DEPARTMENT OF PHYSICS

DIBRUGARH UNIVERSITY

Syllabus for

Ph. D. Coursework in Physics

Approved by the Board of Studies in Physics held on 22nd August, 2022

COURSE STUCTURE AND ALLOTMENT OF PAPERS FOR Ph. D. COURSEWORK IN PHYSICS

The distribution of marks of course work

No./Code	Internal assessment	End Semester Examination	Credits	Total
Course-I (Research Methodology)	40	60	4	100
Course-II (Optional)	40	60	4	100
Course-III (Optional)	40	60	4	100
Course-IV (Optional)	80 (assignment writing)	20 (viva-voce on the assignment)	4	100
Total			16	400 Marks

Course–I
(Research Methodology)

Unit – I: Basics

Survey of literature and preparation of research problem, writing of research papers, typesetting program LaTeX.

Impact Factors, Citation Index of publications, patent, IPR.

Unit – II: Programming Languages

Basics of FORTRAN 77, functions and subroutines in FORTRAN 77; Basics of C++, functions and pointers and classes in C++; programming using MATLAB, Mathematica.

Unit – III: Numerical Methods and Data Handling

Numerical integration and differentiation methods.

Data analysis and interpretation, precision and accuracy, error analysis, propagation oferrors, least square fitting, linear and nonlinear curve fitting, Laplace and Fourier transforms, optimization, regularization and minimization of errors, data manipulation and visualization techniques.

Suggested Readings:

1. Numerical Recipes in C/FORTRAN, press et al., Cambridge University Press
2. Programming in FORTRAN 77, V. Rajaraman, Prentice Hall of India
3. The C++ Programming Language, B. Stroustreep, Addison-Wesley
4. Effective C++, S. Meyers, Addison-Wesley
5. Statistical Methods, J. Medhi, New Age International
6. An Introduction to Error analysis: The study of Uncertainties in PhysicalMeasurements, J. R. Taylor, University Science Book

Course –II (Optional)

A. High Energy Physics-I

Unit I: Group Theory
Symmetries and groups: Lie groups, unitary and special unitary groups (U(1), SU(2) and SU(3)), Tensor method in SU(n), Young tableaux.

Unit II: Particle Physics and Standard Model
Elementary particles, behaviours of elementary particles under parity (P), charge conjugation (C), time reversal (T); CP symmetry and CPT theorem; isospin, hypercharge, eightfold way, hadron octet and decuplet, Gell-Mann-Nakano-Nishijima law, quark model, quark-mass formula, Zweig rule, quark color; gauge symmetries, Yang-Mills theory, Higgs bosons, spontaneous symmetry breaking (SSB) and Higgs mechanism; standard model, LHC and discovery of Higgs boson.

Unit III: QED
Dirac equation; scalar, vector and spinor fields; s-matrix, covariant perturbation theory, path integral formalism; Feynmann diagrams (rules), Wicks theorem, calculation of second order process, electron interaction with electromagnetic field, Mott scattering, Compton scattering (Klein-Nishima formula), Møller scattering, Bhaba scattering, bremsstrahlung, vacuum polarization, self-energy of electron.

Suggested Readings:

1. Introduction to Elementary Particles - D. J. Griffiths (John Wiley & Sons).
2. Quarks and Leptons - Francise Halzen and Alan D. Martin (John Wiley & Sons).
3. Gauge Theory of Elementary Particle Physics - Ta-Pei Cheng and Ling-Fong Li (Oxford University Press).
4. Quarks - Y. Nambu (World Scientific).
5. An Introduction to Quarks and Partons - F. E. Close (Academic Press).
6. Relativistic Quantum Mechanics - James D. Bjorken and Sidney D. Drell (McGraw-Hill).
7. Introduction to High Energy Physics - Donald H. Parkings (Cambridge University Press).
8. Physics of Elementary Particles - H. Muirhead (Pergamon Press).
9. Quantum Field Theory - Lewis H. Ryder (Cambridge University Press).
10. An Introduction to Quantum Field Theory - Michael E. Paskin and Daniel V. Scroeder (Levant
Books).
11. Field Quantization - W. Greiner and J. Reinhardt (Springer).
12. A First Book of Quantum Field Theory, A. Lahiri and P.B. Pal, Narosa.
13. QFT Lecture Notes I and II- David Tong, Cambridge University Press.

B. Astrophysics and Cosmology-I

Unit I: Tensor Analysis
Different tensors, Christoffell's symbols, geodesics, covariant derivatives, curvature tensor, Ricci tensor and scalar, Bianchi identities, energy momentum tensor.

Unit II: General Relativity and Applications
Equivalence principle, general covariance, Einstein's field equations, Newtonian approximation, Schwarzschild solution, bending of light, gravitational redshift, precession of perihelion of Mercury, gravitational lensing, gravitational waves; neutron stars, Oppenheimer-Volkov equation.

Unit III: Astronomy and Astroparticle Physics
Fundamentals of astronomy and observation techniques, multiwavelength astronomy (infrared, radio, optical, x-ray, gamma-ray), cosmic ray physics.

Suggested Readings:

1. General Theory of Relativity - P. A. M. Dirac (Prentice-Hall of India).
2. Gravity : An Introduction to Einstein General Relativity - James B. Hartle (Pearson Education)
3. An Introduction to Cosmology - J. V. Narlikar (Cambridge University Press).
4. Gravitation and Cosmology - S. Weinberg (John Wiley & Sons).
5. General Relativity and Cosmology - S. Banerji and A. Banerjee (Elsevier).
6. General Relativity and Cosmology - S. K. Srivastava (Prentice-Hall of India).
7. Principles of Cosmology and Gravitation - M. V. Berry (Overseas press).
8. Cosmology - S. Weinberg (Oxford University Press).
9. Modern Cosmology - Scott Dodelson (Academic press).
10. An Introduction to Astrophysics - B. Basu (Prentice-Hall of India).
11. Astrophysics : Stars and Galaxies - K. D. Abhyankar(Orient Longman).
12. Stars and Galaxies - Michael A. Seeds (Thomson Learning).
13. Observational Astronomy. - D. Scott Birney (Cambridge).
14. Astronomy: A Physical Perspective - M. L. Kutner (Cambridge).
15. Cosmic Rays - A.W. Wolfendale (Philosophical Library).
16. Extensive Air Showers - W. Galbraith (Academic Press).
17. Cosmic Rays and Particle Physics - Thomas K Gaisser (Cambridge).

C. **Particle Physics**

Unit I:
Elementary particles and their classification- leptons, baryons, mesons, gauge bosons.
Elementary particle interactions and their characteristics- electromagnetic, weak and strong interactions.
Intrinsic properties and quantum numbers- electric charge, lepton number, baryon number, isospin, strangeness etc.; conservation laws.

Unit II:
Examples of weak interactions, Charged Current (CC) and Neutral Current (NC) interactions, relevant Feynman diagrams, parity violation in weak interaction, Fermi theory of beta decay, V-A theory of weak interaction.

Unit III:
Gauge transformation of 4-potential A^{μ}, Gauge principle, U(1) gauge symmetry and theory of electromagnetic interaction, covariant derivative, Yang-Mills theory, SU(2) gauge symmetry.

Unit IV:
Spontaneous symmetry breaking- discrete symmetry of a real scalar field, global U(1) symmetry of a complex scalar field, Goldstone boson, local U(1) symmetry of a complex scalar field, Higgs mechanism, local SU(2) symmetry of complex scalar doublet field.

Unit V:
Standard electroweak model (GWS model): quantum number assignment, construction of the Lagrangian density, masses of gauge bosons, masses of fermions.

Suggested Readings:

1. Introduction to Elementary Particles - D. J. Griffiths (John Wiley & Sons).
2. Quarks and Leptons - Francise Halzen and Alan D. Martin (John Wiley & Sons).
3. Gauge Theory of Elementary Particle Physics - Ta-Pei Cheng and Ling-Fong Li (Oxford University Press).
4. Quarks - Y. Nambu (World Scientific).
5. An Introduction to Quarks and Partons - F. E. Close (Academic Press).
6. Relativistic Quantum Mechanics - James D. Bjorken and Sidney D. Drell (McGraw-Hill).
7. Introduction to High Energy Physics - Donald H. Parkings (Cambridge University Press).
8. Physics of Elementary Particles - H. Muirhead (Pergamon Press).
9. Quantum Field Theory - Lewis H. Ryder (Cambridge University Press).
10. An Introduction to Quantum Field Theory - Michael E. Paskin and Daniel V. Scroeder (Levant Books).
11. Field Quantization - W. Greiner and J. Reinhardt (Springer).
12. A First Book of Quantum Field Theory, A. Lahiri and P.B. Pal, Narosa.
13. QFT Lecture Notes I and II- David Tong, Cambridge University Press.

D. Devices and Techniques in Microwave Electronics

Unit- I

Microwave measurements: Microwave bench-general measurement set up, Measurement devices and Instrumentation (Slotted line, Tunable detector, VSWR meter, Power meter, Wave meter, Spectrum Analyses, Network Analyzer, Test set up for Reflection - Transmission measurement, Test set up for S-Parameter measurement.

Unit- II

Microwave Tubes: High frequency limitations of conventional tubes, inter electrode capacitance effect, Lead inductance effect, Klystrons, Reflex klystrons, Travelling Wave Tube, Magnetrons

Unit- III

Microwave solid state devices: Microwave Transistors, MESFETS, classification of microwave solid state devices, Varactor diode, PIN diodes, transferred electron devices

Unit- IV

Microwave Resonators: Series and Parallel Resonant Circuits-Series Resonant Circuit, Parallel Resonant Circuit, Loaded and Unloaded Q, Transmission Line Resonators Short-Circuited $\lambda/2$ Line, Short-Circuited $\lambda/4$ Line, Open-Circuited $\lambda/2$ Line, Rectangular Waveguide Cavity Resonators-Resonant Frequencies, Unloaded Q of the TE10_ Mode, Dielectric Resonators- Resonant Frequencies of TE01δ Mode, Cavity Perturbations-Material Perturbations, Shape Perturbations Electronically Tunable Ring Resonators Simple Analysis, Varactor Equivalent Circuit, Input Impedance and Frequency Response of the Varactor-Tuned Microstrip Ring Circuit, Effects of the Package Parasitics on the Resonant Frequency, Experimental Results for Varactor-Tuned Microstrip Ring Resonators.

Unit- V

Simulation and analysis techniques: Introduction to High Frequency Structure Simulator, Design and simulation of microwave circuits Introduction to CST microwave studio,Design and simulation of microwave circuits, Introduction to MATLAB, The MATLAB Environment, MATLAB Basics – Variables, Numbers, Operators, Expressions, Input and output, Vectors, Arrays – Matrices. MATLAB Functions 05 Hrs., Built-in Functions, User defined Functions. Graphics with MATLAB 05 Hrs., Files and File Management – Import/Export, Basic 2D, 3D plots, Graphic handling

Reference:

- Microwave Engineering- David M Pozar- Wiley
- Microwave and RADAR Engineering- M. Kulkarni- Umesh Publications
- Introduction to network analyzer Measurements- National Instruments
- Microstrip Antenna Design Handbook- Garg, Bhartia, Bahl- Artech House
- Microwave Devices and Circuit Theory- S Y Liao- Prentice Hall
- HFSS Design guide
- CST Microwave studio- Manual
- Getting started with MATLAB

E. Experimental Techniques in Space and Atmospheric Physics

Unit- I

Ionospheric Measurement Techniques: Langmuir probe, Retarding Potential Analyzer, Ion Drift Meters, Ionosonde, scatter radar, air glow images, satellite orbits like Sun synchronous,polar, equatorial and Molniya orbitsetc. LEO, MEO and GEO, issues in satellite in-situ measurements, different mission and data sources, geomagnetic field, magnetic data, indices and repositories, Global Positioning System, Global Navigation Satellite System, Indian Regional Navigational Satellite System

Unit- II

Ionospheric Models: International Reference Ionosphere, Low Latitude Ionospheric Model-DULLTD, SAMI 2/3

Unit- III

Atmospheric Measurement Techniques: Meteorological sensors: Automatic Weather Station, Radiosonde, Satellite remote sensing techniques for measurement of atmospheric parameters: Clouds, Aerosols, Radiation, Lidar, ST and MST Radars, Photometers and Radiometers, Trace gas analyzers, Aerosol Instrumentation, Mass spectrometry, Reanalysis data

Unit- IV

Atmospheric Models: Introduction, types, components-Earth system modeling, Governing Equations- dynamical core, Parameterizations- microphysics, boundary layer, convection, radiation, land surface, etc; Post processing tools - NCO, CDO, NCL, Python etc., Regional/Global Climate models, CIMIP models, ECMWF

F. General Theory of Relativity I

Unit- I

Review of Associated Mathematical Concepts:
Four vectors and their transformation rules under Lorentz transformation, Lorentz indices, Lorentz scalars, metric. Elementary group theory, Lorentz and Poincarre group, representations of the Lorentz group and SL(2,C).

Unit- II

Review of Special Theory of Relativity:
Empirical evidence for the constancy of c, frames of reference; Lorentz transformations; relativity of simultaneity; twin and other paradoxes, transformation laws for velocity, momentum, energy; mass-energy equivalence; force equations, kinematics of decays and collisions, . Maxwell's equations in covariant form.

Unit-III

Introductory General Relativity:
Principle of equivalence; Mach's principle, Riemannian geometry; Christoffel symbols, the curvature and stress-energy tensors; the gravitational field equations; geodesics and particle trajectories.

Suggested Readings:

1. Special Theory of Relativity, R. Resnick, McGraw Hill
2. Tensor Calculus, D.C. Kay, Schaum's Outlines
3. Tensor Calculus, P. A. M. Dirac, Prentice-Hall of India
4. Gravitation and Cosmology, S. Weinberg, McGraw Hill
5. Gravitation, T. Padmanabhan, Cambridge University Press
6. Gravitation, J. A. Wheeler, C. W. Misner and K. S.Thorne, Princeton University
7. Cosmology, J. V. Narlikar, Cambridge University Press

G. Mathematical Methods and Techniques in Theoretical Physics

Unit- I

Mathematical Basics in Conformal Field Theory: Definition of conformal transformations, Types of conformal transformations, Conformal group, Conformal invariance, Conformal group in two dimensions, three and higher dimensions, Primary fields, Energy- Momentum tensor, Radial Quantization, The operator product expansion, Operator algebra of of chiral quasi primary fields: conformal Ward identity, Two and three point functions, Normal ordered products, The CFT Hilbert space, Examples of CFTs: The free boson, the free Fermion, The (b,c) ghost systems, Highest weight representations of Virasoro algebra, Correlation functions and fusion rules, Non-holomorphic OPE and Crossing symmetry, Fusing and braiding matrices

Unit- II

Mathematical Basics in Supersymmetry: Introduction, The Lorentz and Poincare groups, Spinors, The SUSY algebra and its representations, Superspace and superfields, Supersymmetric gauge theories, Spontaneously broken supersymmetry, The non-linear sigma model, N=2 SUSY gauge theory, Seiberg-Witten duality in N=2 gauge theory.

Unit- III

Manifolds: Introduction, definition, examples, differentiable maps, vectors, one forms, tensors, tensor fields, induced maps, sub-manifolds, flows and Lie derivatives, differential forms, integration of differential forms, Lie groups and Lie algebras, the action of Lie groups on manifolds.

References:

1. Geometry, Topology and Physics : Mikio Nakahara, IOP Publishing.
2. Introduction to Conformal Field Theory: Blumenhagen, Plauschinn.
3. Surveys in theoretical high energy physics 1: Lecture notes from SERC Schools: Edited by P. Ramadevi, Hindustan Book Agency.

H. Experimental techniques for material characterization

Unit I: Preliminary description of error analysis

Errors as Uncertainties, inevitability of uncertainty, importance of knowing error, instrumental errors, estimation of errors in repeatable measurements, how to report and use uncertainties.

Unit II: Basics of instruments for material characterizations:

Vacuum components and systems, X-ray Diffractometer, X-ray Photoelectron Spectroscopy, Transmission electron microscope, Scanning electron microscope, Atomic force microscope, Photoluminescence spectrometer, Fourier transform of infra-red spectrometer, Raman spectrometer, nano indentation

Unit III: Material Characterization

Estimation of thickness; estimation of optical band gap; estimation of crystalline nature, crystallite size; estimation of particle size, identification of elements and compounds, hardness estimation.

Recommended readings:

1. An introduction to error analysis, John R. Taylor, University Science Books, Sauslito, California
2. Handbook of Materials Characterization, Surender Kumar Sharma, Springer
3. Materials CharacterizationIntroduction to Microscopic and Spectroscopic Methods, Yang Leng, Wiley-VCH

I. Methods in Materials Science

Unit I

Electronic structure methods: Introduction, Born-Oppenheimer approximation, Hartree-Fock theory, Density Functional Theory, Hohenberg-Kohn theorem, Kohn-Sham equations, Local density approximation, Generalized gradient approximation, Basis sets, Pseudopotentials, Functionals, Overview of computational methods for material modeling.

Unit II

Experimental techniques: Particle detectors (GM counters, Scintillation detectors etc.), PMT, XRD, FTIR, TEM, SEM, AFM. Photoluminescence.

Course –III (Optional)

A. Advanced Quantum Mechanics

Unit-I

Dirac equation and its Lorentz covariance; Lorentz transformation properties of Dirac bilinear covariant; two component equation of neutrino; Symmetry of Dirac equation under charge conjugation, parity, and time reversal operation; Foldy- Wouthueyesen transformation of Dirac equation for electron in an electromagnetic field; reduction of Dirac Hamiltonian up to seconds order in (v/c).

Unit-II

Feynman propagator method in quantum mechanics; Green function treatment of Schrödinger equation and Dirac equation; Transition amplitude using Dirac equation; Application to scattering of electron by a Coulomb potential.

Unit-III

Field quantization; application to the Schrödinger field and the relativistic Klein- Gordon field; system of bosons and system of fermions.

Recommended Readings:

1. Relativistic Quantum Fields
   Bjorken and Drell
   McGraw Hill
2. Advanced Quantum Mechanics
   J.J. Sakurai
   Pearson Education
3. Quantum Electrodynamics
   R.P. Feynman

B. Nonlinear Systems and Networks

Unit I

Nonlinear dynamics and chaos: Introduction, One dimensional Flows, flows on the line, bifurcations, flows on the circle, two dimensional flows, linear systems, phase plane, limit cycles, chaos

Unit II

Networks: Mathematics of networks, the adjacency matrix weighted networks, directed networks,bipartite networks, planar networks
Measures and metrics: the large-scale structure of networks

Unit III

Computer algorithms for Networks: Basic concepts of algorithms, Running time and computational complexity, Storingnetwork data

The adjacency matrix, The adjacency list, Trees, Other network representations, Heaps Fundamental network algorithms, Algorithms for degrees and degree distributions, Clustering coefficients, Shortest paths and breadth-first search, Shortest paths in networks with varying edge lengths, Maximum flows and minimum cuts, Matrix algorithms and graph partitioning, Leading eigenvectors and eigenvector centrality, Dividing networks into clusters, Network models

Suggested Readings:

1. Nonlinear Dynamics and Chaos
   S. H. Strogatz
   Levant Books, Kolkata
2. Networks: An Introduction
   M. E. J Newman
   Oxford University Press

C. Communication Electronics

Unit- I

DATA Communications and Networking: History of Data communication, network architecture, protocols and standards, layered networking architecture, data communication circuits, serial and parallel data transmission, data communication network, hardware and interfaces.

Unit-II

Transmission Media: Introduction to OF communication, OF versus metallic cable facilities: Block diagram of OF communication system, types of OF, propagation sources, detectors, OF systems link budget.

Unit-III

Digital Modulation: Information capacity, BITS, BIT rate, BAUD and M-ARY encoding, ASK, FSK, PSK, QAM, carrier and clock recovery, probability of error and BIT error rate, error performance.

Unit-IV

Digital Transmission: Pulse modulation, PCM, PCM sampling, signal to quantization noise ratio, coding, compounding, delta modulation PCM, differential PCM, pulse transmission, TDM

Unit-V

Satellite Communication: Satellite classification, spacing and frequency allocation, satellite antenna radiation patterns, footprints, system link, parameters, system link equation, link budget, satellite navigation systems, GPS, GNSS etc.

Recommended Readings:

1. Advanced Electronic Communication Systems
   Wayne Tomasi
   Pearson Education
2. Principles of Communication Systems
   Herbert Toub and Donald L Schilling
   Tata McGraw Hill

D. Laser Physics

Unit- I

History of laser physics and highlights in its development, Atom field interaction, Induced resonant transition, Black body radiation, Inclusion of decay phenomenon, exact Rabi solution, Classical sustained oscillator.

Unit- II

The state vector and Dirac notation, density matrix formalism.

Semi-Classical theory of laser, Polarization of the medium, Gas laser theory, Polarization of Doppler broadened medium.

Unit-III

Quantum theory of radiation, properties of coherent states, Quantum theory lasers, Laser photon statistics.

Recommended Readings:

1. Laser Physics
   Sargent, Scully and Lamb
   Addison Wesley Publishing Company
2. Essentials of Laser and Nonlinear Optics
   G.D. Baruah
   Pragati Prakashan
3. Laser Physics
   H. Haken
   Springer-Verlag.

E. Photonics

Unit-I

Mechanisms of Absorption and Emission of Radiation, Photophysical properties in electronically excited molecules, laws of Photochemistry (Lambert-Beer law)
Absorption Spectroscopy, UV-Vis Spectrophotometer, Photoluminescence Spectroscopy, Spectrofluorimeter, Measurement of Fluorescence, Fluorescence lifetime, Quantum Efficiency, Upconversion, Phosphorescence.
Photon Counting, Photomultiplier tube, Lock in Amplifier, Electro optic, Magneto Optic and Acousto Optic Devices.

Unit-II

Absorption and Emission by trivalent Rare Earth Ions, Electronic Configuration of RE ions, Coupling Schemes, Term Symbols for RE states, Selection rules.
Oscillator Strength, Judd-Ofelt theory, Effect of Crystal Field, Radiative and Non-Radiative transitions, temperature dependent multi phonon relaxation.
Basic mechanism of resonant Energy Transfer, Exchange Interaction, Phonon Assisted energy transfer.
Properties of lasing ions, Lasing efficiency, Diode pumped solid state lasers, Nd-Yag Laser, N_2 Laser, Semiconductor Laser.

Unit-III

Nanomaterials: Introduction, Synthesis and Characterisation, Properties
Nanophotonics, Semiconductor nanoparticle for optical applications, Metal nanoparticles Sensing, Different types of sensors, Optical sensors, FRET based sensors

Recommended Readings:

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1. The Laser
   William V. Smith and P.P. Sorokin
2. Optical Electronics
   A Ghatak and K. Thyagarajan, Cambridge University Press, New Delhi.
3. Optoelectronics, J. Wilson and J.F.B. Hawkes, Prentice Hall of India, New Delhi.

F. High Energy Physics-II

Unit I

Field Interactions: Electromagnetic, weak, strong and gravitational interactions, electro-weak interaction (Weinberg-Salam Model), flavor-conserving neutral-current process, weak mixing angles, GIM mechanism.

Unit II

QCD: Renormalization; partons; gauge theory of quark-quark interactions, MIT bag model, Drell-Yan Process, lattice gauge theories, quark-gluon plasma.

Unit III

Physics Beyond the Standard Model: Supersymmetry, grand unified theory (GUT), magnetic monopoles, neutrino physics, string and superstring theories, solitons and instantons, extra dimensions.

Unit IV

Cosmic Rays: Discovery, types, chemical composition and energy spectrum, source, acceleration and propagation mechanisms, extensive air showers (EAS), EAS phonomenology, detection and simulation techniques.

Suggested Readings:

1. Introduction to Elementary Particles - D. J. Griffiths (John Wiley & Sons).
2. Quarks and Leptons - Francise Halzen and Alan D. Martin (John Wiley & Sons).
3. Gauge Theory of Elementary Particle Physics - Ta-Pei Cheng and Ling-Fong Li (Oxford University Press).
4. Introduction to High Energy Physics, Donald H. Parkings, Cambridge University Press.
5. An Introduction to Quarks and Partons - F. E. Close (Academic Press).
6. Introduction to High Energy Physics - Donald H. Parkings (Cambridge University Press).
7. Physics of Elementary Particles - H. Muirhead (Pergamon Press).
8. Quantum Field Theory - Lewis H. Ryder (Cambridge University Press).
9. An Introduction to Quantum Field Theory - Michael E. Paskin and Daniel V. Scroeder (Levant Books).
10. Field Quantization - W. Greiner and J. Reinhardt (Springer).
11. Introduction to supersymmetry - M. F. Sohnius (North-Holand-Amsterdam).
12. Weak Scale supersymmetry – H. Baer and X. Tata (Cambridge University Presss)
13. Cosmic Rays - A.W. Wolfendale (Philosophical Library).
14. Extensive Air Showers - W. Galbraith (Academic Press).
15. Cosmic Rays and Particle Physics - Thomas K Gaisser (Cambridge).
16. High Energy astrophysics - M.S. Longair (Cambridge).
17. High Energy Particles - Bruno Rossi (Prentice-Hall).
18. Radiation detection and measurement - G.F. Knoll (Wiley).
19. Extensive Air Showers - M.V.S. Rao and B.V. Sreekantan (World Scientific)

G. Astrophysics and Cosmology-II

Unit I

Astrophysics: Stellar properties and distance measurements; stellar structure, evolution and classification; energy transport in stellar environment; variable stars and compact stars, pulsars, quasars; galaxies.

Unit II

Cosmology: Einstein's universe, de Sitter solution, expanding universe, cosmological principles, FRW metric, Hubble's law and expanding universe, Big-Bang model, Friedmann equations, CMBR, matter eras, nucleosynthesis in Big-Bang, baryon-antibaryon asymmetry, topological defects, accelerating universe, dark matter, dark energy, alternative theories of gravity.

Unit III

Early Universe: Limit of classical cosmology, Planck era, inflation, horizon problem, flatness problem, formation of large-scale structure, scalar fields, baryon asymmetry, big-bang nucleosynthesis, topological defects.

Unit IV

Quantum Gravity: Graviton, quantum gravitational field, supergravity.

Suggested Readings:

1. Cosmic Perspective - Bennettt, Donahue, Schneider and Voit (Pearson Addision Wesley).
2. Introduction to Stellar Astrophysics - E. Bohm (Cambridge).
3. Principle of Stellar Evolution and Nucleosynthesis. - D. D. Clayton (University of Chicago Press).
4. An Introduction to the Study of Stellar Structure - S. Chandrasekhar (Dover Publication).
5. An Introduction to Astrophysics - B. Basu (Prentice-Hall of India).
6. Astrophysics : Stars and Galaxies - K. D. Abhyankar(Orient Longman).
7. Stars and Galaxies - Michael A. Seeds (Thomson Learning).
8. An Introduction to Cosmology - J. V. Narlikar (Cambridge University Press).
9. Gravitation and Cosmology - S. Weinberg (John Wiley & Sons).
10. General Relativity and Cosmology - S. Banerji and A. Banerjee (Elsevier).
11. General Relativity and Cosmology - S. K. Srivastava (Prentice-Hall of India).
12. Gravity : An Introduction to Einstein General Relativity - James B. Hartle (Pearson Education)
13. Principles of Cosmology and Gravitation - M. V. Berry (Overseas press).
14. Cosmology - S. Weinberg (Oxford University Press).
15. Modern Cosmology - Scott Dodelson (Academic press).
16. The Early Universe - E. W. Kolb and M. S. Turner (Levant Books, India).

H. Neutrino Physics

Unit I

Pauli's neutrino hypothesis, Reine and Cowan experiment; Neutrinos in the family of elementary particles, neutrino flavors; Sources of neutrinos- natural sources, artificial sources; Raymond Davis' experiment, solar neutrino problem.

Unit II

Neutrino oscillation, two flavor oscillation and mixing, mixing matrix, flavor eigenstates, mass eigenstates, mixing angles, mass eigenvalues, oscillation probability, mass squared difference, three flavor oscillation and mixing, PMNS matrix, properties of PMNS matrix, parametrization of PMNS matrix, CP phases.

Unit III

Oscillation experiments and different types, Super Kamiokande experiment, SNO, KamLAND, LSND, MINOS, T2K, Double Chooz, Daya Bay, RENO etc.

Absolute neutrino mass experiments, Neutrinoless Double Beta Decay experiment, Neutrino masses from cosmology.

Unit IV

Masses of neutrinos within the standard electroweak model, Dirac mass, Majorana mass, see-saw mechanism.

I. Antennas, Wave Propagation and RADAR

Unit- I

Dielectric Materials: Relative Permittivity: Definition, Dipole Moment and Electronic, Polarization, Polarization Vector P, Local Field E_{loc} and Clausius– Mossotti Equation, Electronic Polarization: Covalent Solids, Polarization Mechanisms, Ionic Polarization, Orientational (Dipolar) Polarization, Interfacial Polarization, Total Polarization Frequency Dependence: Dielectric Constant and DielectricLoss, Dielectric Loss, Debye Equations, Cole–Cole Plots, and Equivalent Series Circuit, Metamaterial behavior

Unit- II

Microwave Antenna: Antenna parameters- gain, Half Power Beamwidth, VSWR. Microwave antennas- Horn Antenna; E-Plane, H-Plane, Pyramidal horn, Whip antenna, Dicone antenna Microstrip antenna – Basic Characteristics, Feeding Methods, Method of analysis, Transmission line model and cavity model for rectangular patch antenna, Circular Patch Antenna, Inverted F Antenna, Planar Spiral Antenna. Theory of linear array: Two element and multi element array, isotropic and non-isotropic array, Binomial and Chebyshev distribution; Planar array, phased array and adaptive antenna; Introduction and benefits of Smart Antennas, Structures for Beamforming Systems, MIMO antennas, Spatial diversity. Antenna for cellular communication, satellite communication and wearable devices.

Unit- III

Electromagnetic Wave propagation: Maxwell's equations, constitutive relations, wave equation, plane wave functions, wave propagation in lossy dielectric, plane waves in lossless dielectrics, power and Poynting vector. Transmission lines: transmission line equation in time and frequency domain, losses and dispersion, reflection from an unknown load; quarter wavelength, single stub and double stub matching; Smith Chart and its applications. Waveguides: Rectangular waveguide, circular waveguide, dielectric slab waveguide surface guided waves, TE and TM modes, waveguide components.

Unit- IV

Introduction to RADAR: Block diagram of RADAR, Free space RADAR range equation, Maximum un ambiguous range, Pulsed RADAR system, Modulators, 2.4GHz RADAR boards, Vehicular RADAR for ADAS

Reference:

- Principle of Electronic Material and Devices- S O Kasap-McGraw hill Education
- Antenna Theory-Analysis and Design – Constantine A Balanis- Wiley
- Antenna- J D Kraus- McGraw hill Education
- Introduction to Electrodynamics-D J Griffiths- Prentice Hall
- Introduction to RADAR system- M I Skolnik-Mc Graw Hill Book Company
- Microwave and RADAR Engineering – M Kulkarni- Umesh Publications

- Keysight Technologies Basics of Measuring the Dielectric Properties of Materials
- Microwave Synthesis- Chemistry at the speed of light- Brittany L Hayes-CEM Publishing

J. Space and Atmospheric Physics

Unit- I

Physics of the Earth's Ionosphere: Ionospheric layers, mechanism of production and loss, Chapman profile, diffusion dominated processes, additional stratifications like F3, F1.5, ionospheric conductivity and currents, ionospheric propagation: radio wave in an ionized medium, Appleton-Hartree equation, radio propagation through an irregular plasma, diffraction, Fresnel zone effects,, ion-drag effects,, geomagnetic field and perturbations, Ionospheric Dynamo,F-region drifts, equatorial electrojet, Sporadic E, spread F, Scintillations, high latitude irregularities- blobs, enhancements, or patches, Polar ionosphere, longitudinal structures, effect of lower atmosphere-SSW, space weather events, Planetary ionospheres.

Unit- II

Sun-Earth Interaction: Structure of the Sun, radiation spectrum, solar wind, interplanetary magnetic field, frozen in fields, solar wind interaction with the magnetosphere, geomagnetic storms: primary drivers: prompt penetration and disturbance dynamo electric fields, sunspots, solar cycle, solar flares, CME, Sun-Earth Astronomical relationship, space weather.

Unit- III

Earth's Atmosphere: Atmospheric Composition, Hydrostatic equation, hydrostatic and non-hydrostatic dynamical cores, pressure and density variation with height, atmospheric layers-boundary layer, thermal structure, tropopause phenomena, STE, lower and middle atmospheric phenomena- Jet streams, SSW, PSC, Polar vortex, atmospheric tides, stratospheric cooling.

Unit- IV

Thermodynamics and Dynamics of the Earth's atmosphere: Thermodynamics of dry atmosphere- potential temperature, stability, Brunt Vaisala Frequency; Beer-Lambert law, Energy balance of the earth's atmosphere, Greenhouse effect, Dark heating, Radiative transfer, absorption and scattering of solar radiation: Rayleigh and Mie Scattering, radiative processes in the troposphere and the stratosphere, climate change and climate feedback.

Dynamics of the troposphere and stratosphere- Navier-Stokes theorem, equations and conservation laws, general circulation of the atmosphere, Walker circulation, Hadley Cells, Inter tropical convergence zone, cyclone, Waves and oscillations in the earth's atmosphere: planetary waves-Gravity waves, Rossby waves, Kelvin waves, Acoustic waves, Annual-

interannual-intra-seasonal oscillation, Quasi-biennial oscillation, Madden Julian oscillation, El Nino/La Nina southern oscillations, Atlantic Multidecadal Oscillations.

Atmospheres of other terrestrial planets: Mars, Venus.

Suggested Readings:

1. Meteorology for Scientists and Engineers, R Stull, Brooks/Cole, Thomson Learning
2. Atmospheric Chemistry and Physics, J H Seinfeld and S N Pandis, John Wiley and Sons
3. Introduction to Atmospheric Physics, D G Andrews, Cambridge University Press
4. Fundamentals of Atmospheric Modeling, M Z Jacobson, Cambridge University Press
5. An Introduction to Atmospheric Radiation, K N Liou, Academic Press
6. Stratosphere-Troposphere Interaction - K Mohankumar, Springer
7. Earth's Ionosphere, Plasma Physics and Electrodynamics, M C Kelley, Academic Press

8. The Solar Terrestrial Environment, J K Hargreaves, Cambridge University Press

9. Introduction to Ionospheric Physics, Henry Rishbeth and Qwen K. Garriott, Academic Press.

10. Space Plasma Physics, A C Das, Narosa Publishing House

7. Towards understanding the climate of Venus, L. Bengtsson et al. (eds.), DOI 10.1007/978-1-4614-5064-1 5, Springer
8. The Atmosphere and Climate of Mars - Haberle, R., Clancy, R., Forget, F., Smith, M., & Zurek, R. (Eds.). (2017), Cambridge: Cambridge University Press
9. MARS: An introduction to its interior, surface and atmosphere - Nadine Barlow, Cambridge University Press

K. Solid State Theory

Unit- I

Phonon dispersion relation for a three-dimensional crystal; calculation of force constants; application to simple cubic structures; anharmonicity and thermal expansion.

Unit- II

Energy band theory: Plane wave method; orthogonalized plane wave method; the tight binding method; K.P. method and effective mass theory.

Unit- III

Magnetic interactions of many electron system; the Hartee- Fock approximation; Hartee-Fock exchange and the Heisenberg Hamiltonian; the ground and excited states in Hartee-Fock approximation; microscopic theory of ferromagnetism;

Unit- IV

Ginzberg-Landau theory, Origin and formation of cooper pairs; BCS theory; superconductive tunnelling; Giaever tunnelling; Josephson effect; superconducting quantum interference device.

Recommended Readings:

1. Dynamical theory of crystal lattices
   M. Born and K. Huang.
2. An introduction to lattice dynamics
   A.K. Ghatak and L.S. Kothari.
3. Intermediate quantum theory of crystallire solids
   A.C.E. Animalu.
4. The theory of Brillouin Zones and electronic states in crystals
   S. Jones.
5. Solid state theory
   W.A. Harrison.
6. Principles of the theory of Solids
   J.M. Ziman.

L. Vacuum Techniques and Semiconductor Physics

Unit- I

Vacuum Techniques: Vacuum Pumps: Review on various pumps cryogenic pumps, cryosorption pumps, getter pump.
Vacuum materials: Absorption of gases, out gassing of materials, out gassing rates of vacuum materials, the permeation process, permeability of vacuum materials.
Vacuum assembly techniques: Design and performance of high vacuum system.
Vacuum measurements: Leak detection, pressure measurements (MeLeod, Pirani, Penning gauge) residual gas analysis, Bayard-Albert partial gas analysis, mass spectrometers.

Unit- II

Semiconductor Physics: Electron States: Concept of Brillouin zones, free electron bands, Semiconductor and semimetal bands, Review on K.P. method and effective mass theory effective mass determination, Dynamics of electrons and holes in semiconductors. Density of states and statistics: Fermi – level, conductivity, Diffusion, Theory of impurity states.

Hall Effect in Semiconductor,
Semiconductor – metal contacts:
Surface effects, field effects, Heterojunctions. Semiconducting materials: Si, Ge, and semiconducting compounds .
Optical and High frequency effects: Optical constants, free carrier absorption, fundamental absorption, direct and indirect transition, High frequency effects in a magnetic field, Photoconductivity and Photovoltaic effect .

Recommended Readings:

1.Hand Book of Thin Film Technology, Maissel and Glang .

2.High Vacuum Technology,Yarwood .
3.Semiconductor, R.A. Smith .
4.Transport properties of solid and solid state energyconversation, G.C. Jain and W.B.Berry
5.Photoconductivity of solids,R.H.Bube.
6.Electronic processes in non crystalline MaterialsN.F.Mott and E.A. Davis .

M. Accelerator Physics

Unity I

Introduction to Accelerators and its importance; Types of Accelerators**:** High voltage DC and RF accelerators, Cyclotron, Betatron , Synchrotron and Linear accelerators, Van de Graaff generator, Tandem accelerator, Pelletron accelerator.

Unit II

Ion Sources: Penning ion source, Freemen ion beam source, Sputtered ion source, Negative ion beam sources, Electron Cyclotron Resonance (ECR) ion beam sources, LASER ion source.

Unit III

Beam switch yard: conventional magnet and superconducting magnet Beam optics, Beam profile monitor, Faraday cup, Quadrupole.

Unit IV

Accelerator driven systems: Injection and extraction, Vacuum systems.

Unit V

Application of accelerators: Ion implantation, Surface modifications and research, Materials analysis, Nuclear physics, High energy Physics studies, Production of medical isotopes, Radiotherapy, Radiation and Safety.

Recommended Readings:

1. S Y Lee, 'Accelerator Physics', [World Scientific 1999]
2. Edmund Wilson, 'An Introduction to Particle Accelerators', [Oxford University Press 2001]
3. Alex Chao, 'Handbook of Accelerator Physics and Engineering' [World Scientific 1999]
1. Mario Conte and William W McKay, 'An Introduction to the Physics of Particle Accelerators', [World Scientific 1991]
2. Ashok Das and Thomas Ferbel, 'Introduction to Nuclear and Particle Physics' [John Willey [1994]
3. J.F. Ziegler, 'Ion Implantation Science and Technology'.
4. G. Dearnaley, J.H. Freeman, R.S. Nelson, and J. Stephen, 'Ion implantation', North Holland, Amsterdam 1973.

N. Materials Modelling

Unit- I

Basics of predicting crystal structures: Unit Cell, Direct and Reciprocal lattice, k points, Brillouin Zones

Unit- II

Practical introduction to different electronic structure determination program packages with input descriptions

Computational modelling and visualization of bulk, surfaces and various nano-structured materials

Computing electronic band structure, density of states, phonon dispersion of metals, semiconductors and insulators

Effect of spin polarization on electronic structure of materials

Unit- III

Calculating properties such as mechanical, optical, thermoelectric, catalytic etc. for materials with different crystal structures, compositions, dimensions

O. General Theory of Relativity II

Unit- I

The gravitational field equations and their solutions: Cosmological constant, energy momentum tensor and their role in different solutions. Minkowski, de Sitter and anti de Sitter space solutions. Schwarzchild solution.

Unit-II

Basic Cosmology: Experimental tests of General Relativity, FRW metric; cosmological expansion; cosmic microwave background; helium abundance; anisotropies in the CMBR.

Unit-III

Introduction to Black holes: Black holes in Newtonian gravity and General Relativity, Schwarzschild, Reissner Nordstrom, Kerr. AdS generalizations, elementary ideas about black hole thermodynamics.

Suggested Readings:

8. Special Theory of Relativity, R. Resnick, McGraw Hill
9. Tensor Calculus, D.C. Kay, Schaum's Outlines
10. Tensor Calculus, P. A. M. Dirac, Prentice-Hall of India
11. Gravitation and Cosmology, S. Weinberg, McGraw Hill
12. Gravitation, T. Padmanabhan, Cambridge University Press
13. Gravitation, J. A. Wheeler, C. W. Misner and K. S.Thorne, Princeton University
14. Cosmology, J. V. Narlikar, Cambridge University Press

P. Thin Film Technology

Unit I

Vacuum Nomenclature and Definitions:Basic definitions, applications of vacuum, techniques to achieve vacuum, vapour pumps, pressure measurement gauges.

Unit II

Thin film deposition techniques: Physical and chemical vapour deposition techniques, molecular beam epitaxy, laser ablation, hot wire and microwave CVD techniques.

Unit III

Growth of thin films: nucleation and growth of thin films,thermodynamic and kinetic considerations of thin filmdeposition.

Unit IV

Characterization of thin films: Different methods of thickness measurements, estimation of electrical, optical, chemical and structural properties.

Recommended Readings:

1. Materials science of thin films, M. ohring, Academic press.
2. Vacuum deposition of thin films, L. Holland, Chapman and Hall.
3. Thin film phenomena, K. Chopra, McGraw Hill, New York.
4. High Vacuum Technology, Yarwood