinear Dynamics" (Wiley, 1989)
2. N.C.Rana and P.S.Joag : "Classical Mechanics" (Tata McGraw Hill)
3. R.G.Takwale and P.S.Puranik : "Introduction to Classical Mechanics" (Tata McGraw Hill)
4. Atam P. Arya : "Introduction to Classical Mechanics, (2nd Edition)" (Addison Wesley 1998)
5. Laxmana : "Nonlinear Dynamics" (Springer Verlag, 2001)

For further reference: Classical Physics Video Prof. V. Balakrishnan IIT Madras

<http://nptel.iitm.ac.in/video.php?subjectId=122106027>

Special Topics in Classical Mechanics Video Prof. P.C. Deshmukh IIT Madras

<http://nptel.iitm.ac.in/courses/115106068/>

Physics I - Oscillations & Waves Video Prof. S. Bharadwaj IIT Kharagpur  
<http://nptel.iitm.ac.in/video.php?subjectId=122105023>  
Chaos, Fractals & Dynamic Systems Video Prof. S. Banerjee IIT Kharagpur  
<http://nptel.iitm.ac.in/video.php?subjectId=108105054>

## PHY1C02 : MATHEMATICAL PHYSICS – I (4C)

### 1. Vectors :

Rotation of coordinates, Orthogonal curvilinear coordinates, Gradient, Divergence and Curl in orthogonal curvilinear coordinates, Rectangular, cylindrical and spherical polar coordinates, Laplacian operator, Laplace's equation – application to electrostatic field and wave equations, Vector integration, Enough exercises. (9 hours)

Text : Arfken & Weber , Sections 1.2, 1.6 - 1.9, 1.10, 2.1 – 2.5

### 2. Matrices and Tensors :

Basic properties of matrices (Review only), Orthogonal matrices, Hermitian and Unitary matrices, Similarity and unitary transformations, Diagonalization of matrices, Definition of Tensors, Contraction, Direct products,, quotient rule, Pseudo tensors, Dual tensors, Levi Cevita symbol, irreducible tensors, Enough exercises. (9 hours)

Text : Arfken & Weber , Sections 3.2 - 3.5, 2.6 – 2.9

### 3. Second Order Differential Equations:

Partial differential equations of Physics, Separation of variables, Singular points, Ordinary series solution, Frobenius method, A second solution, Self adjoint differential equation, eigen functions and values, Boundary conditions, Hermitian operators and their properties, Schmidt orthogonalization, Completeness of functions, Enough exercises. (12 hours)

Text : Arfken & Weber , Sections 8.1, 8.3 – 8.6, 9.1 – 9.4

### 4. Special functions :

Gamma function, Beta function, Delta function, Dirac delta function, Bessel functions of the first and second kinds, Generating function, Recurrence relation, Orthogonality, Neumann function, Spherical Bessel function, Legendre polynomials, Generating function, Recurrence relation, Rodrigues' formula, Orthogonality, Associated Legendre polynomials, Spherical harmonics, Hermite polynomials, Laguerre polynomials, Enough exercises. (20 hours)

Text : Arfken & Weber , Sections 10.1, 10.4, 1.15, 11.1 – 11.3, 11.7, 12.1 – 12.4, 12.6, 13.1, 13.2

### 5. Fourier Series :

General properties, Advantages, Uses of Fourier series, Properties of Fourier series, Fourier integral, Fourier transform, Properties, Inverse transform, Transform of the derivative, Convolution theorem, Laplace transform, Enough exercises. (10 hours)

Text : Arfken & Weber , Sections 14.1 – 14.4, 15.2 – 15.5, 15.8

Textbook :

1. G.B.Arfken and H.J.Weber : "Mathematical Methods for Physicists (5th Edition, 2001)" (Academic Press)

Reference books :

1. J.Mathews and R.Walker : "Mathematical Methods for Physics" (Benjamin)
2. L.I.Pipes and L.R.Harvill : "Applied Mathematics for Engineers and Physicists (3rd Edition)" (McGraw Hill)
3. Erwin Kreyzig : "Advanced Engineering Mathematics - 8th edition" (Wiley)
4. M. Greenberg : "Advanced Engineering Mathematics – 2nd edition " (Pearson India 2002)
5. A.W. Joshi : Matrices and tensors
6. Mathematical methods in the physical sciences, 2nd edn, Mary L Boas, John Wiley & Sons
7. Elementary Differential Equations and boundary value problems, William E. Boyce, Richard C. DiPrima, John Wiley & Sons, Inc.
8. Mathematics of Classical and Quantum Physics, F. W. Byron and R. W. Fuller, Dover Publications, Inc., New York

For further reference:

Mathematics I Video Prof. Swagato K. Ray, Prof. Shobha Madan, Dr. P. Shunmugaraj  
<http://nptel.iitm.ac.in/video.php?subjectId=122104017>  
Mathematics II Video Prof. Sunita Gakkhar, Prof. H.G. Sharma, Dr. Tanuja Srivastava IIT Roorkee  
<http://nptel.iitm.ac.in/video.php?subjectId=122107036>  
Mathematics III Video Prof. P.N. Agrawal, Dr. Tanuja Srivastava IIT Roorkee  
<http://nptel.iitm.ac.in/video.php?subjectId=122107037>

### PHY1C03: ELECTRODYNAMICS AND PLASMA PHYSICS (4C)

#### 1. Time varying fields and Maxwell's equations :

Maxwell's equations, Potential functions, Electromagnetic boundary conditions, Wave equations and their solutions, Time harmonic fields, Enough exercises. (8 hours)

Text : Cheng, Sections 7.3 – 7.7

#### 2. Plane electromagnetic waves :

Plane waves in lossless media, Plane waves in lossy media, Group velocity, Flow of electromagnetic power and the Poynting vector, Normal incidence at a plane conducting boundary, Oblique incidence at a plane conducting boundary, Normal incidence at a plane dielectric boundary, Oblique incidence at a plane dielectric boundary, Enough exercises. (10 hours)

Text : Cheng , Sections 8.2 – 8.10

#### 3. Transmission lines, Wave guides and cavity resonators:

Transverse electromagnetic waves along a parallel plane transmission line, General transmission line equations, Wave characteristics on finite transmission lines, General wave behaviour along uniform guiding structures, Rectangular wave guides, Cavity resonators (Qualitative ideas only), Enough exercises. (12 hours)

Text : Cheng, Sections 9.2 - 9.4 , 10.2, 10.4, 10-7.1

#### 4. Relativistic electrodynamics:

Magnetism as a relativistic phenomenon, Transformation of the field, Electric field of a point charge moving uniformly, Electromagnetic field tensor, Electrodynamics in tensor notation, Potential formulation of relativistic electrodynamics, Enough exercises. (14 hours)

Text : Griffiths, Sections 10.3.1 – 10.3.5

#### 5. Plasma Physics :

Plasma - Definition, concepts of plasma parameter, Debye shielding, Motion of charged particles in an electromagnetic field - Uniform electric and magnetic fields, Boltzmann and Vlasov equations, their moments - Fluid equations, Plasma oscillations, Enough exercises. (16 hours)

Text : Chen, Sections 1.1 - 1.6, 2.2 - 2.2.2, 3.1 - 3.3.2, 4.3, 4.18, 4.19, 7.2-7.3

Text Books :

1. David K. Cheng : “ Field and Wave Electromagnetics” (Addison Wesley)
2. David Griffiths : “ Introductory Electrodynamics” (Prentice Hall of India, 1989)
3. F. F. Chen, Introduction to Plasma Physics and Controlled Fusion, Volume I and II, Plenum Press, recent edition

Reference books :

1. K.L. Goswami, Introduction to Plasma Physics – Central Book House, Calcutta
2. J.D.Jackson : “Classical Electrodynamics” (3rd Ed.) (Wiley,1999)

### PHY1C04: ELECTRONICS (4C)

#### 1. Field Effect Transistor :

Biasing of FET, Small signal model, Analysis of Common Source and Common Drain amplifier, High frequency response, FET as VVR and its applications, Digital MOSFET circuits, Enough exercises. (8 hours)

Text : Millman and Halkias : “Integrated Electronics” (Tata McGraw Hill 2002) Sections 10.4 - 10.11

Reference : Electronic devices and circuit theory, Robert L Boylstead & L. Nashelsky – Pearson Education (fifth Edition)

#### 2. Microwave and Photonic Devices :

Tunnel diode, Transferred electron devices , negative differential resistance and device operation, radiative transitions and optical absorption, Light emitting diodes (LED) – visible and IR, semiconductor lasers - materials, operation (population inversion, carrier and optical confinement, optical cavity and feedback, threshold current density), Photodetectors - photoconductor (Light dependent resistor- LDR) and photodiode, p-n junction solar cells - short circuit current, fill factor and efficiency, Enough exercises. (12 hours)

Text : “Semiconductor Devices- Physics and Technology” - S.M.Sze , John Wiley and Sons (2002) Sections 8.2, 8.4, 9.1, 9.2, 9.3 - 9.3.3, 9.4, 9.5 – 9.5.3

### 3. Operational Amplifier :

Basic operational amplifier characteristics, OPAMP differential amplifier, Emitter coupled differential amplifier, OPAMP parameters (Open loop gain, CMRR, Input offset current and voltage, output offset voltage, slew rate) and their measurement, Frequency response, Principle of Bode plots, Phase and gain margins, Dominant pole, pole zero and lead compensation, Enough exercises. (10 hours)

Text : Millman and Halkias : "Integrated Electronics" (Tata McGraw Hill 2002), Sections 15.1 – 15.4, 15.6, 15.8 – 15.13

### 4. OPAMP Application :

OPAMP as inverter, scale changer, summer, V to I converter, Analog integration and differentiation, Electronic analog computation, Active low pass filter, High pass Butterworth filters, Band pass filter, Active resonant band pass filter, OPAMP based astable and monostable multivibrators, Schmidt trigger, Enough exercises. (12 hours)

Text : Millman and Halkias : "Integrated Electronics" (Tata McGraw Hill 2002), Sections 16.5 – 16.7, 16.15, 16.16

Reference :

1. Ramakant A. Gaekwad : "OPAMPS and Linear Integrated Circuits"
2. D. Roychoudhuri : "Linear Integrated circuits" – New Age International Publishers (1997)

### 5. Digital Electronics :

Minimization of functions using Karnaugh map, Representation using logic gates, JK and MSJK flip-flops, Synchronous and asynchronous counters, MOD 3,5,10,16 counters, Cascade counters, Static and dynamic random access memory, CMOS, Non-volatile NMOS, Magnetic memories, Charge coupled devices, Microprocessor architecture, Organization of a general microcomputer, CPU architecture of 8 bit processor such as INTEL 8085, Enough exercises.(20 hours)

Texts:

1. Malvino and Leach : "Digital Principles and Applications(3rd Ed.)" (Tata McGraw Hill, 1978) Sections 6.5 - 6.9, 7.2 - 7.5, Chapter 8 complete, 12.1, 12.4, 12.5
2. R.P.Jain : "Modern Digital Electronics" (Tata McGraw Hill) sections 11.9, 11.91 - 11.93 (For charge coupled devices)
3. B.Ram : "Fundamentals of Microprocessors and Microcomputers (Dhanapathi Rai & Sons) Sections 1.5 to 1.7, 3.1 - 3.1.6

Reference:

1. M.S.Tyagi ; "Introduction to Semiconductor Devices" (Wiley)
2. Millman and Halkias : "Integrated Electronics"
3. Gupta and Kumar : "Handbook of Electronics"

For further reference: Electronics Video Prof. D.C. Dube IIT Delhi

<http://nptel.iitm.ac.in/courses/115102014/>

Digital Integrated Circuits Video Prof. Amitava Dasgupta IIT Madras

<http://nptel.iitm.ac.in/video.php?subjectId=108106069>

## SEMESTER - II

### PHY2C05: QUANTUM MECHANICS-I (4C)

#### 1. The Formulation of Quantum Mechanics:

Vector spaces, The Hilbert space, Dimensions and basis, Operators and properties, Representation of vectors and operators, Commutator, Functions of operators, Eigen values and eigen vectors, Matrix representation of bras, kets and operators, Coordinate and momentum representations and their connection, The fundamental postulates Probability density, Superposition principle, Observables and operators, The uncertainty principle,. (13 hours)

Texts: Thankappan, Sections 2.1 – 2.4, 3.1, 3.2

#### 2. Quantum Dynamics:

The equation of motion, Schrodinger, Heisenberg and the Interaction pictures of time development, The linear harmonic oscillator in the Schroedinger and Heisenberg pictures, Hydrogen atom (9 hours)

Texts : Thankappan , Sections 4.1, 4.2

#### 3. Theory of Angular Momentum:

Angular momentum operators, Matrix representation of angular momentum operators, Pauli spin matrices, Orbital angular momentum, The hydrogen atom, Addition of angular momenta , Clebsch-Gordon coefficients, Simple examples (16 hours)

Texts : Thankappan, Sections 5.1 – 5.5 A

#### 4. Symmetry and Conservation Laws :

Space-time symmetries, Space translation and conservation of linear momentum, Time translation and conservation of energy, Space rotation and conservation of angular momentum, Space inversion and time reversal, Identical particles, Construction of symmetric and anti symmetric wave functions, Slater determinant, Pauli exclusion principle, Bosons and Fermions, Spin wave functions for two electrons, (10 hours)

Texts : Thankappan, Sections 6.1, 6.2, 9.1 – 9.3

#### 5. Scattering:

a) Scattering cross section: General considerations, kinematics of scattering process : differential and total cross-section: wave mechanical picture of scattering ;the scattering amplitude Green's functions; formal expression for scattering amplitude. b) The Born And Elkonal Approximations :The born approximations, Validity of the born approximations ,The born series, c) Partial Wave Analysis: Asymptotic behavior of partial waves; phase shifts ,the scattering amplitude in terms of phase shifts, the differential and total cross-section: optical theorem, phase shifts: Relation to the potential, potential of finite range, low energy scattering. d) Exactly Soluble Problems: scattering by a square well potential, scattering by a hard sphere . e) Mutual Scattering Of Two Particles :Collisions between identical particles, Enough exercises. (12 hours)

Text : P.M Mathews & K. Venkatesan,

Sections 6.1,6.2,6.3,6.5,6.6,6.8,6.9,6.10,6.11,6.12,6.13,6.14,6.15,6.19

Textbooks :

1.V.K. Thankappan : "Quantum Mechanics" (Wiley Eastern)

2.N. Zettili, "Quantum Mechanics – Concepts and applications" (John Wiley & Sons, 2004)

3.P.M.Mathews and K.Venkatesan : "A Textbook of Quantum Mechanics" (Tata McGraw Hill)

Reference books :

1. N. Zettili, "Quantum Mechanics – Concepts and applications" (John Wiley & Sons, 2004)

2. L.I.Schiff : "Quantum Mechanics" (McGraw Hill)

3. P.M.Mathews and K.Venkatesan : "A Textbook of Quantum Mechanics" (Tata McGraw Hill)

4. A.Messiah : "Quantum Mechanics"

5. J.J.Sakurai : "Modern Quantum Mechanics" (Addison Wesley)

6. Stephen Gasiorowics : "Quantum Physics"

7. A.Ghatak and S.Lokanathan : "Quantum Mechanics" (Macmillan)

8. V. Devanathan : "Quantum Mechanics " (Narosa, 2005)

For further reference:

Quantum Physics Video Prof. V. Balakrishnan IIT Madras

<http://nptel.iitm.ac.in/video.php?subjectId=122106034>

Quantum Mechanics and Applications Video Prof. Ajoy Ghatak IIT Delhi

<http://nptel.iitm.ac.in/courses/115102023/>

### PHY 2C06: MATHEMATICAL PHYSICS-II (4C)

#### 1. Functions of Complex Variables:

Introduction, Analyticity, Cauchy-Reimann conditions, Cauchy's integral theorem and integral formula, Laurent expansion, Singularities, Calculus of residues and applications (15 hours)-Sections 6.1 to 6.5, 7.1, 7.2

#### 2. Group Theory:

Groups, multiplication table, conjugate elements and classes, subgroups, direct product groups, isomorphism and homomorphism, permutation groups, distinct groups of given order, reducible and irreducible representations -Sections 1-1.8, Joshi.

Generators of continuous groups, rotation groups  $SO(2)$  and  $SO(3)$ , rotation of functions and angular momentum,  $SU(2)$ - $SO(3)$  homomorphism,  $SU(2)$  isospin and  $SU(3)$  eightfoldway (15 hours) - Sections 4.2, Arfken 5th edition.

#### 3. Calculus of Variations:

One dependent and one independent variable, Applications of the Euler equation, Generalization to several independent variables, Several dependent and independent variables, Lagrange Multipliers, Variation subject to constraints, Rayleigh-Ritz variational technique. (11 hours)- Sections 17.1 to 17.8

#### 4. Integral equations:

Integral equations- introduction, Integral transforms and generating functions, Neumann series, separable kernel (10 hours)-Sections 16.1 to 16.3



## 5. Green's function:

Green's function, eigenfunction expansion, 1-dimensional Green's function, Green's function integral-differential equation, eigenfunction, eigenvalue equation Green's function and Dirac delta function, Enough exercises.(9 hours) Section 9.51

Textbook :

1. G.B.Arffken and H.J.Weber : "Mathematical Methods for Physicists (5th Edition, 2001)" (Academic Press)
2. A.W.Joshi, Elements of Group theory for Physicists()(New Age International (P).Ltd)

Reference books :

1. J.Mathews and R.Walker : "Mathematical Methods for Physics" (Benjamin)
2. L.I.Pipes and L.R.Harvill : "Applied Mathematics for Engineers and Physicists (3rd Edition)" (McGraw Hill)
3. Erwin Kreyzig : "Advanced Engineering Mathematics - 8th edition" (Wiley)
4. M. Greenberg : "Advanced Engineering Mathematics – 2nd edition " (Pearson India 2002)
5. Mathematical methods in the physical sciences, 2nd edn, Mary L Boas, John Wiley & Sons
6. Elementary Differential Equations and boundary value problems, William E. Boyce, Richard C. DiPrima, John Wiley & Sons, Inc.
7. Mathematics of Classical and Quantum Physics, F. W. Byron and R. W. Fuller, Dover Publications, Inc., New York

For further reference:

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<http://nptel.iitm.ac.in/video.php?subjectId=122107036>  
Mathematics III Video Prof. P.N. Agrawal, Dr. Tanuja Srivastava IIT Roorkee  
<http://nptel.iitm.ac.in/video.php?subjectId=122107037>

## PHY2C07: STATISTICAL MECHANICS (4C)

### 1. The Statistical Basis of Thermodynamics:

The macroscopic and the microscopic states – Contact between statistics and Thermodynamics: Expressing  $T$ ,  $P$  and  $\mu$  in terms of  $\Omega$  – The classical Ideal gas - The entropy of mixing and the Gibbs paradox - Phase space of a classical system - Liouville's theorem and its consequences. (9 Hours), Text : Pathria, Sections 1.1 – 1.6, 2.1 – 2.2

### 2. Microcanonical, Canonical and Grand Canonical Ensembles:

The microcanonical ensemble – Examples : (1) Classical Ideal gas, (2) Linear harmonic oscillator - Quantum states and the phase space – Equilibrium between a system and a heat reservoir- Physical significance of the various statistical quantities in the canonical ensemble- Alternative expressions for the partition function- Examples: (1) The classical systems: Ideal gas, (2) A system of harmonic oscillators, (3) The statistics of paramagnetism - Energy fluctuations in the canonical ensemble -Equipartition theorem - Virial theorem - Equilibrium between a system and a particle-energy reservoir- Physical significance of the various statistical quantities in the grand canonical ensemble- Example : Classical Ideal gas - Density and energy fluctuations in the grand canonical ensemble. (15 Hours)-Text : Pathria, Sections 2.3 -2.5, 3.1, 3.3 - 3.9, 4.1, 4.3 – 4.5

### 3. Formulation of Quantum Statistics:

Quantum-mechanical ensemble theory: The density matrix- Statistics of the various ensembles- Example: An electron in a magnetic field - Systems composed of indistinguishable particles- An ideal gas in a quantum-mechanical microcanonical ensemble- An ideal gas in other quantum-mechanical ensembles- Statistics of the occupation numbers (12 Hours) Text : Pathria, Sections 5.1 - 5.4, 6.1 – 6.3

### 4. Ideal Bose Systems:

Thermodynamic behaviour of an ideal Bose gas- Thermodynamics of the blackbody radiation- The field of sound waves. (6 Hours) Text : Pathria, Sections : 7.1 - 7.3

### 5. Ideal Fermi Systems:

Thermodynamic behaviour of an ideal Fermi gas- Magnetic behaviour of an ideal Fermi Gas : (1) Pauli paramagnetism, (2) Landau diamagnetism – The electron gas in metals (Discussion of heat capacity only), Enough exercises. (8 Hours)  
Text : Pathria, Sections : 8.1 - 8.3

Text Book:

1. Statistical Mechanics ( 2nd Edition ), R. K. Pathria , Butterworth-Heinemann / Elsevier (1996)

Reference Books:

1. Statistical Mechanics : An Elementary Outline, Avijit Lahiri, Universities Press (2008)
2. An Introductory Course of Statistical Mechanics, Palash. B. Pal, Narosa (2008)
3. Statistical Mechanics : An Introduction, Evelyn Guha, Narosa (2008)
4. Statistical and Thermal Physics : An Introduction, S. Lokanathan and R.S.Gambhir, Prentice Hall of India (2000).
5. Introductory Statistical Mechanics (2nd Edition), Roger Bowley and Mariana Sanchez, Oxford University Press (2007)
6. Concepts in Thermal Physics, Stephen. J. Blundell and Katherine. M. Blundell, Oxford University Press (2008)
7. An Introduction to Thermal Physics, Daniel. V. Schroeder, Pearson (2006)
8. Statistical Mechanics, Donald. A. McQuarrie, Viva Books (2005)
9. Problems and Solutions on Thermodynamics and Statistical Mechanics, Ed. by Yung – Kuo Lim, Sarat Book House (2001)

For further reference:

Basic Thermodynamics Video Prof. S.K. Som IIT Kharagpur  
<http://nptel.iitm.ac.in/video.php?subjectId=112105123>

## PHY2C08: COMPUTATIONAL PHYSICS (4C)

### 1. Introduction to Python language: (12 hours)

Inputs and Output methods, Variables, operators, expressions and statements, Strings, Lists, list functions and methods (len, append, insert, del, remove, reverse, sort, +, \*, max, min, count, in, not in, sum), sets, set functions and methods(set, add, remove, in, not in, union, intersection, symmetric difference)-Tuples and Dictionaries, Conditionals, Iteration and looping - Functions and Modules - File input and file output, Exercises.

Ref: (1) Python for Education, Ajith Kumar B.P., (2) Python tutorials available on the net (<http://www.altaway.com/resources/python/tutorial.pdf>)

### 2. Numpy module-Arrays and Matrices: (12 hours)

Creation of arrays and matrices ( arrange, linspace, zeros, ones, random, reshape, copying arrays), Arithmetic Operations, cross product, dot product , Saving and Restoring, Matrix inversion, solution of simultaneous equations( use functions in linalg module),Exercises.

Ref: Guide to NumPy, Travis E. Oliphant

### 3. Data visualization-The Matplotlib, Module: (12 hours)

Methods defined in matplotlib, Plotting graphs, Multiple plots, Polar plots-, Pie Charts, Plotting Sine, Log, Exponential, Bessel, Legendre, Gaussian and Gamma functions. Parametric plots, Exercises.

Ref: Matplotlib for python developers, Sandro Tosi,

### 4. Numerical methods: (12 hours)

Inverse of a function, Interpolation with Cubic Spline, Zeros of polynomials, Monte Carlo Methods: simple integration, integration by Importance Sampling, Eigenvalues and eigen functions shooting and relaxation methods, Sampled Data: Sampling Theorem, Discrete Fourier Transform, Fast Fourier Transform (FFT).Exercises.

Ref: 1. Numerical Recipes in C, W.H.Press,S.A.Teukolsky et al.

2. Introductory methods of numerical analysis, S.S. Shastri , (Prentice Hall of India,1983)

### 5. Introduction to Computational approach in Physics\*: (12 hrs)

Formulation: from Analytical methods to Numerical Methods - Oscillatory motion – Ideal Simple Harmonic Oscillator (Euler method), Driven LCR circuit (R-K method), circuit analysis using Kirchoff's laws, central field motion, simulations of standing waves, Monte-Carlo simulations- value of  $\pi$ ,simulation of radioactivity, Logistic maps, enough exercises.

(\*Programs are to be discussed in Python, Visualisation can be done with matplotlib/pylab)

Text book: Computational Physics-An Introduction,R.C.Verma, P.K.Ahluwalia & K.C.Sharma, New Age

International Publishers

Reference: Computational Physics, V.K.Mittal, R.C.Verma & S.C.Gupta, Ane's Student Edition.

More References:

(For Python any book can be used as reference. Moreover a number of open articles are available freely in internet. Python is included in default in all GNU/Linux platforms and it is freely downloadable for Windows platform as well. However use of GNU/Linux may be encouraged).

1. www.python.org
2. Python Essential Reference, David M. Beazley, Pearson Education
3. Core Python Programming, Wesley J Chun, Pearson Education
4. Python Tutorial Release 2.6.1 by Guido van Rossum, Fred L. Drake, Jr., editor. This Tutorial can be obtained from website <http://www.altaway.com/resources/python/tutorial.pdf>
5. How to Think Like a Computer Scientist: Learning with Python, Allen Downey , Jeffrey Elkner , Chris Meyers, <http://www.greenteapress.com/thinkpython/thinkpython.pdf>
6. Numerical Recipes in C, second Edition(1992), Cambridge University Press
7. Numerical Recipes in Fortran 77, second Edition(1992), Cambridge University Press
8. Numpy reference guide, <http://docs.scipy.org/doc/numpy/numpy-ref.pdf> (and other free resources available on net)
9. Matplotlib , <http://matplotlib.sf.net/Matplotlib.pdf> (and other free resources available on net)
10. Numerical Methods, E Balagurusamy, Tata McGraw-Hill
11. Numerical Methods , T Veerarajan, T Ramachandran, Tat MCGraw-Hill
12. Numerical Methods with Programs I BASIC, Fortran & Pascal, S Balachandra Rao, C K Shantha. Universities Press
13. Numerical methods for scientists and engineers, K. Sankara Rao, PHI
14. Numerical Methods in Engineering with Python by Jaan Kiusalaas

For further reference:

1. Computational Techniques - Video <http://nptel.iitm.ac.in/courses/103106074/>
2. Numerical Analysis Web Prof. Vittal Rao IISc Bangalore [http://nptel.iitm.ac.in/courses/Webcourse-contents/IISc-BANG/Numerical%20Analysis/New\\_index1.html](http://nptel.iitm.ac.in/courses/Webcourse-contents/IISc-BANG/Numerical%20Analysis/New_index1.html)
3. Numerical Analysis and Computer Programming Video Prof. P.B. Sunil Kumar IIT Madras <http://nptel.iitm.ac.in/video.php?subjectId=122106033>
4. Numerical Analysis in Computer Programming Web Prof. Rathish Kumar, Prof. V. Raghavendra, Prof. M.K. Kadalbajoo, Prof. P.B. Sunil Kumar IIT Kanpur, IIT Madras <http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT-KANPUR/Numerical%20Analysis/front.htm>
5. Numerical Methods and Computation Video Prof. S. R. K. Iyengar IIT Delhi <http://nptel.iitm.ac.in/video.php?subjectId=122102009>

### Practical for Semester I & II

#### a) PHY 1P01 & PHY 2P03 (GENERAL PHYSICS )

Note :

1. All the experiments should involve error analysis. Internal evaluation to be done in the respective semesters and grades to be intimated to the controller at the end of each semester itself. Practical observation book to be submitted to the examiners at the time of examination.
2. Eight experiments are to be done by a student in a semester. One mark is to be deducted from internal marks for each experiment not done by the student if the required total of experiments are not done in the semesters.
3. The PHOENIX/expEYES Experimental Kit developed at the Inter University Accelerator Centre, New Delhi, may be used for the experiments wherever possible.

(At least 16 experiments should be done, 8 each for I & II semesters)

1.  $Y$  and  $\sigma$  - Interference method (a) elliptical (b) hyperbolic fringes. To determine  $Y$  and  $\sigma$  of the material of the given specimen by observing the elliptical and hyperbolic fringes formed in an interference set up
2.  $Y$  &  $\sigma$  by Koenig's method

3. Variation of surface tension with temperature-Jaegar's method. To determine the surface tension of water at different temperatures by Jaegar's method of observing the air bubble diameter at the instant of bursting inside water
4. Stefan's constant-To determine Stefan's constant
5. Thermal conductivity of liquid and air by Lee's disc method.
6. Dielectric constant by Lecher wire- To determine the wave length of the waves from the given RF oscillator and the dielectric constant of the given oil by measurement of a suitable capacitance by Lecher wire setup.
7. Viscosity of a liquid - Oscillating disc method. To determine the viscosity of the given liquid by measurements on the time period of oscillation of the disc in air and in the liquid
8. Mode constants of a vibrating strip. To determine the first and second mode constants of a steel vibrating strip;  $Y$  to be measured by the Cantilever method and frequency of vibration by the Melde's string method
9. Constants of a thermocouple and temperature of inversion.
10. Study of magnetic hysteresis - B-H Curve using standard toroid / specimen in any form.
11. Maxwell's L/C bridge -To determine the resistance and inductance of the given unknown inductor by Maxwell's L/C bridge OR Anderson's Bridge – L/C and self inductance. .(The kit developed by Indian Academy of Science can also be used)
12. Susceptibility measurement by Quincke's and Guoy's methods - Paramagnetic susceptibility of salt and specimen
13. Michelson's interferometer - (a)  $\lambda$  and (b)  $d\lambda$  and thickness of mica sheet.
14. Photoelectric effect. Determination of Plank's constant
15. Frank Hertz experiment .To measure the ionization potential of Mercury by drawing current versus applied voltage.
16. Fabry Perot etalon -Determination of thickness of air film.
17. Elementary experiments using Laser: (a) Study of Gaussian nature of laser beam (b) Evaluation of beam spot size (c) Measurement of divergence (d) Diameter of a thin wire
18. Diffraction Experiments using lasers (a)Diffraction by single slit/double slit/circular aperture (b)Diffraction by reflection grating
19. Measurement of the thermal and electrical conductivity of Cu to determine the Lorents number.(The kit developed by Indian Academy of Science can also be used)
20. Passive filters .(The kit developed by Indian Academy of Science can also be used)
21. Microwave experiments - Determination of wavelength, VSWR, attenuation, dielectric constant.
22. Experiments with Lock-in Amplifier(a) Calibration of Lock In Amplifier (b) Phase sensitive detection (c) Mutual inductance determination (d) Low resistance determination.(The kit developed by Indian Academy of Science can also be used)
23. Cauchy's constants using liquid prism
24. Forbe's method of determining thermal conductivity
25. Zeeman effect using Fabry-Perot etalon.

Reference Books:

1. B.L. Worsnop and H.T. Flint - Advanced Practical Physics for students - Methusen & Co (1950)
2. E.V. Smith - Manual of experiments in applied Physics - Butterworth (1970)
3. R.A. Dunlap - Experimental Physics - Modern methods - Oxford University Press (1988)
4. D. Malacara (ed) - Methods of experimental Physics - series of volumes - Academic Press Inc (1988)
5. S.P. Singh –Advanced Practical Physics – Vol I & II – Pragati Prakasan, Meerut (2003) – 13th Edition

**b) PHY1P02 & PHY2P04 (ELECTRONICS)**

**(At least 16 experiments should be done, 8 each for I & II semesters.)**

1. MOSFET characteristics and applications: To study the characteristics of a MOSFET and use it as a common source amplifier. Study bode-plot and determine I/O impedances.
2. UJT characteristics and application as a relaxation oscillator & sharp pulse generator. Use of UJT in a time delay circuit.
3. Characteristics of Silicon Controlled Rectifier - half wave and full wave; use of SCR as a power control device.

4. Voltage Regulation using transistors with feedback (regulation characteristics with load for different input voltages and variation of ripple % with load) / Voltage regulation based on opt coupler feedback; study of load and line regulation characteristics.
5. Single stage RC coupled Negative feedback amplifier( input, output resistance, frequency response with & without feedback)
6. Two stage RC coupled amplifier; study of bode plots, input, output impedances & power gain.
7. Common source FET amplifier - frequency response, input & output impedance.
8. Design and construction of Complementary symmetry Class B push-pull power amplifier transformerless) for small power outputs ( less than 10 W); study of I/O impedances, efficiency and frequency response.
9. Differential amplifier using transistors; study of I/O impedances, frequency response & CMRR.
10. Design of Amplitude modulation circuit. Detection using diodes. Determination of modulation index & recovery of modulating signal.
11. Darlington pair amplifier; study of gain, frequency response, input & output impedances.
12. Basic configurations of OPAMP IC 741 – Inverting, Non-inverting and Difference amplifiers: design and construction for specified gain; study of bode-plots.
13. Design and construction of Wien bridge oscillator using OPAMP for different frequencies.
14. Design and construction of astable and monostable multivibrators using OPAMPS.
15. Design and construction of Sawtooth generator using transistors/OPAMP for different frequencies.
16. IC 555 Timer – Astable & Monostable multivibrators, Voltage control oscillator, Saw tooth generator, Frequency modulator for sinusoidal signal.
17. Two stage IF amplifier; study of the performance of single stage and coupled stages.
18. Schmidt triggers using OPAMPS – for symmetrical and non-symmetrical LTP/UTP. Trace hysteresis curve.
19. Design and construction of Crystal Oscillator & evaluation of frequency stability against temperature variations.
20. Analog integration and differentiation using OPAMPS ; study the integrator and differentiator characteristics.
21. Analog computation using OPAMPS (LM 324) – solution of differential equations / simultaneous equations
22. Second order Butterworth Low pass, High Pass and Band Pass filters using OPAMP – study of frequency response.
23. Negative resistance oscillator using Tunnel diode for high R.F frequencies.
24. Bootstrap Amplifier; study of frequency response, input & output impedance.
25. Organize M X N random access memory with basic memory unit(IC); 16 X 4/32 X 8; Verify READ and WRITE operations.
26. 4 bit D/A converter using R-2R ladder network. Realization of 4 bit A/D converter using D/A converter.
27. Study of 4 bit binary counter (IC 7493) and 4 bit decade counter(IC 7490) at various modes. Use of counters as frequency dividers.
28. Minimization of a three variable truth table using Karnaugh map and realization using NAND gates.
29. Microprocessors experiments; addition, subtraction, division and multiplication of 1 byte numbers using Intel 8085 kit.

Reference Books :

1. Paul B. Zhar and A.P. Malvino - Basic Electronics - A Text Book Manual - JMH publishing (1983)
2. A.P. Malvino - Basic Electronics - A text lab manual - Tata McGraw Hill (1992)
3. R. Bogart and J. Brown -Experiments for electronic devices and circuits - Merrill International series (1985)
4. Buchla - Digital Experiments - Merrill International series (1984)
5. S.P. Singh – Pragati Advanced Practical Physics – Vol I & II – Pragati Prakasan Meerut (2003) – 13th Edition

For further reference:

Basic Electronics and Lab Video Prof. T.S. Natarajan IIT Madras  
<http://nptel.iitm.ac.in/video.php?subjectId=122106025>

SEMESTER - III  
**PHY3C09: QUANTUM MECHANICS –II (4C)**

**1. Approximation methods for time-independent problems:**

The WKB approximation, connection formulae, Bound state verification of Bohr-Sommerfeld old quantum theory, Penetration of a potential barrier. Time-independent perturbation theory, Non-degenerate and degenerate cases, Anharmonic oscillator stark and Zeeman effects in hydrogen,. (16 hours)

Texts : Thankappan, Sections 8.1, 8.3

**2. Variational method :**

The variational equation, ground state and excited states, application to ground state of the hydrogen and Helium atoms, ( 6 hours)

Texts: Thankappan, Sections 8.2

**3. Time dependent perturbation theory :**

Transition probability, Harmonic perturbation, Interaction of an atom with the electromagnetic field, Induced emission and absorption, The dipole approximation, Enough exercises. (12 Hours)

Texts : Thankappan, Sections 8.4

**4. Relativistic Quantum Mechanics :**

The Dirac equation, Dirac matrices, Solution of the free-particle Dirac equation, The Dirac equation with potentials, Equation of continuity, Spin of the electron, Non-realistic limit, spin-orbit coupling, Hole theory, The Weyl equation. The Klein Gordon equation, Charge and current densities, The Klein-Gordon equation(18 Hrs).

Texts : V.K.Thankappan Sec. 10.1,10.2,10.2A,10.2B,10.3A

**5. Quantization of fields :**

The principles of canonical quantization of fields, Lagrangian density and Hamiltonian density, Second quantization of the Schrödinger wave field for bosons and fermions, Enough exercises.(12 Hrs.)

Texts: V.K.Thankappan Sec. 11.1,11.2,11.3

Textbooks :

1. V.K. Thankappan: "Quantum Mechanics" (Wiley Eastern)
2. N.Zittili, , "Quantum Mechanics – Concepts and applications" (John Wiley & Sons, 2004)
3. P.M Mathews and Venkatesan., "A Textbook of Quantum Mechanics" (Tata McGraw Hill)
4. J.D. Bjorken and D. Drell : "Relativistic Quantum Fields" (McGraw Hill 1998)

Reference books :

1. L.I. Schiff : "Quantum Mechanics" (McGraw Hill)
2. J.J. Sakurai : "Advanced Quantum Mechanics " (Addison Wesley)
3. Stephen Gasiorowicz : "Quantum Physics"

For further reference:

Relativistic Quantum Mechanics Video Prof. Apoorva D Patel IISc Bangalore  
<http://nptel.iitm.ac.in/courses/115108074/>

**PHY 3C10 : NUCLEAR AND PARTICLE PHYSICS (4C)**

**1. Basic properties of nuclei and study of nuclear force:**

Nuclear size, shape, mass and binding energy, semi empirical mass formula, Angular momentum and parity, nuclear electromagnetic moments, characteristics of nuclear force, the deuteron, nucleon-nucleon scattering the exchange force model.

Texts: Introductory Nuclear Physics by Kenneth S Krane

Sections: - 3.1 →3.5, 4.1, 4.2, 4.4 & 4.5

Reference Books: (1) Introduction to Nuclear Physics by Harald Enge

(2) Nuclear Physics by Roy & Nigam

**2. Nuclear Models:**

The shell model, shell model potential, spin-orbit potential, magnetic dipole moments, electric quadrupole moments, valence nucleons, Even Z-even N nuclei and collective structure.

Text: Kenneth S Krane- Section 5.1 & 5.2

Reference: Harald Enge and Roy & Nigam

**3. Nuclear Decays:**

Beta decay, Energy release in beta decay, Fermi theory of beta decay, Experimental tests of the

Fermi theory, angular momentum and parity selection rules, parity violation in beta decay. Energetics of gamma decay, classical electromagnetic radiation, transition to quantum mechanics, angular momentum and parity selection rules, Internal conversion.

Text: Kenneth S Krane - Sections 9.1 → 9.4 and 9.9, 10.1 → 10.4 and 10.6

Ref : Harald Enge and Roy & Nigam

#### **4. Nuclear Reactions, Fission and Fusion:**

Types of reactions and conservation laws, Energetics of nuclear reactions, reaction cross sections, compound nucleus reactions, Nuclear fission, characteristics of fission, energy in fission, Nuclear fusion: basic fusion processes, characteristics of fusion, solar fusion.

Text: Kenneth S Krane - sections 11.1, 11.2, 11.4 and 11.10, 13.1, 13.2 and 13.3, 14.1, 14.2 and 14.3

References : Harald Enge and Roy & Nigam

#### **5. Particle Physics**

Basic forces and classification of particles: The four basic forces, The force of gravity, the electromagnetic force, the weak force and electroweak theory, the strong force.

Conservations laws: Conservation laws and symmetries, conservation of energy and mass, conservation of linear momentum, conservation of angular momentum, conservation of electric charge, conservation of baryon and lepton numbers, conservation of strangeness, conservation of isospin and its components, the TCP theorem, conservation of parity.

Quark model: The eightfold way, discovery of omega minus, the quark model, the confined quarks, experimental evidences for quark model, coloured quarks, quantum chromodynamics and gluons, Enough exercises.

Text: The particle Hunters - Yuval Ne'eman & Yoram Kirsh

Sections : 6.1-6.3, 7.1-7.11 and 9.1-9.8.

References: 1. Introductory nuclear Physics by Samuel S.M. Wong, Chapter 2

2. Introduction to Elementary Particles-David Griffiths.

For further reference:

Nuclear Physics: Fundamentals and Applications Video Prof. H.C. Verma IIT Kanpur  
<http://nptel.iitm.ac.in/courses/115104043/>

### **PHY3C11: SOLID STATE PHYSICS (4C)**

#### **1. Crystal Structure and binding:**

Symmetry elements of a crystal, Types of space lattices, Miller indices, Diamond Structure, NaCl Structure, BCC, FCC, HCP structures with examples, Description of X-ray diffraction using reciprocal lattice, Brillouin zones, Vander Waals interaction, Cohesive energy of inert gas crystals, Madelung interaction, Cohesive energy of ionic crystals, Covalent bonding, Metallic bonding, Hydrogen-bonded crystals (10 hours)

#### **2. Lattice Vibrations:**

Vibrations of monatomic and diatomic lattices, Quantization of lattice vibrations, Inelastic scattering of neutrons, Einstein and Debye models of specific heat, Thermal conductivity, Effect of imperfection (8 hours)

#### **3. Electron States and Semiconductors:**

Free electron gas in three dimensions, Specific heat of metals, Sommerfield theory of electrical conductivity, Wiedemann-Franz law, Hall effect, Nearly free electron model and formation of energy bands, Bloch functions, Kronig Penny model, Formation of energy gap at Brillouin zone boundaries, Number of orbitals in a band, Equation of motion of electrons in energy bands, Properties of holes, Effective mass of carriers, Intrinsic carrier concentration, Hydrogenic model of donor and acceptor states. Direct band gap and indirect band gap semiconductors (16 hours)

#### **4. Dielectric, Ferroelectric and magnetic properties:**

Theory of Dielectrics: polarization, Dielectric constant, Local Electric field, Dielectric polarisability, Polarisation from Dipole orientation, Ferroelectric crystals, Order-disorder type of ferroelectrics, Properties of Ba Ti O<sub>3</sub>, Polarisation catastrophe, Displasive type ferroelectrics, Landau theory of ferroelectric phase transitions, Ferroelectric domain, Antiferroelectricity, Piezoelectricity, Applications of Piezoelectric Crystals, Diamagnetism and Paramagnetism: Langevin's theory of diamagnetism, Langevin's theory of paramagnetism, theory of Atomic magnetic moment, Hund's rule, Quantum theory of magnetic Susceptibility Ferro, Anti and Ferri magnetism: Weiss theory of ferromagnetism, Ferromagnetic domains, Neel Model of Antiferromagnetism and Ferrimagnetism, Spinwaves, Magnons in Ferromagnets (qualitative) (20 hours)

## 5. Superconductivity:

Meissner effect, Type I and Type II superconductors, energy gap Isotope effect, London equation and penetration of magnetic field, Cooper pairs and the B C S ground state (qualitative, Flux quantization, Single particle tunneling, DC and AC Josephson effects, High Tc Superconductors(qualitative) description of cuprates, Enough exercises. (10 hours)

Text Books:

1. C.Kittel,: Introduction to Solid State Physics 5th edition (Wiley Eastern)
2. A.J.Dekker: Solid State Physics (Macmillian 1958)

Reference Books:

1. M.Ali Omar, Elementary Solid State Physics, Addison-Wesley Publishing Company
2. N.W.Ashcroft and Mermin : Solid State Physics (Brooks Cole (1976)
3. Elements of Solid State Physics, Srivastava J.P. Prentice Hall of India (2nd edn)
4. Ziman J.H. Principles of Theory of Solids - ( Cambridge 1964)
5. Luth – Solid State Physics.

### ELECTIVE I:

(Elective-I to be opted from PHY3E01- PHY3E07)

#### PHY3E01: PLASMA PHYSICS:

##### 1. Introduction to Plasma Physics :

Existence of plasma, Definition of Plasma, Debye shielding 1D and 3D, Criteria for plasma, Applications of Plasma Physics (in brief), Single Particle motions -Uniform E & B fields, Nonuniform B field, Non uniform E field, Time varying E field, Adiabatic invariants and applications (13 hours)

Text : Chen, Sections 1.1 to 1.7.7, 2.1 to 2.8.3

##### 2. Plasma as Fluids and waves in plasmas :

Introduction –The set of fluid equations, Maxwell's equations, Fluid drifts perpendicular to B, Fluid drifts parallel to B, The plasma approximations, Waves in Plasma - Waves, Group velocity, Phase velocity, Plasma oscillations, Electron Plasma Waves, Sound waves, Ion waves, Validity of Plasma approximations, Comparison of ion and electron waves, Electrostatic electron oscillations parallel to B, Electrostatic ion waves perpendicular to B, The lower hybrid frequency, Electromagnetic waves with  $B_0$  , Cutoffs and Resonances, Electromagnetic waves parallel to  $B_0$ , Experimental consequences, Hydromagnetic waves, Magnetosonic waves, The CMA diagrams (12 hours)

Text : Chen, Sections 3.1 to 3.6, 4.1 to 4.21

##### 3. Equilibrium and stability :

Hydro magnetic equilibrium, The concept of b, Diffusion of magnetic field into plasma, Classification of instability, Two stream instability, the gravitational instability, Resistive drift waves, the Weibel instability (10 hours)

Text : Chen, Sections 6.1 to 6.8

##### 4. Kinetic Theory :

The meaning of  $f(v)$ , Equations of kinetic theory, Derivation of the fluid equations, Plasma oscillations and Landau damping, the meaning of Landau damping, Physical derivation of Landau damping, Ion Landau damping, Kinetic effects in a magnetic field (10 hours)

Text : Chen, Sections 7.1 to 7.6.2

##### 5. Introduction to Controlled Fusion :

The problem of controlled fusion, Magnetic confinements such as Toruses, Mirrors, Pinches, Laser Fusion, Plasma heating, Fusion Technology (10 hours)

Text : Chen, Sections 9.1 to 9.8

Text Book : .F. F. Chen, Introduction to Plasma Physics and Controlled Fusion, Volume I and II, Plenum Press, recent edition.

#### PHY3E02: FOUNDATIONS OF QUANTUM MECHANICS

##### 1. Basic Concepts: ((8 Hours)

Reflections on the uncertainty principle, Complementarity principle, Information, Theory of quantum beats, The Aharonov – Bohm effect.

Chapter 3.3, 3.4 and 4.1 to 4.5 of George Greenstein & Arthur G. Zajonc

##### 2. The EPR Experiment And Bell's Theorem: (12 Hours)

The EPR argument, The BKS theorem, The hidden variable theories, The Bell's theorem and its



proof, Tests of Bell's inequalities, Alain Aspect's experiments.

Chapter 5.1 to 5.3 and 6.1 of George Greenstein & Arthur G. Zajonc & 12.2 of David J Griffiths.

### **3. Nonlocality: (10 Hours)**

Bohm's nonlocal hidden variable theory, The Mystery of the EPR correlations, Nonlocality and principle of relativity, Quantum Nonlocality.

Chapter 6.2 to 6.5 & 6.7 of George Greenstein & Arthur G. Zajonc

### **4. Decoherence (14 Hours)**

Schrödinger's cat, Super positions and mixtures, Non-observation of quantum behaviour in macro systems, Decoherence, Watching decoherence

Chapter 7.1 to 7.6 of George Greenstein & Arthur G. Zajonc

### **5. The measurement problem in quantum mechanics: (16 hours)**

The measurement problem, The collapse of wave function, The infinite regress, The active nature of measurement in quantum mechanics, Decoherence and measurement problem, Elementary ideas of quantum cryptography and quantum teleportation

Chapter 8 complete & 9.1 to 9.3 of George Greenstein & Arthur G. Zajonc

Text Book : The Quantum Challenge: Modern Researches on the foundations of Quantum Mechanics - George Greenstein & Arthur G. Zajonc, Narosa

References:

1. Introduction to Quantum Mechanics: David J Griffiths, Pearson Education
2. Understanding Quantum Mechanics: Roland Omnès, Prentice-Hall, India
3. Quantum Theory and Measurement: J. A. Wheeler and W. H. Zurek, Princeton University Press, Princeton
4. Quantum Mechanics: V.K. Thankappan, Wiley Eastern

For further reference:

Quantum Mechanics and Applications Video Prof. Ajoy Ghatak IIT Delhi

<http://nptel.iitm.ac.in/courses/115102023/>

Quantum Physics Video Prof. V. Balakrishnan IIT Madras

<http://nptel.iitm.ac.in/video.php?subjectId=122106034>

## **PHY3E03: RADIATION PHYSICS**

### **1. Radiation source :**

Types of radiations, ionizing, non ionizing, electromagnetic, particles, neutral -gamma-neutrino-neutron, charged alpha, beta, gamma, and heavy ion sources, radioactive sources – naturally occurring production of artificial isotopes, accelerators–cyclotrons, nuclear reactors.(10 hours) {Ref 1, 2}

### **2. Interaction of radiations with matter :**

Electrons – classical theory of inelastic collisions with atomic electrons, energy loss per ion pair by primary and secondary ionization, specific energy loss, bremsstrahlung, range energy relation, energy and range straggling Heavy charged particles – stopping power, energy loss, range and range – energy relations, Bragg curve, specific ionization, Gamma rays – Interaction mechanism – Photoelectric absorption, Compton scattering, Pair production, gamma ray attenuation, attenuation coefficients, Elastic and inelastic scattering, Cross sections, linear and mass absorption coefficients, stopping power, LET, Neutrons – General properties, fast neutron interactions, slowing down and moderation.(14 hours) Ref 1,2}

### **3. Radiation quantities, Units and Dosimeters :**

Particle flux and fluence, calculation of energy flux and fluence, curie, Becquerel, exposure and its measurements, absorbed dose and its relation to exposure, KERMA, Biological effectiveness, weighting factors, (WR and WT), Equivalent dose, Effective dose, Dosimeters, Primary and secondary dosimeters, Pocket dosimeter, Films and solid dosimeter (TLD and RPL), Clinical and calorimetric devices, Radiation survey meter for area monitoring. (13 hours) {Ref 2,3}

### **4. Biological effects :**

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

### **5. Radiation protection, shielding and transport :**

Effective radiation protection, need to safeguard against continuing radiation exposure, justification and responsibility, ALARA, concept of radiologic practice. time distance and shielding, safety specifications. method of radiation control, Shielding factor for radiations, Choice of material, Primary and secondary radiations, Source geometry, Beta shielding, Gamma shielding, neutron shielding, Shielding requirements for

medical, industrial and research facilities, handling of the source, sealing, transport and storage of sealed and unsealed sources. records, spills. waste disposal, Enough exercises. (13 hours) {Ref 3,4,5}

Reference Books :

1. G.F.Knoll, Radiation detection and measurement, John Wiley & sons, Newyork, (2000)
2. K.Thayalan, Basic radiological physics, Jaypee brothers medical Publishers, New Delhi, (2003)
3. W.J. Meredith and J.B. Masse, Fundamental Physics of radiology, Varghese publishing house , Bombay (1992)
4. M.A.S. Sherer, P.J.Visconti, E.R Ritenour, Radiation Protection in medical radiography, Mosbey Elsevier,(2006)
5. Lowenthal G.C and Airey P.L., Practical applications of radioactivity and nuclear radiation sources, Cambridge University Press (2005)

### **PHY3E04: COMPUTER SOFTWARE AND APPLICATIONS**

#### **1. Language Processors :**

Introduction-Language Processing activities - Fundamentals of Language Processing -Fundamentals of Language Specification- Language Processor Development Tools (10 hours)

Text : Dhamdhare, sections 1.1 - 1.5

#### **2. Assemblers, Macros and Macro Processors :**

Elements of Assembly Language Programming- A Simple Assembly Scheme - Pass Structure of Assemblers - Design of a Single Pass Assembler for IBM PC, Macro Definition and Cal I- Macro Expansion. (10 hours)

Text : Dhamdhare, sections 4.1 – 4.4, 5.1, 5.2

#### **3. Compilers, Interpreters and Linkers :**

Aspects of Compilation- Memory Allocation - Compilation of Expressions- Compilation of Control Structures- Code Optimization - Interpreters, Relocation of Linking Concepts- Design of a Linker-Self-Relocating Programs - A linker for MS DOS- Linking of Over layers-Loaders. (15 hours)

Text : Dhamdhare, sections 6.1 – 6.6, 7.1 – 7.6

#### **4. Operating systems :**

Batch processing systems - Multiprogramming systems - Time Sharing Systems – Real Time Systems - OS Structure. The Process Concept-Process Definition- Process Control - Interacting Processes- Implementation of Interacting Processes- Scheduling Policies- Job Scheduling – Process Scheduling (15 hours)

Text : Dhamdhare, sections 9.1 - 9.5 , 10.1 – 10.5, 11.1 – 11.3

#### **5. Software Tools and deadlocks :**

Software Tools for Program Development- Editors - Debug Monitors -Programming Environments - User Interfaces, Deadlocks:, Definition - Modelling the Resource Status – Handling Deadlocks –Dead lock detection and Resolution - Deadlock (14 hours)

Text : Dhamdhare, sections 8.1 – 8.5, 12.1 - 12.5

Text Book:

1. “Systems Programming and Operating Systems”., D.M.Dhamdhare (2nd revised edition), Tata McGraw Hill.Publishing Co. Ltd.,New Delhi, 2003.

Reference Books:

1. “System programming”, John. J.Donovan., Tata McGraw- Hill.
2. “Operating System” , Milan Milankovic., McGraw Hill International Edition.
3. “Operating System” , Colin Ritchie., (Second Edn) BPB-Publication.
4. “An Introduction to Operating Systems” , Deitel. H.M.,(2nd edition), Pearson education 2002.
5. “Operating System Concepts” , Silberschatz A and P Galvin., (5th edition), Addison- Wesley, (1999).

### **PHY3E05: FLUID DYNAMICS**

(Syllabus to be framed)

## PHY3E06: DIGITAL SIGNAL PROCESSING

### 1. Introduction:

Signals and systems, Classification of signals, Concept of frequency in continuous time and discrete – time signals. Theory of A/D and D/A conversion, Sampling of analog signals, sampling theorem. Quantization of continuous amplitude signals. Quantization of sinusoidal signal, Coding of quantized samples- Digital to analog conversion (8 hours)

Text Book : Digital Signal Processing by Proakis & Manolakis, Prentice Hall of India (Fourth edition -2007) – chapter 1 (complete)

### 2. Discrete- time signals and systems:

Discrete- time linear time-invariant systems-Techniques of analysis of linear systems, Resolution of a discrete time signal into impulses- Response of LTI systems to arbitrary inputs : Convolution sum-Properties of convolution and the interconnection of LTI systems- Casual LTI systems Stability of LTI systems- Systems with finite duration and infinite duration impulse, response. Discrete- time systems described by difference equations- Recursive and non-recursive discrete, time systems LTI systems characterized by constant coefficient difference equations, Solution to linear constant coefficient difference equations, correlation of discrete-time signals. (10 hours)

Text Book : Digital Signal Processing by Proakis & Manolakis, Prentice Hall of India (Fourth edition -2007) Chapter 2 (complete)

### 3. The Z-transform:

The Direct Z-Transform, The Inverse Z-Transform. Properties of Z-transform, Rational Ztransforms, Poles and zeros, Inversion of Z-transforms. The inverse Z-Transform by contour integration, Power series expansion, Partial fraction expansion – Decomposition of rational Z-transform – Analysis of linear time-invariant systems in the Z-domain – one sided Z-Transform. (12 hours)

Text Book : Digital Signal Processing by Proakis & Manolakis, Prentice Hall of India (Fourth edition -2007) Chapter 3 (complete)

### 4. Frequency Analysis of Signals and Systems:

Frequency analysis of continuous-time signals. The Fourier Series for continuous Time Periodic signals, Power Density Spectrum of Periodic Signals, The Fourier Transform of Continuous -Time Aperiodic Signals, Energy Density Spectrum of Aperiodic Signals, Frequency analysis of discrete time signals, The Fourier Series for discrete time Periodic Signals, Power Density Spectrum of Periodic Signals, Fourier transform for discrete time aperiodic signal, Convergence of the Fourier Transform, Energy Density Spectrum of aperiodic signals, Relationship of the Fourier Transform to the Z Transform, The Cepstrum, The Fourier Transform of Signals with poles on the unit circle, The frequency Domain classification of signals, Concept of Bandwidth, Properties of the Fourier Transform for Discrete Time Signals – LTI systems as Frequency selective filters: Ideal filter characteristics, Lowpass, Highpass and Bandpass filters, Digital resonators, Notch filters, Comb filters, All-pass filters, Digital sinusoidal oscillators (20 hours)

Text Book : Digital Signal Processing by Proakis & Manolakis, Prentice Hall of India (Fourth edition -2007) chapter 4 (complete), section 5.4

### 5. Discrete Fourier Transform:

Frequency domain sampling and reconstruction of discrete time signals – The Discrete Fourier transform – DFT as a linear transformation - Relationship of the DFT to the other transforms. Properties of DFT, Multiplication of two DFTs and Circular convolution, Linear filtering methods based on DFT - Frequency analysis of signals using the DFT – Discrete cosine transform - Computation of the Discrete Fourier Transform - Fast Fourier Transform algorithm (basic ideas only) , Enough exercises.(10 hours)

Text Book : Digital Signal Processing by Proakis & Manolakis, Prentice Hall of India (Fourth edition -2007) chapter 7 (complete), sections 8.1.1, 8.1.2

Books:

1. Digital Signal Processing by Oppenheim & Schaffer, Prentice Hall India –1995
2. Digital Signal Processing by paulo S.R. Piniz, Eduardo A.B. De Silva and Sergio Netto – Cambridge University Press
3. Analog and digital signal processing by Ashok Ambradar
4. Theory and Applications of Digital Signal Processing , Rabiner & Gold, Prentice Hall India -1996.

For further reference:

Digital Signal Processing Video Prof. T.K. Basu IIT Kharagpur  
<http://nptel.iitm.ac.in/video.php?subjectId=108105055>

## PHY3E07: EXPERIMENTAL TECHNIQUES (4C)

### Unit I - Vacuum Science and Technology (14 hours)

#### Production of Vacuum-

Basic definitions and units, Expression for Pumping speed, Different vacuum regimes, Knudsen number, Classification of vacuum Pumps, Construction and working of Oil sealed rotary vane pump, Diffusion Pump, Turbo molecular Pump, Sorption Pump, Gettering Pump, Sputter-ion Pump, and Cryogenic Pump.

#### Pressure Measurement in Vacuum Systems-

Classification of Gauges, Mechanical Gauges-Bourdon Gauge and diaphragm Gauge, Liquid manometers-Open - ended and Closed- ended U-tube manometers. Pirani gauge, Penning gauge, Thermocouple gauge, Hot and Cold Cathode ionization gauges.

#### Vacuum Accessories –

Vacuum Valves -Diaphragm valve, Gate valve, Butterfly valve, Baffle and isolation valves, magnetic valves, adjustable valves, air inlet valves, Traps - Liquid nitrogen trap, Sorption traps, Flanges, Gaskets and O- Rings, Bellows, Couplings.

Text Books:

1. Vacuum Science and Technology, V.V. Rao, T.B. Ghosh, K.L. Chopra (Allied Publishers Limited, New Delhi)
2. Advanced Experimental Techniques in Modern Physics, K.M.Varier, Antony Joseph, P.P. Pradyumnan,( Pragati Prakshan, Meerut)

Reference Books:

1. Basic Vacuum Technology, B.S. Halliday, A.Chambers, (Overseas Press India Limited)
2. High Vacuum Techniques -Theory and Practice, J.Yarwood (Chapman and Hall Limited)

### Unit – II Thin film fundamentals (10 hours)

Introduction, Nature and Applications of thin films, Distribution of deposit, Knudsen Cosine law

#### Thermal Deposition Techniques-

Resistive Heating, Flash Evaporation, Exploding wire, Electron Beam evaporation, Laser Evaporation, Arc Evaporation techniques

#### Sputter Deposition Technique-

Sputtering theory, Sputtering yield, Different parameters controlling sputter yield, Cathodic sputtering, Glow Discharge sputtering, Variables influencing glow discharge sputter deposition.

#### Thin film Thickness Measurement-

On line and off line measurement, Mechanical techniques-Microbalance and Quartz Crystal Oscillator methods, Electrical techniques-Wheatstone's Bridge method, Collinear Four-Probe method, Optical Techniques-Photometric, Spectro photometric, Interferometric methods

Multi layer thin film Optical Systems - Reflection and Anti reflection coatings (mathematical conditions), Interference filters.

Text Books:

1. Thin film fundamentals, A. Goswami, (New Age International Publishers, New Delhi)
2. Advanced Experimental Techniques in Modern Physics, K.M.Varier, Antony Joseph, P.P. Pradyumnan,( Pragati Prakshan, Meerut)

Reference Books:

1. Thin film phenomena – K.L. Chopra, (Mc Graw Hill International)
2. Text Book of Optics, Brijlal, Subrahmaniam, Avadhanulu (S-Chand Company)

### Unit – III Cryogenic techniques: (15 hours)

#### Introduction,

Review of history, General techniques of Liquefaction of gases – Internal and external work methods, Adiabatic Expansion, Joule-Kelvin effect, Isenthalpic curve, Inversion curve, Regenerative cooling.

#### Liquefiers-

Linde's Air Liquefier, Dewar's Hydrogen liquefier, Kammerlingh Onne's helium Liquefier, Uses of Liquefied gases, Special properties of Liquid Helium-Super fluidity, Lambda point-Helium I and Helium II.

#### Maintenance of Cryogenic Temperatures –

Dewar flask, Henning cryostat, Hydrogen vapour cryostat.

#### Production of Sub Kelvin Temperatures -

Adiabatic Demagnetization of Paramagnetic Salts (working and thermodynamic equations), Nuclear Adiabatic demagnetization to produce micro Kelvin temperatures, He<sup>3</sup>-He<sup>4</sup> Dilution Refrigerator, Magnetic Refrigerator.

Measurement of low temperatures -

Primary and Secondary Thermometers, Gas thermometers and corrections, Resistance thermometers, (Relevant equations), Vapour pressure thermometer, Thermo-Electric thermometers, Magnetic Thermometer.

Text Books:

1. Matter and Methods at Low Temperatures (Frank Pobell, Springer-Verlag, Third Indian Edition, )
2. Advanced Experimental Techniques in Modern Physics, K.M.Varier, Antony Joseph, P.P. Pradyumnan, (Pragati Prakshan, Meerut)

Reference Books:

1. Heat, Thermodynamics and Statistical Physics, Brijlal, Subrahmanyam, Hemne, (S-Chand and Company, New Delhi, 2010 Multi coloured edition)
2. Heat and Thermodynamics by Zemansky and Dittman (Tata Mc Graw Hill)
3. Low temperature Physics, L.C.Jackson (John Wiley & Sons)

**Unit – IV Charged Particle Accelerator techniques: (10 hours)**

DC accelerators-

General set up of an accelerator installation, Cock-Croft Walton accelerator, Van de Graff accelerator, Tandem Van de Graff accelerator, Pelletron.

AC accelerators-

Construction and working principles of Linear accelerator, Cyclotron, Sector focussed cyclotron, Synchro-cyclotron, principle of phase stability, Microtron, Betatron, Electron and Proton Synchrotron, Particle smashers (Colliders) qualitative idea only.

Ion sources –

Ionization processes, simple ion source, Duoplasmatron, RF ion source, important applications of accelerators, and Major accelerator installations in India (general awareness).

Text Books:

1. Nuclear and Particle Physics, S. Kakani, Shubhra Kakani, (VIVA Books New Delhi)
2. Introduction to Nuclear and Particle Physics, (Chapter 6) V.K.Mittal, R.C.Verma (PHI Learning Private Limited, New Delhi)

Reference Books:

1. An Introduction to Particle accelerators, E.J.N. Wilson, (Oxford University Press, ISBN 0-19-850829-8)
2. Advanced Experimental Techniques in Modern Physics, K.M.Varier, Antony Joseph, P.P. Pradyumnan, (Pragati Prakshan, Meerut)
3. Nuclear Physics, S.N. Ghoshal, (S. Chand & Company Ltd, New Delhi)

**Unit – V Material Analysis Techniques: (13 hours)**

Introduction, Salient features of an effective elemental analysis, General Experimental set up-source, sample, detectors etc, mathematical basis of quantitative estimate, Nuclear reaction kinematics.

Rutherford Backscattering Spectrometry (RBS) – Introduction, Kinematic factor, Energy Straggling, Differential scattering cross section, Experimental set up, typical RBS spectrum analysis, Applications.

Neutron Activation Analysis (NAA) – Types of neutrons, Interaction of neutrons with nucleus, Prompt and Delayed analysis, Sources of Neutrons for NAA, Instrumentation, Yield equations, typical spectrum, Applications.

Proton Induced X-ray Emission Spectroscopy (PIXE) – Principle, Yield equations, Instrumentation, Applications of PIXE to water samples, biological samples, Aerosol samples, Limitations of PIXE.

XRD Technique - Introduction, Lattice planes and Bragg's Law, Diffractometer-Instrumentation, Single crystal and Powder diffraction, Scherrer equation, Debye-Scherrer Camera, Applications of XRD-Crystallinity, Unit Cell Parameters, Phase transition studies, thin film studies, Rietveld Structure Refinement (qualitative ideas only), Awareness on Powder Diffraction File (PDF) of the International Centre for Diffraction Data.

*\*\* (With sufficient number of Exercises from each unit)*

Text Books:

1. Advanced Experimental Techniques in Modern Physics, K.M.Varier, Antony Joseph, P.P. Pradyumnan, (Pragati Prakshan, Meerut)
2. Solid State Physics, N.W.Ashcroft, N.D.Mermin (Thomson Book India Ltd, 2006 Edition) for XRD.

#### Reference Books-

1. Nuclear Physics – Principles and Applications, J.S. Lilley, (John Wiley & Son Ltd, Indian Edition)
2. Particle-Induced X-Ray Emission Spectrometry (PIXE) Johansson, A. E. Campbell, (ISBN 978-0-471-58944-0 - John Wiley & Sons)
3. Introductory Nuclear Physics,(Chapter 20) Kenneth S. Krane, (Wiley India Private Ltd)
4. Useful Link for XRD-<http://pd.chem.ucl.ac.uk/pdnn/powintro/whatdiff.htm>
5. Materials Science and Engineering, V.Raghavan, Prentice Hall India Ltd.

#### Practical for Semesters III & IV **A) PHY3P05 & PHY4P06 (MODERN PHYSICS)**

*At least 10 experiments are to be done from Part A and 2 each from the optional papers. If no practical have been given for the particular optional papers, two more experiments from Part A should be done. It may be noted that some experiments are given both in Part A and B – of course such experiments can be done only once: either as included in A or in B. Internal evaluation to be done and grades to be intimated to the controller at the end of the semester itself. One mark is to be deducted from internal marks for each experiment not done by the student if the required total of experiments are not done in the semesters. The PHOENIX Experimental Kit developed at the Inter University Accelerator Centre, New Delhi, may be used for experiments wherever possible.*

#### **PART A**

1. G.M. Counter plateau and statistics of counting - To obtain the plateau, operating voltage and to verify the distribution law satisfied by the radioactive decay
2. Absorption coefficient for beta & gamma rays -To determine the absorption coefficient of the given materials using a G.M.Counter
3. Feather analysis – End point energy - To determine the end point energy of the beta particles from a given source using Feather analysis
4. Scintillation counter - To calibrate the given gamma ray (scintillation) spectrometer using standard gamma sources and to determine the energy of an unknown gamma ray source
5. Compton scattering - To verify the theoretical expression for the energy of the Compton scattered gamma rays at a given angle using a Scintillation gamma spectrometer / determine the rest mass energy of the electron
6. Half life of Indium – thermal neutron absorption - To determine the half life of In-116 by irradiation of In foil and beta counting using a GM counter
7. Photoelectric effect in lead - To get the spectrum of X rays emitted from lead target by photo electric effect using Cs-137 gammas
8. Conductivity, Reflectivity, sheet resistance and refractive index of thin films
9. Hall effect in semiconductors-To determine the carrier concentration in the given specimen of semiconducting material
10. ESR spectrometer – Determination of g factor
11. Rydberg constant determination
12. Absorption spectrum of  $\text{KMnO}_4$  and Iodine. To determine the wavelength of the absorption bands of  $\text{KMnO}_4$  and to determine the dissociation energy of iodine molecule from its absorption spectrum.
13. Ionic conductivity of KCl/NaCl crystals
14. Curie Weiss law -To determine the Curie temperature
15. To study the Thermoluminescence of F-centres of Alkali halides
16. Variation of dielectric constant with temperature of a ferroelectric material (Barium Titanate)
17. Polarization of light and verification of Malu's law.
18. Refractive index measurement of a transparent material by measuring Brewster's angle
19. Measurement of the thermal relaxation time constant of a serial light bulb.
20. Dielectric constant of a non polar liquid
21. Vacuum pump – pumping speed
22. Pirani gauge – characteristics
23. Ultrasonic interferometer. To determine the velocity and compressibility of sound in liquids.
24. Study of LED characteristics - Determination of wavelength of emission, I-V characteristics and variation with temperature, variation of output power vs. applied voltage

25. Optical fibre characteristics - To determine the numerical aperture, attenuation and band width of the given optical fibre specimen
26. Band gap energy of Ge by four probe method.-To study bulk resistance and to determine band gap energy.
27. Thomson's e/m measurement.-To determine charge to mass ratio of the electron by Thomson's method.
28. Determination of Band gap energy of Ge and Si using diodes.
29. Millikan's oil drop experiment .To measure the charge on the electron
30. Zener voltage characteristic at low and ambient temperatures – To study the variation of the Zener voltage of the given Zener diode with temperature
31. Thermionic work function – To determine the thermionic work function of the material of the cathode of the given vacuum diode/triode from the characteristic at different filament currents

## **PART B**

### **I . ADVANCED ELECTRONICS**

1. Simple temperature control circuit
2. Binary rate multiplier
3. Optical feedback amplifier
4. Frequency modulation and pulse modulation
5. Binary multiplier
6. Write ALP and execute using 8085 kit for generating a square wave of desired frequency using PPI 8255 interfacing. observe the output on CRO and measure frequency.
7. Write ALP to alternately switch on/off a green and a red LED within a given small time interval. Execute using 8085 kit.
8. Write ALP to convert a given d.c voltage (between 0 and 5 V) using ADC 0800/0808 interfaced to 8085 microprocessor. Execute using the given kit and check the result.

### **II. MATERIAL SCIENCE / CONDENSED MATTER PHYSICS**

1. Curie-Weiss law – (To determine the Curie temperature)
2. Solid-liquid phase transitions – measurement of resistivity of metals
3. Growth of a single crystal from solution and determination of structural, electrical and optical properties
4. Study of colour centres – Thermoluminescence glow curves
5. Ionic conductivity in KCl/NaCl crystals
6. Thermoluminescence spectra of alkali halides
7. Thermo emf of bulk samples (Al/Cu)
8. Electron spin resonance
9. Strain gauge – Y of a metal beam
10. Variation of dielectric constant with temperature of a ferro electric material ( Barium titanate)
11. Ferrite specimen – variation of magnetic properties with composition

### **III. COMMUNICATION ELECTRONICS**

1. Amplitude modulation and demodulation
2. Frequency modulation and demodulation
3. Pulse amplitude modulation and demodulation
4. Pulse code modulation and demodulation
5. Pulse position modulation and demodulation
6. Study of crystal detector
7. L-C transmission line characteristic
8. Tuned RF amplifier
9. Seely discriminators
10. AM transmitter
11. Radiation from dipole antenna
12. Optical fibre characteristics (Numerical aperture, attenuation and bandwidth)
13. Optical feed back circuit (Feedback factor, gain and frequency response)

### **IV. ADVANCED NUCLEAR PHYSICS and RADIATION PHYSICS**

1. Half-life of Indium – thermal neutron absorption - To determine the half-life of In-116 by irradiation of In foil and beta counting using a GM counter
2. Alpha spectrometer - To calibrate the given alpha spectrometer and determine the resolution
3. Photoelectric effect in lead - To get the spectrum of X rays emitted from lead target by photo electric effect using Cs-137 gammas

4. Inner bremsstrahlung - To study the intensity spectrum of inner bremsstrahlung from given gamma source
5. Coincidence circuits - To construct and study the performance of series and parallel coincidence circuits using transistors and to determine the resolving time
6. Single channel analyzer - Study of characteristics of a SCA using precision pulser
7. Ionization chamber - Study of variation of pulse height with applied voltage and to obtaining the pulse height spectrum of X-rays
8. Proportional counter - Study of variation of pulse height with applied voltage and to obtaining the pulse height spectrum of X-rays
9. Track detector – track diameter distribution - To measure the diameters of the alpha tracks in CR-39 track detector
10. Beta ray spectrometer - To plot the momentum distribution of beta particles from given beta sources
11. Range of alpha particles in air and mylar - To determine the range of alpha particles from Am-241 source in air and in mylar using either a surface barrier detector or a GM counter

#### **V. EXPERIMENTAL TECHNIQUES**

1. Rydberg constant – hydrogen spectrum
2. ESR – Lande g factor
3. IR spectrum of few samples
4. Vacuum pump – pumping speed
5. Vacuum pump – Effect of connecting pipes
6. Absorption bands of Iodine
7. Vibrational bands of AlO
8. Pirani gauge – characteristics
9. Thin films – electrical properties (sheet resistance)
10. Thin films – optical properties (Reflectivity, transmission, attenuation, refractive index)

#### **VI. ELECTRONIC INSTRUMENTATION**

1. Strain gauge
2. Simple servomechanism
3. Temperature control
4. Coincidence circuits
5. Multiplexer
6. IEEE 488 Electrical interface
7. Single channel analyzer
8. Differential voltmeter
9. Frequency synthesizer – Signal generator
10. Silicon controlled rectifier – characteristics
11. Silicon controlled rectifier – power control

#### **VII. DIGITAL SIGNAL PROCESSING**

1. Write a MATLAB program to plot the solution of selected difference equations like  $u(n) = x(n-2) + x(n-1) + x(n)$  and  $u(n-1/2) y(n-1) = x(n)$
2. Compute and plot the correlation coefficients of discrete time signals using MATLAB
3. Compute the convolution of two discrete time signals and plot using MATLAB.
4. Find the frequency of the given tuning fork by the FFT spectral analysis method and check the frequency resolution using different windowing methods
5. Design an FIR filter by using Filter Design toolbox in MATLAB. Analyse the stability using pole-zero analysis.

#### **VIII. LASER AND FIBRE OPTICS**

1. Optical fibre characteristics (Numerical aperture, attenuation and bandwidth)
2. Optical feed back circuit (Feedback factor, gain and frequency response)
3. Determination of size of lycopodium particles by Laser diffraction

Reference Books for PHY 305 & PHY 405 :

1. B.L. Worsnop and H.T. Flint – Advanced Practical Physics for students – Methusen & Co (1950)
2. E.V. Smith – Manual of experiments in applied Physics – Butterworth (1970)
3. R.A. Dunlap – Experimental Physics – Modern methods – Oxford University Press (1988)



4. D. Malacara (ed) – Methods of experimental Physics – series of volumes – Academic Press Inc (1988)
5. Experiments in Modern Physics: Mellissinos

### B) PHY 4P07: COMPUTATIONAL PHYSICS

*The programs are to be executed in Python. For visualization Pylab/matplotlib may be used. At least **ten** experiments are to be done, opting any **five** from **Part A** and another **five** from **Part B**. The Practical examination is of 6 hours duration.*

#### Part A

1. Interpolation : To interpolate the value of a function using Lagrange's interpolating polynomial
2. Least square fitting :To obtain the slope and intercept by linear and Non-linear fitting.
3. Evaluation of polynomials. Bessel and Legendre functions: Using the series expansion and recurrence relations.
4. Numerical integration : By using Trapezoidal method and Simpson's method
5. Solution of algebraic and transcendental equations .Newton Raphson method, minimum of a function
6. Solution of algebraic equation by Bisection method
7. Matrix addition, multiplication, trace, transpose and inverse
8. Solution of second order differential equation- Runge Kutta method
9. Monte Carlo method : Determination of the value of  $\pi$  by using random numbers
10. Numerical double integration
11. Solution of parabolic/elliptical partial differential equations  
(eg: differential equations for heat and mass transfer in fluids and solids, unsteady behaviour of fluid flow past bodies, Laplace equation etc.,)

#### Part B

1. To plot the trajectory of a particle moving in a Coulomb field (Rutherford scattering) and to determine the deflection angle as a function of the impact parameter
2. Generate phase space plots - To plot the momentum v/s position plots for the following systems : (i) a conservative case ( simple pendulum) (ii) a dissipative case ( damped pendulum)
3. Simulation of the wave function for a particle in a box - To plot the wave function and probability density of a particle in a box; Schrödinger equation to be solved and eigen value must be calculated numerically.
4. Simulation of a two slit photon interference experiment : To plot the light intensity as a function of distance along the screen kept at a distance from the two slit arrangement.
5. Trajectory of motion of (a) projectile without air resistance (b) projectile with air resistance
6. Logistic map function – Solution and bifurcation diagram
7. Experiment with Phoenix/expEYES kit - Time constant of RC circuits by curve fitting. \*
8. Experiment with Phoenix/expEYES kit - Fourier analysis of different waveforms captured using the instrument. \*  
(\*If Phoenix is not available, data may be given in tabulated form)
9. Simulation of Keplers' orbit and verification of Kepler's laws.
10. Simulations of small oscillations in simple molecules:: Diatomic molecule/Triatomic molecule for various lengths(any one case)
11. Simulation of random walk in 1D/2D and determination of mean square distance.
12. Simulation of magnetic field - To plot the axial magnetic field v/s distance due to a current loop carrying current.
13. Simulation of the trajectory of a charged particle in a uniform magnetic field.
14. Simulation of polarisation of electromagnetic waves.
15. Simulation of coupled oscillators - Phase space portraits.

#### Text Books :

1. Computational Physics -An introduction., R.C.Varma, P.K.Ahluwalia and K.C.Sharma, New Age International Publishers
2. Numpy Reference guide, <http://docs.scipy.org/doc/numpy/numpy-ref.pdf> (also, free resources available on net)
3. Matplotlib , <http://matplotlib.sf.net/Matplotlib.pdf> (and other free resources available on net)
4. Numerical Methods in Engineering and Science, Dr. B S Grewal, Khanna Publishers, New Delhi (or any other book)

5. Numerical Methods, E Balagurusamy, Tata McGraw-Hill
6. Numerical Methods , T Veerarajan, T Ramachandran, Tat MCGraw-Hill
7. Numerical Methods with Programs I BASIC, Fortran & Pascal, S Balachandra Rao, C K Shantha. Universities Press
8. Numerical methods for scientists and engineers, K. Sankara Rao, PHI
9. Introductory methods of numerical analysis, S.S.Shastry , (Prentice Hall of India,1983)
10. Numerical Methods in Engineering with Python by Jaan Kiusalaas

Note: Experiments from Part A can be done with data from physical situations where ever possible. For example consider the following cases.

- a) The load W placed on a spring reduces its length L. A set of observations are given below. Calculate force constant and length of the spring before loading

W (kg)	0.28	0.51	0.67	0.93	1.15	1.38	1.60	1.98
L (m)	6.62	5.93	4.46	4.25	3.3	3.15	2.43	1.46

- b) The displacements of a particle at different instants are given below. What is the time instant at which the displacement is 70.2 m

t(s)	1.0	2.2	301	4.5	5.8	6.7	7.6	8.3	9.4
s(m)	3.0	10.56	19.07	37.12	59.16	77.38	98.04	115.78	146.6

## SEMESTER IV

### PHY4C12: ATOMIC AND MOLECULAR SPECTROSCOPY (4C)

#### 1. Atomic Spectroscopy: (10 hours)

Vector Atom model – L S coupling & J J coupling effect of electric & magnetic field on atoms and molecules; Zeeman effect, Paschen Back effect and stark effect

Text: Sections 10.1 to 10.11, 12.1 to 12.10, 13.1 to 13.9, 20.1 to 20.8 –Introduction to atomic spectra by H E White

#### 2. Microwave and Infrared spectroscopy: (14 hours)

The spectrum of non rigid rotator, e.g. of HF, spectrum of symmetric top molecule e.g. of CH<sub>3</sub>Cl, Instrumentation for Microwave Spectroscopy Stark Modulator, Information derived from Rotational Spectrum: I R Spectroscopy: Born –Oppenheimer approximation, Effect of Breakdown of Born Oppenheimer approximation, Normal modes and vibration of H<sub>2</sub>O and CO<sub>2</sub>. Instrumentation for I R Spectroscopy – Fourier transformation I R Spectroscopy

Text: Sections 6.6, 6.7, 6.8, 6.9, 6.11, 6.13, 6.14, 7.1 to 7.7, 7.12, 7.15, 7.16, 7.17, 7.18 Molecular structure and Spectroscopy by G.Aruldas

#### 3. Raman Spectroscopy: (12 hours)

Rotational Raman Spectrum of Symmetric top molecules, e.g. of CHCl<sub>3</sub> Combined use of Raman & IR Spectroscopy in structure determination e.g. of CO<sub>2</sub> and NO<sub>3</sub>. Instrumentation for Raman Spectroscopy, Non-linear Raman effects, Hyper Raman effect, stimulated Raman effect and Inverse Raman Effect

Text: Sections 8.32, 8.4, 8.5, 8.6, 8.7, 8.10, 15.1, 15.2, 15.3, 15.4 Molecular structure and Spectroscopy by G.Aruldas

#### 4. Electronic Spectroscopy of molecules: (10 hours)

Vibrational Analysis of band systems, Deslander's table, Progressions & sequences, Information Derived from vibrational analysis, Franck Condon Principle. Rotational fine structure and P R and R Branches, forttrat Diagram, Dissociation Energy, Example of Iodine molecule Text: Sections 9.1 to 9.9 Molecular structure and Spectroscopy by G.Aruldas

#### 5. Spin Resonance Spectroscopy: (15 hours)

Interaction of nuclear spin and magnetic field, level population Larmour precession, Resonance Conditions, Bloch equations, Relaxation times, Spin-spin and spin lattice relaxation. The chemical shift, Instrumentation for NMR spectroscopy, Electron Spin Spectroscopy of the unpaired e, Total Hamiltonian, Fine structure, Electron Nucleus coupling, and hyperfine spectrum ESR spectrometer. Mossbauer Spectroscopy, Resonance fluorescence of  $\gamma$ -rays, Recoilless emission of  $\gamma$ -rays and Mossbauer effect, Chemical shift, effect of magnetic field. Eg. of Fe<sup>57</sup> Experimental techniques, Enough exercises.

Text: Sections 10.1 to 10.9, 11.1 to 11.5.4, 13.1 to 13.5 Molecular structure and Spectroscopy by G.Aruldas

Text Books:

1. Molecular Structure & Spectroscopy G Aruldas
2. C N Banwell & E.M. Mccash – Fundamentals of Molecular Spectroscopy
3. Atomic Spectroscopy – White

References:

1. Straughan and Walker Spectroscopy Volume I, II and III
2. G.M.Barrow – Introduction to Molecular Spectroscopy
3. H.H. Willard, Instrumental Methods of Analysis, 7th Edition, CBS-Publishers, New Delhi.
4. Atomic Spectroscopy –K P Rajappan Nair, MJP Publishers, Chennai
5. Elements of spectroscopy Gupta & Kumar –Pragati Prakasan, Meerut

Elective -II

**(Elective-II to be opted from PHY4E08- PHY4E14)**

### **PHY4E08: ADVANCED NUCLEAR PHYSICS**

#### **1. Nuclear Shell Model:**

Shell structure and magic numbers, The nuclear one particle potential, spin-orbit term, realistic one body potentials, Nuclear volume parameter, single particle spectra of closed shell + 1 nuclei, Harmonic oscillator and infinite square well potentials in 3- dimensions, coupling of spin and orbital angular momentum, magnetic dipole moment and electric quadrupole moment, Schmidt diagram; Single particle orbitals in deformed nuclei, perturbation treatment, asymptotic wave functions, single particle orbitals in an axially symmetric modified oscillator potential (15 Hours)

Text : “Shapes and Shells in Nuclear Structure”, S.G. Nilsson and I. Ragnarsson, Sections Chapter 5, 6, 7, 8.1 – 8.6

#### **2. Nuclear collective models:**

Nuclear rotational motion- rotational energy spectrum and wave functions for even-even and odd-A nuclei - Nuclear moments- collective vibrational excitations, Rotational Bands - The particle rotor model, strong coupling- deformation alignment, Decoupled bands - rotational alignment; two particle excitations and back- bending; Fast nuclear rotation- the cranking model; Rotating harmonic oscillator (10 Hours)

Texts :

1. “Nuclear Physics- Theory and Experiment”, R.R. Roy and B.P. Nigam (Wiley Eastern) Sections, 8.1 – 8.5
2. “Shapes and Shells in Nuclear Structure”, S.G. Nilsson and I. Ragnarsson, Sections : 11, 11.1 – 11.3, 12, 12.1, 12.2

#### **3. Nuclear Reactions:**

Reactions and Cross-sections, Resonances, Breit-Wigner formula for  $l = 0$ , Compound Nucleus formation, continuum theory, statistical theory, evaporation probability, Heavy ion reactions (10 Hours)

Texts :

1. “Nuclear Physics- Theory and Experiment”, R.R. Roy and B.P. Nigam (Wiley Eastern) Sections 6.1, 6.2, 6.4 – 6.8
2. Kenneth Krane – “Introductory Nuclear Physics”, (Wiley), Section 11.13

#### **4. Nuclear Fission:**

The semi-empirical mass formula, The stability peninsula, nuclear fission and the liquid drop model, some basic fission phenomena, fission barrier. Nuclear Fission- cross-section, spontaneous fission, Mass and energy distribution of fragments, Statistical model of Fission (12 Hours)

Text : “Nuclear Physics- Theory and Experiment”, R.R. Roy and B.P. Nigam (Wiley Eastern) Sections, Chapter 5 full

#### **5. Reactor Physics:**

Fick’s law and its validity, Diffusion equation, diffusion length, Energy loss in elastic collision, Lethargy, Fermi age equation- solutions and measurement of age, Fermi age theory of bare thermal reactors, criticality, one region finite thermal reactor, criticality condition for different geometries (12 Hours)

Text Book : “Introduction to Nuclear Reactor Theory”, B.R. Lamarsh (Addison- Wesley) Sections 5.1, - 5.7, 5.11, 6.1, 6.4, 6.9 – 6.14, 9.1 – 9.8

Reference Books :

1. “Introductory Nuclear Physics”, Samuel M. Wong (Prentice Hall India 1996) Chapter 7)
2. “Nuclear Physics – Experimental and theoretical” – H.S. Hans, New Age International (2001)
3. “Theory of nuclear structure” – M.K Pal, (East West Press Pvt Ltd)

## PHY4E09: ASTROPHYSICS

### 1. Radiative Process:

Theory of Black Body Radiation-Photoelectric Effect-Pressure of Radiation -Absorption and Emission spectra - Doppler Effect - Zeeman Effect- Bremsstrahlung - Synchrotron Radiation - Scattering of Radiation - Compton Effect - and Inverse Compton effect (8 Hours)

Text : Baidyanath Basu, Ch 2

### 2. Variable stars:

Classification of Variable stars – Cepheid variables – RV Tauri variables - Mira variables – Red Irregular and Semi-regular variables – Beta Canis Majoris Variables–U Geminorum and Flare stars–Theory of Variable stars. (8 hours)

Text : Baidyanath Basu, Ch. 8

### 3. Galaxies:

The Milkyway galaxy - Kinematics of the Milkyway – Morphology – Galactic Centre – Morphological classification of galaxies – Effects of environment – Galaxy luminosity function – The local group – Surface photometry of galaxies - ellipticals and disk galaxies – Globular cluster systems – Abnormal galaxies-Active galactic nuclei. (20 Hours)

Text : Binney & Merrifield, Ch.4

### 4. General Relativity:

General Considerations - Connection Between Gravity and Geometry - Metric Tensor and Gravity - Particle Trajectories in Gravitational field - Physics in curved space-time – Curvature - Properties of Energy and momentum Tensor - Schwarzschild Metric - Gravitational Collapse and BlackHoles – Gravitational Waves (15 Hours)

Text : Padmanabhan, Vol 2, Ch.11

### 5. Cosmology:

Cosmological Principle - Cosmic Standard Coordinates - Equivalent Coordinates – Robertson-Walker Metric - The Red Shift - Measures of Distance - RedShift Versus Distance Relation - Steady State Cosmology (10 Hours)

Text : Narlikar, Sections 3.1-3.8

Books Suggested:

1. Gravitation & Cosmology-Steven Weinberg- John Wiley (1972) ISBN: 0-471-92567-5
2. Theoretical Astro Physics Vol 1 and 2- T. Padmanabhan- Cambridge University Press (2000) ISBN: 0-521-56240-6, 0-521-56241-4
3. Quasars and Active Galactic Nuclei- Ajit K Kembhavi and Jayant V Narlikar-Cambridge University Press (1999) ISBN:0-521-47477-9
4. The Physical Universe, An Introduction to Astronomy-F. Shu-Oxford University Press- (1982) ISBN: 0-19-855706-X
5. A Different Approach to Cosmology - Fred Hoyle, Geoffrey, Jayant V Narlikar Cambridge University Press (2000) ISBN:0-521-66223-0
6. An Introduction to AstroPhysics - Baidyanath Basu- Prentice Hall India ( 1997) ISBN:81-203-1121-3
7. Discovering the Cosmos-R.C. Bless - University Science Books (1996) - ISBN:0-935702-67-9
8. Text Book of Astronomy and Astrophysics with Elements of Cosmology- V.B. Bhatia-Narosa publications (2001)ISBN:81-7319-339-8
9. Modern Astrophysics - B.W. Carroll & D.A. Ostille - Addison Wesley (1996) ISBN:0-201-54730-9
10. Galactic Astronomy – J. Binney & M. Merrifield, Princeton University Press
11. Galactic Dynamics – J. Binney & S. Tremaine, Princeton University Press
12. An Introduction to Cosmology, Third Edition- J. V. Narlikar, Cambridge University Press (2002)

For further reference:

Astrophysics & Cosmology Video Prof. S. Bharadwaj IIT Kharagpur  
<http://nptel.iitm.ac.in/courses/115105046/>

## PHY4E10: ADVANCED STATISTICAL MECHANICS

- 1. Thermodynamics of crystal lattice**, the field of sound waves, phonons and second sound, The Debye model, Debye temperature, specific heat of solid in the Debye model (10 hours)
- 2. Non ideal systems**, intermolecular interactions, Lennard Jones potential, Corrections to the ideal gas law, Van der Waals equation, Short distance and long distance interaction, The plasma gas and ionic solutions, The Debye-Huckel radius (12 hours)
- 3. Phase transition**, critical point, First order phase transition, Phase diagrams, The theory of Lang and Lee, A dynamical model for phase transitions, Weiss theory of ferromagnetism, Second order phase transition, Landau theory, Critical point exponents, Chemical equilibrium and chemical reactions (12 hours)
- 4. Ising model** as a macroscopic model of phase transition, Why the Ising model is very important? Relationship between lattice models, models of ferroelectrics and Ising model, The classical formulation of the problem, Exact solutions, Drawbacks of the mean field approximation, The static fluctuation approximation as new method for solving the Ising problem (14 hours)
- 5. Fluctuations**, fluctuations of macroscopic variables, Theory of random processes, Response and fluctuation, Correlation functions, Spectral analysis of fluctuations: the Weiner-Khintchine theorem, The Nyquist theorem, Applications of the Nyquist theorem (12 hours)

Text Book : Patria : "Statistical Mechanics" (Butterworth-Heinemann,1996)

Reference Books:

1. Kerson Huang : "Statistical Mechanics" (second edition) (Wiley,1987)
2. B.K. Agarwal and Melvin Eisner : "Statistical Physics"
3. Guptha and Kumar : "Statistical Physics"
4. J.E. Meyer and M.G. Meyer, Statistical Mechanics, John Wiley

## PHY4E11: MATERIALS SCIENCE

- 1. Crystal Imperfections- 6 Hours**  
Point imperfections- The geometry of dislocations- Other properties of dislocations- Surface imperfections  
Text book: 'Materials Science and Engineering – A First Course' – IV th Edition- V.Raghavan (Prentice-Hall of India- 1988) (Sections: 6.1 to 6.4)
- 2. Phase Diagrams & Diffusion In Solids - 12 Hours**  
The phase rule- Single component system- Binary phase diagrams- The Lever rule- Some typical phase diagrams and applications  
Text book: 'Materials Science and Engineering – A First Course' – IV th Edition- V.Raghavan (Prentice-Hall India- 1988) (Sections: 7.1 to 7.7)  
Fick's law and solutions- Applications based on the second law solution- The Kirkendall effect- The atomic model of diffusion- Other diffusion processes  
Text book: 'Materials Science and Engineering – A First Course' – IV th Edition- V.Raghavan (Prentice-Hall of India- 1988) (Sections: 8.1 to 8.6)
- 3. Plastic Deformation And Fracture Of Materials-10 Hours.**  
The tensile stress- Strain curve- Plastic deformation by slip- Shear strength of perfect and real crystals- The stress to move a dislocation- Dislocation multiplication-Work hardening- The effect of grain size and precipitate particles on dislocation motion- Mechanism of creep.  
Text book: 'Materials Science and Engineering – A First Course' – IV th Edition- V.Raghavan (Prentice-Hall India- 1988) (Sections: 11.1, 11.2, 11.3, 11.4, 11.6,11.7, 11.8, 11.10 & 11.11 )  
Ductile fracture- Brittle fracture- Fatigue fracture- Methods of protection against fracture.  
Text book: 'Materials Science and Engineering – A First Course' – IV th Edition- V.Raghavan (Prentice-Hall of India- 1988) (Sections: 12.1, 12.2, 12.5 & 12.6)
- 4. Engineering Materials- 22 Hours**  
Giant molecules-Linear polymers- Three dimensional polymers-Deformation of plastics-Electrical behavior of polymers-Stability of polymers  
Text book : 'Elements of Materials Science' –IIIrd Edition – Lawrence H. Van Vlack ( Addison- Wesley Publishing Company Inc.1964.) ( Sections : 7.1, 7.2, 7.4, 7.5, 7.6 & 7.7)  
Ceramic phases- Silicate structures- Glasses- Electromagnetic behavior of ceramics- Mechanical behavior of ceramic materials.  
Text book : 'Elements of Materials Science' – IIIrd Edition – Lawrence H. Van Vlack ( Addison- Wesley Publishing Company Inc. 1964. ) ( Sections : 8.1, 8.5, 8.6, 8.7 & 8.8) -16 Hours

Growth techniques of nanomaterials- Top-down Vs.Bottom-up technique-Lithographic process and its limitations- Nonlithographic techniques-Plasma arc discharge-Sputtering- Evaporation-Thermal evaporation- e-beam evaporation – Chemical vapor deposition- Molecular beam epitaxy-Other processes.

Text book : ‘ Introduction to Nanoscience & Technology ’- K.K.Chathopadhyay, A.N.Banerjee ( Prentice-Hall of India -2011.) ( Sections 6.2, 6.3, 6.4, 6.4.1, 6.4.2,6.4.3, 6.4.3.1, 6.4.3.2, 6.4.4, 6.4.6 & 6.4.9.)

- 6 Hours

#### 5. **Characterization Of Nanomaterials-** 10 Hours

Characterization tools of Nanomaterials-Scanning probe microscopy- Tunnelling current- Local barrier height-Applications of STM- AFM- Scanned –Proximity probe microscopes-Laser beam deflection-AFM cantilevers-piezoceramics-feedback loop-Alternative imaging modes-AFM and biology-Electron microscopy-Resolution vs. magnification-Scanning Electron microscope-SEM techniques-Electron gun-Specimen interactions-Environmental SEM- Transmission electron microscopy-Buckminsterfullerene-Carbon nanotube.

Text book : ‘ Introduction to Nanoscience & Technology ’- K.K.Chathopadhyay, A.N.Banerjee ( Prentice-Hall of India -2011.) ( Sections 7.1.2, 7.1.3.1, 7.1.3.2, 7.1.3.5, 7.2.1,7.2.2, 7.2.3, 7.2.4, 7.2.5, 7.2.6, 7.2.7, 7.3.1, 7.3.2, 7.3.3, 7.3.4, 7.3.5, 7.3.6, 7.3.7, 7.4, 8.2.1 & 8.2.2)

References:

1. ‘Solid State Physics’- A.J.Dekker (MacMillan India Ltd.- 1958)
2. ‘Principles of the Solid State’- H. V.Keer ( Wiley Eastern – 1993)
3. ‘Solid State Physics: Structure and Properties of Materials’- M.A.Wahab ( Narosa- 2007).
4. ‘Materials Science and Processes’ – S.K. Hajra Choudhury ( Indian Book Publishing Co.-2009)
5. ‘Nanotechnology ’- Richard Booker, Earl Boysen (Wiley Publishing Inc. 2005).

### **PHY4E12: ELECTRONIC INSTRUMENTATION**

#### **1. Electronic Instrumentation for measuring basic parameters:**

Electronic DC voltmeters, DC voltmeter circuit with FET, amplified voltage and current meter, chopper stabilized amplifier, electronic AC voltmeters (average responding, peak responding and true rms responding types), electronic multimeters , differential voltmeters –digital voltmeters (ramp and staircase type), RF millivoltmeter, Q meter (basic circuit and measurement methods, sources of error), bolometer and RF power measurement (12 hours)

#### **2. Signal generators and Oscilloscopes:**

Standard signal generator, laboratory signal generator, AF sine wave and square wave generator, function generator and pulse generator, Block diagram of general purpose CRO, CRT circuits , vertical deflection system , delay line, multiple trace, horizontal deflection system, oscilloscope probes and transducers, oscilloscope technique, storage oscilloscopes, sampling oscilloscopes. (14 hours)

#### **3. Fibre optic measurements and Transducers:**

Sources and detectors, fibre optic power measurement, stabilized light sources, optical time domain reflectometer, Classification of transducers – strain gauges – displacement transducers – temperature measurements – photosensitive devices - Radiation detectors – solid state and scintillation detectors – neutron detectors, ECG and EEG (brain imaging – X ray, CT, MRI and nuclear imaging) (15 hours)

#### **4. Computer controlled test systems:**

Testing an audio amplifier – testing a radio receiver – instruments used in computer controlled instrumentation – IEEE 488 electrical interface – digital control – signal timing in a microprocessor based measurement. (9 hours)

#### **5. Power control: SCR**

Control of current in rectifiers with an inductive load – triggering control by phase shifting – saturable reactor control – combined d.c. and phase control – on off pulse control of the SCR – SCR supply for d.c. motor – speed regulation by armature voltage and current control –armature current limiting control of low torque a.c. motors (10 hours)

Books:

- 1.Modern Electronic instrumentation and measurement technique – Albert D Helfrick and William D Cooper (Tata Mc Graw Hill) for modules 1, 3, 4 and second part of 2
- 2.Electronic Instrumentation – Second edition – H.S. Kalsi (Tata Mc Graw Hill) for modules 1 and first part of module 2
- 3.Principles of Medical electronics and bio medical instrumentation – C Rajarao and S.K. Gupta (Universities Press) for Transducers
- 4.Bio Instrumentation – John G Webster (Wiley student edition) – for Transducers
- 5.“Introduction to Experimental Nuclear Physics”, Singru,R.M., (Wiley Eastern, 1972). for transducers
- 6.“Engineering Electronics”, 2nd Edition,Ryder, J.D., (McGraw Hill, 1967). for module 5

## PHY4E13: LASERS AND FIBRE OPTICS

### 1. Basic Laser Theory And Optical Resonators:

Einstein coefficients , Evaluation of transition rates, Line broadening mechanisms, Laser rate equations for three level system, Cavity Modes, Q of cavity, Q Switching, Mode locking , Confocal Resonator, Analysis of optical resonators using geometrical optics. ( 12 Hrs )

### 2. Types Of Lasers And Applications:

Ruby laser, Helium-Neon laser, Four level solid state lasers, CO<sub>2</sub> lasers Dye lasers, Semiconductor lasers, Spatial frequency filtering and holography, Laser induced fusion, Second Harmonic Generation. ( 8 Hrs )

### 3. Optical Fibers:

Introduction, What are optical fibers, Importance, propagation of light in optical fibers, Basic structure, Acceptance angle, Numerical aperture, Stepped index monomode fibers, disadvantages, Graded index monomode fibers, Optical fibers as cylindrical waveguides, Scalar wave equation and the modes of a fiber, Modal analysis for a step index fiber, Single mode fibers. ( 15 Hrs)

### 4. Fiber Losses:

Attenuation in optical fibers, Absorption losses, Leaky modes, Radiation induced losses, Inherent defect losses, Inverse square losses, Core and cladding losses. ( 6 Hrs )

### 5. Measurement On Fibers:

Measurement of numerical aperture and its related terms, measurement of fiber attenuation, Insertion loss method and by optical time domain reflectometer, Measurement of refractive index by reflection method and transmitted near field method, Enough exercises. (9 Hrs)

Books:

1. K.Thyagarajan and Ajoy. K. Ghatak, Lasers : Theory and Application, Macmillan
2. Ajoy Ghatak and K. Thyagarajan, Optical Electronics, Foundation Books (Cambridge University)

Reference Books:

1. William T. Silfast, Laser Fundamentals
2. Subirkumar Sarkar, Optical Fiber and Fiber Optic Communication Systems, S. Chand & Co.
3. Ajoy Ghatak and K.Thayagarajan, Introduction to Fiber Optics, Cambridge.
4. John. M.Senior, Optical Fiber Communications: Principles and Practice

## PHY4E14: COMMUNICATION ELECTRONICS

### 1. Amplitude and angle modulation:

Amplitude modulation – Amplitude modulation and demodulation circuits – single side band generation and detection – SSB balanced modulator – Comparison of signal to noise ratios – Frequency modulation - Phase modulation – Angle modulation circuits – Detection of FM signals –Foster–Seeley discriminator – Ratio detector – Noise in FM (10 hours)

### 2. Pulse modulation and digital communication:

Elements of information theory – Pulse transmission – Pulse amplitude modulation – Pulse time modulation – Pulse code modulation – Coding – Codes – Error detector and correction codes – Digital carrier systems – Teleprinter and telegraph circuits (10 hours)

### 3. Communication systems:

Receivers – Superheterodyne receiver – AM receivers – Automatic gain control –Communications receivers – FM receivers – Single and independent side band receivers. Transmitters –Telegraph transmitters – AM transmitters – FM transmitters – Television transmitters HF radio systems –VHF/UHF systems – Microwave systems – Satellite communications (12 hours)

### 4. Signals and Systems:

Classifications of signals, concept of frequency in continuous - time and discrete –time signals. Theory of A/D and D/A conversion, Sampling of Analog signals, sampling Theorem. Quantization of continuous amplitude signal, Coding of quantized samples, Discrete time linear time invariant systems - Techniques of analysis of linear systems, Resolution of a discrete time signal into impulses- Response of LTI systems to arbitrary inputs :Convolution sum- properties of convolution and the interconnection of LTI systems-Casual LTI systems – Stability of LTI systems. (12 hours)

### 5. Radiation and antennas:

Potential functions and the EM field – Radiation from an oscillating dipole –Power radiated by a current element – Radiation resistance of a short dipole – Radiation from a quarter wave monopole -

Directivity – Gain and effective aperture - Antenna arrays – Two element, linear and binomial – Frequency independent antennae – Log periodic antennae – Yagi antennae. Propagation of radio waves - Ground waves, Sky wave propagation, Space waves, Tropospheric scatter propagation, Extra terrestrial communication. Ionosphere –Reflection and refraction of waves by the ionosphere – Attenuation, Enough exercises. (14 hours)

References:

1. “Electronic Communications”, Roddy and Coolen, J., (PHI, 1986). Chapters 7, 8, 9, 10, 11, 12, 18, 19
2. “Electronic Communication Systems”, 4th Edition, Kennedy, G. and Davis, B. (McGraw Hill, 1992). Chapter 6,8.
3. “Electromagnetic waves and Radiating Systems”, Jordan E.C. and Balmain, K.G. (PHI, 1979). Chapters 10,11,15,17.
4. “Digital Signal Processing” by Proakis and Manolakis, Prentice Hall of India (1997)

ELECTIVE -III  
(Elective-III to be opted from PHY4E15- PHY4E20)

**PHY4E15: QUANTUM FIELD THEORY**

**1. Classical Field Theory :**

Harmonic oscillator, The linear chain- classical treatment, the linear chain – quantum treatment, classical field theory, Hamiltonian formalism, Functional derivatives , Canonical quantization of nonrelativistic fields, Lagrangian and Hamiltonian for the Schroedinger field, Quantization of fermions and bosons, Normalization of Fock states (12 hours)

Text Book : “Field Quantization” Greiner and Reinhardt (Spinger-Verlag -1996), Sections 1.3 – 1.5, 2.2, 2.3, 3.1 – 3.3, Exercise 3.1

**2. Canonical quantization of Klein Gordon and photon fields :**

The neutral Klein – Gordon field Commutation relation for creation and annihilation operators, Charged Klein – Gordon field, Invariant commutation relations, Scalar Feynman propagator, Canonical quantization of photon field - Maxwells equations, Larangian density for the Maxwell field, Electromagnetic field in the Lorentz gauge, Canonical quantization of the Lorentz gauge – Gupta-Bleuler method, Canonical quantization in the Coulomb gauge (14 hours)

Text Book : “Field Quantization” Greiner and Reinhardt (Spinger-Verlag -1996), Sections 4.1, 4.2, 4.4, 4.5, 7.1 – 7.4, 7.7

**3. Canonical quantization of spin  $\frac{1}{2}$  fields :**

Lagrangian and Hamiltonian densities for the Dirac field, Canonical quantization of the Dirac field, Plane wave expansion of the field operator, Feynman propagator for the Dirac field (10 hours)

Text Book : “Field Quantization” Greiner and Reinhardt (Spinger-Verlag -1996), Sections 5.1 – 5.4

**4. Interacting quantum fields and Quantum Electrodynamics :**

The interaction picture, Time evolution operator, Scattering matrix, Wick’s theorem, Feynman rules for QED, Moller scattering and Compton scattering (10 hours)

Text Book : “Field Quantization” Greiner and Reinhardt (Spinger-Verlag -1996), Sections 8.2 – 8.6, Example 8.4

**5. The path integral method :**

Path integrals in non-relativistic Quantum Mechanics, Feynman path integral, Multidimensional path integral, Time ordered product and n-point functions, Path integrals for scalar quantum fields, The Euclidian field theory, The Feynman propagator, Generating functional and Green’s function, Generating functional for interacting fields, Enough exercises. (12 hours)

Text Book : “Field Quantization” Greiner and Reinhardt (Spinger-Verlag -1996), Sections 11.2 – 11.5, 12.1 – 12.5

References :

1. “Quantum Field theory”, Lewis H. Ryder (Cambridge University Press -1995)
2. “Field Theory – A modern primer” – Pierre Ramond (Bengamin – 1996)
3. “Quantum Field theory”, Itzyskon and Zuber (McGraw Hill – 1989)
4. “Quantum Field theory”, Karson Huang (Wiley)



## PHY4E16: CHAOS AND NONLINEAR PHYSICS

### 1. The Dynamics of Differential Equations :

Integration of linear second order equations by quadrature, The damped oscillator, Integration of nonlinear second order equation, Jacobi elliptic functions, Weierstrass elliptic functions, Periodic structure of elliptic functions, The pendulum equation, Phase portrait of the pendulum, Phase portraits for conservative systems, Linear stability analysis, Linear stability matrix, Classification of fixed points, Examples of fixed point analysis, Limit cycle, Time dependent integrals, Non autonomous systems, The driven oscillator, Remarks on integration of differential equations, Elliptic functions .(Chap 1, Tabor) (13 hours)

### 2. Hamiltonian Dynamics :

Lagrangian formulation of mechanics, Lagrangian function and Hamilton's principle, Properties of the Lagrangian and generalized momentum, Hamiltonian formulation of mechanics, Hamilton's equations, Canonical transformations, The preservation of phase volume, The optimal transformation, Generating function, Hamilton Jacobi equation for one degree of freedom, Action angle variable for one degree of freedom, Integrable Hamiltonians, Separable systems, Properties of integrable systems, Examples of integrable systems, Motion on the tori, Fundamental issues, KAM theorem (Chap 2 and sec 3.4, Tabor) (13 hours)

### 3. Chaos in Hamiltonian systems and area preserving mappings :

Surface of section, Surface of section for two degrees of freedom Hamiltonians, The Henon Heiles Hamiltonian, The Toda lattice, Surface of section as a symplectic mapping, Twist maps, Mapping on the plane, Connection between area preserving maps and Hamiltonians, The standard maps, The tangent map, Classification of fixed points, Poincare Birkhoff fixed point theorem, Homoclinic and heteroclinic points, The intersection of H<sup>+</sup> and H<sup>-</sup> whorls and tendrils, Criteria for local chaos, Lyapunov exponents, Power spectra, Criteria for onset of widespread chaos, Method of overlapping resonances, Greene's method, Statistical concepts in strongly chaotic systems, Ergodicity, Mixing, The Baker's transformation and Bernoulli systems, Hierarchies of randomness, Hamiltonian chaos in liquids, Fluid mechanical background, The model system, Experimental results (Sec 4.1 to 4.8, Tabor) (13 hours)

### 4. Dynamics of dissipative systems :

Dissipative systems and turbulence, The Navier Stokes equations, The concept of turbulence-a Hamiltonian degeneration, Experimental observations on the onset of turbulence, Couette flow, Rayleigh-Benard convection, Landau-Hopf theory, Hopf bifurcation theory, Ruelle-Takens theory, Other scenarios, Fractals, Mathematical model of strange attractors, Lorentz systems, Variations on Lorentz model, The Henon map, Period doubling bifurcations - Period doubling mechanism - Bifurcation diagram - Behaviour beyond  $1\mu$  - Other universality classes (Sec. 5.1 to 5.5, Tabor) (13 hours)

### 5. Solitons :

Historical background, Russel's observations, The F U P experiment, Discovery of the soliton, Basic properties of KdV equations, Effects of nonlinearity and dispersion, The traveling wave solution, Enough exercises. (Sec 7.1 and 7.2, Tabor) (8 hours)

Text Book:

1. "Chaos and Integrability in Nonlinear Dynamics", M.Tabor (Wiley, New York)

References:

1. "Chaos and Nonlinear Dynamics-An Introduction for Scientists and Engineers", R.Hilborn(Oxford University Press)
2. "Deterministic Chaos -An Introduction", H.G. Schuster (Wiley, New York)
3. "Chaos in Dynamical Systems", E. Ott (Cambridge University Press)
4. "Chaotic Dynamics-An Introduction", G.Baker and J. Gollub (Cambridge University Press)
5. "An Introduction to Chaotic Dynamical Systems", R.L.Devaney(Benjamin-Cummings, CA)
6. "Deterministic Chaos", N.Kumar
7. "Nonlinear dynamics", Laxmana (Springer Verlag, 2001)

## PHY4E17: ADVANCED CONDENSED MATTER PHYSICS

### 1. Elementary Excitations in Solids

Interacting electron gas- Hartree Fock approximation; Plasmons and electron plasmon interactions; Linder equation for dielectric constant of electron gas; Electron Hole interactions-excitons; Bloch and Wannier representations, Frenkel excitons, Ion-ion interactions,-classical equations of motion- Energy in lattice vibrations;Phonon dispersion relations-density of states Spin-spin interactions-magnons.

Text: Introduction to solid state theory O Madlung Springer Ny1978

## 2. Alloying phenomenon:

Physics of alloy formation-Phase diagrams and alloy formation-Ternary groups and quaternary groups- band structure calculation of alloys superstructures-quantum well structures- super lattices

Text: Semiconductor physics and Devices: S S Islam Oxford

## 3. Defects in solids and strength of materials:

Diffusion in solids, Vacancies, dislocations and mechanical strengths, ionic conductivity etching, photographic processes, radiation damage in solids, Fracture, Ductile and brittle fractures, Fracture mechanics, Fatigue, Crack initiation and propagation, Creep, Generalized creep behaviour, Stress and temperature effects.

Text: Elementary solid state physics, Ali Omar; Pearson and Mechanical properties of matter: AH Cortell, Wiley NY.

## 4. Nano scale science and technology

Nano materials and Quantum mechanics- quantum dots-Three dimensional Systems(bulk materials)-two dimensional systems(films)-one dimensional systems( quantum wires)-Zero dimensional systems(quantum dots)- Energy levels of quantum dots- nano wires and nano tubessynthesis and applications

Text: Nano technology- Principles and fundamentals: Ed G nter ü Schmid, Wiley

## 5. Thin Film Technology and Applications

Thin film Growth process- Nucleation & film growth- Semiconducting thin films-Vapour deposition techniques- Solution deposition techniques- Optoelectronic applications of thin films- Micro electronic applications, Enough exercises.

Texts: Thin film devices and applications: Chpora & I Kaur, Plenum Press

Thin Film Fundamentals: A Goswami New Age Publishers

Text and Reference books:

1. Solid State Physics: Structure and Properties of Materials by A. M. Wahab (Narosa Publishing House, India) 2nd Edition 2005
2. Elements of Solid State Physics (second Edition) by J. P. Srivatsava (Printice Hall of India) 2001
3. Introductory Solid State physics by H. P. Myers (Taylor & Francis Ltd, London) 2nd Edition 1998
4. Solid State Physics by Ashcroft & Mermin 1st edition 2003
5. Solid State Physics by C. M. Kachhava (Tata McGraw-Hill) 1st Edition 1996
6. Solid State Physics by Kittle (Wiley, 7th Edition) 2004

## PHY4E18: MODERN OPTICS

### 1. Light Propagation and Vectorial Nature :

Electromagnetic wave propagation, Harmonic waves, phase velocity, group velocity, Energy flow Poynting vector. Different polarizations – Matrix representations – Jone’s calculus. Ray vectors and ray matrices, Gaussian beams in homogeneous media, ABCD law. (11 hours)

### 2. Coherence :

Principle of superposition – Theory of partial coherence and visibility of fringes - coherence time and coherence length – Physical origin of line width. Spatial coherence, Hanburry-Brown-Twiss experiment. Basic idea of Fourier Transform Spectroscopy. (11 hours)

### 3. Interference with multiple beams :

Interference with multiple beams – Fabry-Perot interferometer –Resolving power, applications. Theory of multilayer films. ( 8 hours)

### 4. Diffraction :

Kirchoff’s theorem, Fresnel-Kirchoff formula, Babinet’s principle, Fresnel and Fraunhofer diffraction, Fraunhofer diffraction patterns of single slit, double slit and circular aperture, theory of diffraction grating. Fresnel diffraction pattern – zone plate, Rectangular aperture, Fresnel integrals, Corn spiral. Applications of Fourier transforms to diffraction. Aperture function, Apodization, Spatial filtering, phase contrast and phase gratings, wave form reconstruction by diffraction holography. (14 hours)

### 5. Optics of Solids :

Microscopic fields and Maxwell’s equations. Propagation of light in isotropic dielectric media. Dispersion-Sellmier’s formula. Propagation of light in anisotropic media – double refraction, phase velocity surface, polarizing prisms. Optical activity, Faraday rotation in solids, Kerr effect and Pockel’s effect (basic ideas only). Elements of nonlinear optics, Physical origin of nonlinearity. Second harmonic generation. Phase matching conditions. Applications of second harmonic generation, Enough exercises. (16 hours)

Text Books :

1. G.R. Fowles, Introduction to Modern Optics (Dover Publishers) ISBN: 0486659577
2. A. Yariv, Optical Electronics (1985)

References:

1. S.G. Lupon, H.L. Upaon and D.S. Tannhauser, Optical Physics (Cambridge University Press)
2. A.N. Matvev, Optics (MIR Publishers)
3. Hecht, Optics (Addison Wealey)
4. Ajoy-Ghatak, Optics (Tata Mc Graw Hill)

## PHY4E19: PHYSICS OF SEMICONDUCTORS

### 1. Band structural aspects :

Effects of temperature and electric field on band structure, Frank-Keldysh effect, Localized states of impurities : theoretical models and experimental probes (Capacitive and spectroscopic techniques), optical properties : allowed and forbidden, and phonon assisted transitions and their spectral shapes, Burstein Moss effect, excitons : free and bound excitons. ( 12 hours)

### 2. Statistical thermodynamics of carriers :

Fermi level in intrinsic and doped materials, Non stoichiometric semiconductors, role of structural defects, Heavy doping and degeneracy, electrical conductivity, Hall effect – two band model, mobility of carriers, Mechanisms of scattering, measurements of mobility, recombination process, Boltzmann equation for electron transport, equilibrium and non equilibrium processes, effective mass and its measurement, Thermoelectric power, magneto resistivity. ( 14 hours)

### 3. Metal-semiconductor contacts :

Schottky barrier, P-N junctions, theory of carrier transport in p-n junctions, characteristics of practical junctions and deviations from ideality, capacitance effects, space charge and diffusion capacitance, impurity profiling through capacitance measurements, tunnel diode and applications (12 hours)

### 4. Photoconductivity :

Role of traps and recombination, photo voltaic devices for solar cells and radiation detection, luminescence, light emitting diodes and laser action in p-n junction diodes (8 hours)

### 5. Surface states :

Band bending and effect on bulk properties, Thin film structures, low dimensional semiconductors, Quantum wells, multiple quantum well structures, quantum dot structures, methods of preparation, special characteristics and devices based on quantum wells, Quantum Hall effect, high electron mobility transistor , Enough exercises. (14 hours)

References :

1. R.A Smith – Semiconductors, Academic Publishers, Calcutta (1989)
2. A.B. Lev – Semiconductors and electron devices, Prentice Hall (1987)
3. M. Shur – Physics of Semiconductor devices, Prentice Hall (1990)
4. S.M. Sze – Physics of Semiconductor devices, Wiley Eastern (1991)
5. W. Shockley – Electrons and Holes in semiconductors, D. Van Nostrand (1950)
6. W.C. Dunlop – An introduction to semiconductors, Wiley (1957)

## PHY4E20: MICROPROCESSORS AND APPLICATIONS (4C)

### 1. Microprocessor, Microcomputer and Assembly Language Programming:

Organization of microcomputers, microprocessor as CPU, Organization and internal architecture of the Intel 8085, instruction set, Assembler Programming. Examples of Assembly Language Programming: Addition, Subtraction of two 8 bit & 16 bit numbers, One's compliment, Two's compliment, Shifting of 8 bit & 16 bit numbers, Square from Lookup table, Largest and Smallest in a data array, sorting of numbers in ascending and descending order, Sum of a series of 8 bit & 16 bit numbers, 8 bit multiplication and division, Multi byte addition and subtraction. (16 hrs)

Text: 1. Introduction to Microprocessors–A.P. Mathur (Tata-McGraw Hill).

2. Fundamentals of Microprocessors and Micro Computers”– B. Ram- Dhanapati Rai

### 2. Microprocessor Timings, Interfacing Memory and I/O Devices :

Timing and control unit, Timings of Intel 8085, Address space partitioning, Memory interfacing, Data transfer schemes, Programmed Data transfer, Direct Memory Access Data Transfer, Serial data transfer. (12 hrs)

Text: “Introduction to Microprocessors” –A.P. Mathur (Tata-McGraw Hill).

### **3. Peripheral Devices and Interfacing:**

Generation of control signals for memory and I/O devices, Programmable peripheral interface-8255, Programmable DMA controller 8257, Programmable interrupt Controller 8259, Programmable communication interface-8251, Programmable interval timer -8253, Programmable Keyboard/Display interface- 8279.(14 hrs)

Text 1. Fundamentals of Microprocessors and Micro Computers– B. Ram -Dhanapati Rai

2. Introduction to Microprocessors –A.P. Mathur (Tata-McGraw Hill).

3. Microprocessors – Architecture, Programming and Applications with 8085 - R.S.Gaonkar (Wiley Eastern)

### **4. Applications of Microprocessors:**

Microprocessor based data acquisition system: Analog to Digital converter, Clock for A/D conversion, Sample and Hold circuit, Analog multiplexer, ADC 0800, Digital to Analog Converter, DAC 0800, Realization of A/D Converter using D/A Converter, 7 segment LED displays, decoders/drivers-7448, Interfacing of 7 segment display, Display of decimal and alphanumeric characters, Measurement of frequency, Voltage, Current, Resistance; Temperature measurement and control, Generation of square wave using microprocessor. (12 hrs)

Text : Fundamentals of Microprocessors and Micro Computers - B. Ram, Dhanapati Rai

### **5. Micro controllers:**

Overview of 8051 microcontroller; Inside 8051; 8051 register and stack, Enough exercises. (6 hrs)

Text : 1. Microcontrollers & Embedded systems by Muhammed Ali Mazidi & Janice Guillespie Mazidi (Prentice Hall)

2. Introduction to Microprocessors –A.P. Mathur (Tata-McGraw Hill).

Reference Books:

1. Microprocessors – Architecture, Programming and Applications with 8085- R.S.Gaonkar(Wiley Eastern)

2..Microprocessors and programmed logic, Kenneth L. Short ( Prentice Hall India).

3. Digital System from Gates to Microprocessors, S.K. Bose ( Wiley Eastern)

4. Microprocessors and Microcomputer system design, M. Rafiquazzaman (Universal Book Stall , New Delhi).

5. Microprocessor (8085) and its applications- A.Nagoor Kani (RBA Publications)

f) **MODEL QUESTION PAPERS (CSS)**

MODEL QUESTION PAPER  
I Semester M.Sc(Physics)Programme(CSS) 2010  
PHY1C01 - **Classical Mechanics**

Total weightage: 36

Time: 3 Hours.

**Section A**

*Answer all questions, each has weightage 1*

1. What do you mean by generalized potential? Give an example.
2. Write down the Lagrangian for Kepler problem and derive Kepler's second law.
3. State the principle of least action and use it to obtain principle of least time.
4. Define Poisson bracket of two variables and discuss its important properties.
5. Explain how action angle variables can be used to obtain the frequencies of periodic motion.
6. Explain how action angle variables provides a procedure for quantization of systems.
7. Show that infinitesimal rotations can be represented as rate of change of a vector.
8. Define Coriolis force. Explain its effect on the flight of a missile in the northern hemisphere.
9. The potential energy function between two atoms of a diatomic molecule is given by  $V = ax^{-3} - bx^{-2}$  where  $a$  and  $b$  are positive constants and  $x$  is the separation between atoms. Find the equilibrium position.
10. Establish that for a particle executing simple harmonic motion, the trajectory in the phase plane is an ellipse.
11. Explain the term 'limit cycle'
12. What is a Lyapunov exponent? How is it related to chaos?

*(Total weightage 12 x 1 = 12 )*

**Section B**

*Answer any two questions, each has weightage 6*

13. (a) Define scattering cross section. What is differential cross section?  
(b) Derive Rutherford expression for differential scattering cross section.
14. (a) What do you mean by Legendre transformation? Use Legendre transformation to obtain Hamiltons canonical equations of motion.  
(b) Solve Kepler problem using H-J equation.  
(2+4)
15. (a) Obtain Euler equations of motion. Derive the period of precession of earth.  
(b) Explain with example the period doubling route to chaos.  
(3+3)
16. (a) Explain the free vibrations of a linear triatomic molecule. Obtain the expressions for normal frequencies and and normal coordinates.

*(Total weightage 2 x 6 = 12)*

### Section C

Answer any **four**, each has weightage 3

17. Consider a pendulum made out of a spring with a mass  $m$  on the end. The spring is arranged to lie in a straight line (which we can arrange by, say, wrapping the spring around a rigid massless rod). The equilibrium length of the spring is  $l$ . Let the spring have length  $l + x(t)$ , and let its angle with the vertical be  $\theta(t)$ . Assuming that the motion takes place in a vertical plane, find the equations of motions for  $x$  and  $\theta$ .
18. Using Lagrange's equation of motion, explain the motion of a projectile.
19. Show that the transformation  $Q = \ln((\sin p)/q)$  and  $P = qcot p$  is canonical using Poisson brackets and hence show  $[H, [P, Q]] = 0$
20. For what values of  $a$  and  $b$ , do the equations  $Q = q^a \cos bp$ ,  $P = q^a \sin bp$  represent a canonical transformation. Find the generating function.
21. Using H.J formalism explain the motion of a freely falling body
22. Obtain the components of the angular velocity along the space set of axes in terms of the Euler angles.

(Total weightage  $4 \times 3 = 12$ )

MODEL QUESTION PAPER  
I Semester M.Sc(Physics)Programme(CSS) 2010  
PHY1C02 - **MathematicalPhysics**

Total weightage: 36

Time: 3 Hours.

**Section A**

*Answer all questions, each has weightage 1*

1. Express arc length in general orthogonal curvilinear coordinate system.
2. Resolve circular cylindrical unity vectors into cartesian components.
3. Show that Kronecker delta is a second rank mixed tensor.
4. What is a metric tensor? Determine the metric tensor in spherical polar coordinate system.
5. Show that every square matrix can be uniquely expressed as the sum of Hermitian and Skew Hermitian matrices.
6. Show that the trace of a matrix is invariant under similarity transformation.
7. Explain the Schmidt orthogonalisation procedure of constructing an orthonormal set of functions from a non orthogonal set.
8. What is a singular point as applied to a differential equation? Explain different types of singular points.
9. Define  $\Gamma$  function. By direct integration show that  $\Gamma_{n+1} = n\Gamma_n$
10. Using the generating function of  $H_n(x)$ , show that

$$\frac{1}{e} \cosh 2x = \sum_{n=0,1}^{\infty} \frac{1}{(2n)!} H_{2n}(x)$$

11. Find the Laplace transform of the function  $f(t) = \sinh at$
12. Explain the essential conditions to be satisfied for a function to be expanded in a Fourier series.

*(Total weightage 12 x 1 = 12 )*

**Section B**

*Answer any two questions, each has weightage 6*

13. Obtain the expression for gradient and divergence in general curvilinear coordinates. Hence deduce the expression for gradient and divergence in spherical polar coordinates.
14. (a) What are Hermitian and Unitary matrices?  
(b) Show that the eigenvalues of a Hermitian matrix are real and eigenvectors are orthogonal to each other.
15. (a) Outline the technique of solving partial differential equations by variable separation method.  
(b) Apply the method to solve three dimensional wave equation in spherical polar coordinates.
16. Establish the orthonormality relation

$$\int_0^{2\pi} P_m(x) P_n(x) dx = \frac{2\delta_{mn}}{2n+1}$$

*(Total weightage 2 x 6 = 12)*

**Section C**

*Answer any four questions, each has weightage 3*

17. Find the eigen values and normalized eigenvectors of the matrix,

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{pmatrix}$$

18. Find the power series solution for Hermite differential equation

$$y'' - 2xy' + 2ny = 0$$

19. Prove the recurrence relation for Bessel function  $J_{n+1}(x) + J_{n-1}(x) = \frac{2n}{x}J_n(x)$

20. Using

$$\begin{aligned} f(x) &= -x; \pi < x < 0 \\ &= x; 0 < x < \pi \end{aligned}$$

Show that,

$$\sum_{n=0,1}^{n=\infty} \frac{1}{(2n+1)^2} = \frac{\pi^2}{8}$$

21. Using Fourier sine and cosine transform, Evaluate ;

$$\begin{aligned} (a) & \int_0^{\infty} \frac{\cos nx}{a^2 + b^2} dn \\ (b) & \int_0^{\infty} \frac{n \sin nx}{a^2 + n^2} dn \end{aligned}$$

22. If  $L_n(x)$  represents Laguerre polynomial of order n, prove that

$$\int_0^{\infty} e^{-x} L_m(x) L_n(x) dx = \delta_{mn}$$

(Total weightage 4 x 3 = 12)



MODEL QUESTION PAPER  
I Semester M.Sc(Physics)Programme(CSS) 2010  
PHY1C03 - **Electrodynamics and Plasma Physics**

Total weightage: 36

Time: 3 Hours.

**Section A**

*Answer **all** questions, each has weightage 1*

1. Describe how Maxwell fixed up Ampere's law on theoretical grounds.
2. Obtain the homogeneous vector wave equations for E and H, for a source free region.
3. Obtain an expression for pointing vector.
4. Define group velocity. In what way does it differ from phase velocity?
5. List the expression for the four distributed parameters of a parallel plate transmission line of width  $w$  and separation  $d$ .
6. Explain the terms 'propagation constant' and 'characteristic impedance' of a transmission line.
7. For a  $\mathbf{TE}_{10}$  in a rectangular waveguide, show that  $\mathbf{TE}_{10}$  is the dominant mode.
8. What is meant by cut off frequency of a wave guide? Can a wave guide have more than one cut off frequency?
9. Obtain the equation of continuity in tensor notation.
10. Write down the components of 4-vector potential.
11. Explain plasma frequency. Deduce an expression for plasma frequency.
12. What is Debye shielding? Obtain an expression for Debye length.

*(Total weightage 12 x 1 = 12 )*

**Section B**

*Answer any **two** questions, each has weightage 6*

13. (a) Derive the nonhomogenous wave equation for vector magnetic potential.  
(b) Derive the nonhomogenous wave equation for scalar potential. (4 + 2)
14. Discuss the case of uniform plane wave incident on a reflecting plane conducting surface obliquely for perpendicular polarisation.
15. (a) Derive the Maxwell's equation and lorentz force in tensor notation.  
(b) Describe the potential formulation of relativistic electrodynamics (3 + 3)
16. Discuss the motion of charged particles in uniform electric and magnetic fields and obtain the expression for drift velocity.

*(Total weightage 2 x 6 = 12)*

### Section C

Answer any **four**, each has weightage 3

17. A 2(m) lossless air spaced transmission line having a characteristic impedance  $50 \text{ } (\Omega)$  is terminated with an impedance  $40+j30 \text{ } (\Omega)$  at an operating frequency of  $200 \text{ MHz}$ . Find the input impedance.
18. Find the Pointing vector on the surface of a long straight conducting wire of radius 'b' and conductivity ' $\sigma$ ' which carries a current 'I'. Using pointing's theorem, show that the power loss is  $I^2R$ . what is the SI unit of Poynting vector?
19. Prove that the resonant frequency of a rectangular cavity resonator is

$$f_{mnp} = \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}$$

20. Given  $E = \mathbf{a}_y 0.1 \sin(10\pi x) \cos(6\pi 10^9 t - \beta z)$  in air. Find  $\mathbf{H}$  and  $\beta$ .
21. A hollow rectangular wave guide has  $a=6 \text{ cm}$  and  $b= 4 \text{ cm}$ . Determine the cut off wavelength and guide wavelength for the dominant mode.
22. (a) Show that  $(\mathbf{E} \cdot \mathbf{B})$  is relativistically invariant.  
(b) Show that  $E^2 - c^2 B^2$  is relativistically invariant.

(Total weightage  $4 \times 3 = 12$ )

MODEL QUESTION PAPER  
I Semester M.Sc(Physics)Programme(CSS) 2010  
PHY1C04 - **Electronics**

Total weightage: 36

Time: 3 Hours.

**Section A**

*Answer all questions, each has weightage 1*

1. Draw the structure of a P-channel enhancement type MOSFET. Show its symbol. What are its advantages over JFET
2. Explain the design and working of a MOSFET NOR circuit.
3. Explain the action of the memory cell used in RAM.
4. What is race around condition in flip-flops? How it is solved in MS JK flip-flops?
5. Explain the importance of Karnaugh map..
6. Explain the function of Schmitt trigger.
7. Draw the basic OPAMP integrator circuit and show that the circuit is able to perform analog integration.
8. Bring out the idea of virtual ground in relation to OP-AMP circuits.
9. Define
  - (a) input bias current
  - (b) input offset current
  - (c) input offset voltage
  - (d) output offset voltage for an OPAMP
10. What are the functions of Program counter, Stack pointer, and flags.
11. What is transferred electron effect? How does this effect lead to negative differential resistivity?
12. Discuss the light dependence of resistance in LDRs. Construct a circuit showing the application of LDR.

*(Total weightage 12 x 1 = 12 )*

**Section B**

*Answer any **two** questions, each has weightage 6*

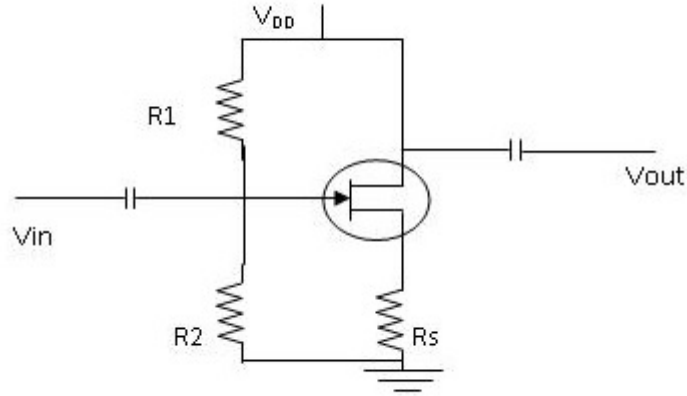
13. (a) Briefly sketch the working of an n-channel JFET. (b) Draw the circuit diagram of common source FET amplifier with unby-passed source resistance and explain. (c) Draw the low frequency small signal FET equivalent circuit and obtain expressions for the voltage gain and output resistance.
14. (a) What are the different registers in INTEL 8085 microprocessor? Explain their functions. (b) With a block diagram, explain the architecture of INTEL 8085 microprocessor.
15. Discuss the tunnel diode operation on the basis of energy band diagrams for different biasing conditions. Explain the nature of the I - V characteristics. Give a brief account of any one application.
16. Discuss the design, working and circuit analysis of an emitter coupled differential amplifier.

*(Total weightage 2 x 6 = 12)*

### Section C

*Answer any four, each has weightage 3*

17. An FET with  $r_d = 50 \text{ K}$ ,  $R_s = 2 \text{ K}$  and  $g_m = 2500 \text{ A/V}$  is used in a common drain circuit shown in figure. Calculate the voltage gain and output impedance of the circuit.



18. A MOSFET has a drain-circuit resistance  $R_d$  of  $120 \text{ K}$  and Operates at  $10 \text{ KHz}$ . Calculate the Voltage gain of this device as a single-stage transistor amplifier. The MOSFET parameters are  $g_m = 1.5 \text{ mA/V}$ ;  $r_d = 47 \text{ K}$ ;  $C_{gs} = 3 \text{ pf}$ ;  $C_{ds} = 1 \text{ pf}$  and  $C_{gd} = 2.4 \text{ pf}$
19. Calculate the photon current and carrier transit time for a photoconductor from the following data. Quantum efficiency = 75%, number of photons reaching per second = 1010, mobility =  $3000 \text{ cm}^2/\text{V-s}$ , effective electric field =  $5 \text{ KV/cm}$ ,  $L = 10 \mu\text{m}$ , carrier life time  $0.7 \text{ ns}$ .
20. A Truth table has output 1s for these inputs: A B C D= 0 0 1 1 , A B C D= 0 1 1 0 , A B C D= 1 0 0 0 , A B C D= 1 1 0 0 , Draw the Karnaugh map . Using the map, find the simplified Boolean equation for the truth table and the logic circuit.
21. Draw the logic diagram of Mod 6 counter with 000 and 001 as omitted states. Write down the Truth table and show the timing diagram.
22. Calculate the gain at  $2 \text{ KHz}$  and cut-off frequency of a first order high pass filter shown in the figure. Sketch the nature of the frequency response curve. How do you convert it into a second order filter? What would be the nature of the curve?

