THIRUVALLUVAR UNIVERSITY
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M.Phil / Ph.D Common Entrance Test Syllabus
PHYSICS

1. MATHEMATICAL PHYSICS

I. Linear Vector Spaces and Matrices

Linear Vector Spaces: Linear independence, basis and dimension - inner products. Orthonormality and completeness - Schwartz Inequality - Orthonormal basis - Gram-Schmidt orthogonalization process - Linear operators - Vectors in n dimensions - Matrix algebra, similarity transforms, matrix diagonalization - Orthogonal, Hermitian and Unitary matrices- Properties.

II. Tensors

Coordinate transformation– summation convention - Contravariant, Covariant and mixed tensors – Rank of a tensor – symmetric and anti-symmetric tensors - Invariant tensors - Kronecker delta, Levi-civita tensor in three dimensions – contraction of tensors - product rule - Quotient rule - tensors of higher rank- Tensor forms of Operators.

III. Ordinary Differential Equations

Second order linear differential equations: Wronskian, Ordinary and singular points- series solutions - Generating functions – Rodrigue's formula - Orthogonality relations - Important recurrence relations for Bessel, Legendre, Hermite and Laguerre functions - Spherical harmonics.

IV. Green's functions

Dirac-delta function - Green's function - One dimensional Green function - boundary conditions – Eigen function - expansion of the Green's function- Reciprocity theorem – Sturm-Liouville type equations in one dimension and their Green's functions.

V. Probability theory and Random variables

Probability distributions and probability densities - Binomial, Poisson's and Normal - standard discrete and continuous probability distributions - moments and generating functions - Central limit theorem (statement and applications).

2. CLASSICAL AND STATISTICAL MECHANICS

(a) CLASSICAL MECHANICS

i. Lagrangian and Hamiltonian formulation

Hamilton's Variational Principle and Lagrange's equation - Lagrange Problems - Double Pendulum, Spherical pendulum, Cylinder rolling down an inclined plane - Hamilton's equations - cyclic variables – Principle of least action – Hamiltonian Problems - motion of a particle in a central force field, charged particle moving in an electromagnetic field – Equations of motion and first integrals –Scattering by central potential – Kepler's laws – Transformation from centre of mass to laboratory frame.

ii. Rigid body dynamics and Canonical transformations

Rigid body motion – Kinematics - Euler's angles - Angular momentum and kinetic Energy – Moment of inertia tensor - Euler's equations of motion – Torque-free motion of a rigid body - Motion of a symmetrical top under the action of gravity - Canonical transformation and their generators – simple examples – Poisson brackets – Equations of motion in Poisson bracket form - Noether's theorem

iii. Hamilton - Jacobi Theory and Theory of Small Oscillations

Hamilton-Jacobi equations – Application to Linear harmonic oscillator problem - Action Angle variables - Application to Kepler's problem - Oscillatory motion - Theory of small oscillation –Two coupled pendulums - Linear triatomic molecule - Stability of Oscillatory motion - Forced Harmonic Oscillator - non- linear Oscillation in a symmetric potential.

(B) STATISTICAL MACHANICS

iv. Thermodynamics and Classical statistics

Thermodynamic parameters – thermodynamic potentials – Gibbs phase rule – First and second order phase transitions – Ehrenfest's equations - Random walk - Brownian motion - Langevin theory - Einstein theory.

Classical Statistics: Microstates and Macrostates - Phase space - Liouville theorem and it's significance - ensembles - Micro Canonical, Canonical and Grand Canonical ensembles - Partition function - Translational partition functions - Gibb's Paradox - Sackur- Tetrode equation.

v. Quantum Statistics

Quantum Statistics of ideal gas - Ideas of Bose-Einstein and Fermi-Dirac Particles - Degeneracy of gases - Bose-Einstein condensation of gases - Photon gas - Planck's law of radiation and its limitation - Thermionic emission - Pauli's theory of Paramagnetism - Ising model.

3. QUANTUM MECHANICS

i. Basic formalism

Wave functions for a free particle - Interpretation and conditions on the wave function - Postulates of quantum Mechanics and the Schrödinger equations – time dependent, independent - Expectation Value - Stationary States - Ehrenfest's theorem - Hermitian Operators for dynamical variables - Eigen values and Eigen functions - Uncertainty Principle.

ii. One Dimensional and Three Dimensional Problems

One Dimensional: Particle in a box – simple harmonic oscillator - Square well potential – Barrier penetration – Three Dimensional: Orbital angular momentum and spherical harmonics - Central forces and reduction of two body problem - Particle in a Spherical well - Hydrogen atom.

iii. General formalism

Hilbert's space - Dirac notation - Representation theory - Co-ordinate and momentum representations - Time evolution - Schrödinger, Heisenberg and Interaction pictures - Symmetries and conservation laws.

iv. Approximation methods

Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of an harmonic oscillator and Stark effect in Hydrogen - Variation method -Application to ground state of Helium atom - WKB approximation - WKB quantization rule - Application to simple Harmonic Oscillator.

v. Angular momentum and identical particles

Ladder Operators - Commutation rules for angular momentum operators - Eigen value spectrum from angular momentum algebra - Matrix representation - Spin angular momentum – Non-relativistic Hamiltonian including spin - Addition of two angular momenta - Clebsch- Gordan coefficients - Symmetry and anti symmetry of wave functions - Pauli's spin matrices.

4. ELECTROMAGNETIC THEORY AND PLASMA PHYSICS

i. Electrostatics

Laplace and Poisson equations – Boundary value problems - boundary conditions and uniqueness theorem – Laplace equation in three dimensions– Solution in Cartesian and spherical polar co ordinates – Examples of solutions for boundary value problems - Polarization and displacement vectors - Boundary conditions - Dielectric sphere in a uniform field – Molecular polarisability and electrical susceptibility –Langevin Theory of Polar molecules - Electrostatic energy in the presence of dielectric – Multipole expansion.

ii. Magnetostatics

Biot-Savart Law - Ampere's circuital law - Magnetic vector potential and magnetic field of a localised current distribution - Magnetic moment, force and torque on a current distribution in an external field - Magnetostatic energy - Magnetic induction and magnetic field in macroscopic media - Boundary conditions - Uniformly magnetised sphere.

iii. Maxwell Equations

Faraday's laws of Induction - Maxwell's displacement current - Maxwell's equations – free space and linear isotropic media - Vector and scalar potentials - Gauge invariance - Wave equation and plane wave solution- Coulomb and Lorentz gauges - Energy and momentum of the field - Poynting's theorem - Lorentz force - Conservation laws for a system of charges and electromagnetic fields.

iv. Electromagnetic Waves

Plane waves in non-conducting media - Linear and circular polarization, reflection and refraction at a plane interface- Fresnel's law, interference, coherence and diffraction - Waves in a conducting medium - Propagation of waves in a rectangular wave guide -

Inhomogeneous wave equation and retarded potentials - Radiation from a localized source - Oscillating electric dipole.

v. Elementary Plasma Physics

The Boltzmann Equation - Simplified magneto-hydrodynamic equations - Electron plasma oscillations - The Debye shielding problem - Plasma confinement in a magnetic field - Magneto-hydrodynamic waves - Alfven waves and magnetosonic waves.

5. SPECTROSCOPY

i. Microwave spectroscopy

Pure rotational spectra of diatomic molecules - Polyatomic molecules - Study of linear molecules and symmetric top molecules - Hyperfine structure and quadruple moment of linear molecules - Experimental techniques - Molecular structure determination - Stark effect - inversion spectrum of ammonia - Applications to chemical analysis.

ii. Infrared spectroscopy

Vibrational spectroscopy of diatomic and simple polyatomic molecules - Harmonic Oscillator - Anharmonic Oscillator - Rotational vibrators - Normal modes of vibration of Polyatomic molecules - Experimental techniques - Applications of infrared spectroscopy - H2O and N2O molecules - Reflectance spectroscopy.

iii. Raman Spectroscopy

Classical theory of Raman Scattering - Raman effect and molecular structure - Raman effect and crystal structure - Raman effect in relation to inorganic, organic and physical chemistry - Experimental techniques - Coherent anti-Stokes Raman Spectroscopy - Applications of infrared and Raman spectroscopy in molecular structural confirmation of water and CO2 molecules - Laser Raman Spectroscopy.

iv. NMR and NQR Spectroscopy

Theory of NMR - Bloch equations - Steady state solution of Bloch equations - Theory of chemical shifts - Experimental methods - Single Coil and double coil methods - Pulse Method - High resolution method - Applications of NMR to quantitative measurements. Quadruple Hamiltonian of NQR - Nuclear quadruple energy levels for axial and non-axial symmetry - Experimental techniques and applications.

v. ESR and Mossbauer Spectroscopy

Quantum mechanical treatment of ESR - Nuclear interaction and hyperfine structure - Relaxation effects - Basic principles of spectrographs - Applications of ESR method - Mossbauer Effect - Recoillness emission and absorption - Mossbauer spectrum – Experimental methods - Mossbauer spectrometer - Hyperfine interactions - Isomer shift - Magnetic hyperfine interactions - Electric quadruple interactions - Simple biological applications.

6. NUCLEAR AND PARTICLE PHYSICS

i. Nuclear Interactions

Nuclear forces – Exchange forces - Two body problem – Ground state of deutron - Magnetic moment – Quardrupole moment - Tensor forces – Nucleon – Nucleon interaction –Meson theory of nuclear forces – Nucleon-Nucleon scattering – Effective range theory – Spin dependence of nuclear forces – Charge independence and charge symmetry of nuclear forces – Isospin formalism.

ii. Nuclear Reactions

Types of reactions and conservation laws – Energetics of nuclear reactions – Dynamics of nuclear reactions – Q-value equation – Scattering and reaction cross sections – Compound nucleus reactions – Direct reactions – Resonance scattering – Breit-Wigner one level formula.

iii. Nuclear Models

Liquid drop model – Bohr-Wheeler theory of fission – Experimental evidence for shell effects – Shell model – Spin-orbit coupling - Magic numbers – Angular momenta and parities of nuclear ground states – Qualitative discussion and estimate of transition rates – Magnetic moments and Schmidt lines – Collective model of Bohr and Mottelson.

iv. Nuclear Decay

Beta decay – Fermi theory of beta decay – Shape of the beta spectrum – Total decay rate - Mass of the neutrino – Angular momentum and parity selection rules – Allowed and forbidden decays – Comparative half-lives – Neutrino physics – Non-conservation of parity – Gamma decay – Multipole transitions in nuclei – Angular momentum and parity selection rules – Internal conversion – Nuclear isomerism.

v. Elementary Particle Physics

Types of interaction between elementary particles – Hadrons and leptons – Symmetries and conservation laws – Elementary ideas of CP and CPT invariance – Classification of hadrons – SU(2) and SU(3) multiplets –- Gell-Mann-Okubo mass formula for octet and decuplet hadrons – Quark model- Types of quarks.

7. MICROPROCESSOR AND MICROCONTROLLER

i. 8085 Architecture and Programming

8085 Architecture - Programmer's model - ALU - Registers and Flags - Stacks - Complete instruction set of Intel 8085 - State transition and timing diagrams - T States - Machine cycles - Instruction cycles - Timing diagram for memory read and memory write cycles - Addressing modes - Maskable and Non-maskable Interrupts - Assembly language programs – time delay subroutines and delay calculations.

ii. Interfacing Memory and I/O devices

Interfacing memory and devices – I/O and Memory mapped I/O – Simple polled I/O and Handshaking operations - Programmable keyboard / display interface 8279 - Programmable peripheral device 8255A - 8253 Timer Interface – DAC and ADC interface - Wave form generation (Sine, square, triangular and ramp wave) - Programmable communication interface 8251 (USART).

iii. Microcontroller 8051

Introduction – 8 and 16 bit Microcontroller families –Flash series – Embedded RISC Processor – 8051 Microcontroller Hardware – Internal registers – Addressing modes – Assembly Language Programming – Arithmetic, Logic, Sorting operations and BCD to binary and binary to BCD conversion.

iv. Interfacing I/O and Memory With 8051

Interfacing I/O Ports, External memory, counters and Timers - Serial data input/output, Interrupts – Interfacing 8051 with ADC, DAC, LED display, Keyboard, Sensors and Stepper motor.

v. Embedded Microcontroller

Embedded microcontroller system – types of embedded operating system – Micro chip PIC 16C6X /7X family – features – Architecture – Memory Organization – Register

file map – I/O ports – Data and flash program memory – asynchronous serial port – Applications in communication and industrial controls.

8. MATERIALS SCIENCE AND LASER PHYSICS

i. Defects and dislocations

Point defects - Schottky and Frenkel defects - number of defects as a function of temperature - Diffusion in metals - Diffusion and ionic conductivity in ionic crystals - Dislocations - Edge and screw dislocations - Burgers vector - Plastic deformation - Slip - Motion of dislocations under uniform shear stress - Stress fields around dislocations - Density - Work hardening function- Effect of grain size on dislocation motion - Effect of solute atoms on dislocation motion.

ii. Optical Properties, Dielectric Properties and Ferro Electrics

Color centers - Photo conductivity - electronic transitions in photo conductors - Trap, Capture, recombination centers - General mechanism - Luminescence - Excitation and emission - Internal electric field in a dielectric - Clausius-Mossotti and Lorentz - Lorenz equations - Dielectric dispersion and loss - Ferroelectrics - Ferro electricity - General properties - Dipole theory - Ionic displacements and the behaviors of BaTiO3.

iii. Elastic Behaviour, Polymer and Ceramics

Anelastic and visco elastic behaviour - Atomic model of elastic behaviour - rubber like elasticity - Anelastic deformation - Relaxation process - Model for visco elastic behaviour - Polymers - Polymerization mechanism - Polymer structures - Deformation of polymers - Behaviour of polymers. Ceramics:Ceramic phases - Structure - classes - Effect of structure on the behaviour of ceramic phases - composites.

iv. Nano Material and Its Applications

Classification of Nanomaterials – Synthesis – Ball milling, Solgel and CVD methods – metal and semiconductor nanoparticles by colloidal route – microorganism method – Analytical methods: STM- TEM – Electrical, Magnetic and optical properties of nanoparticles – Applications Optoelectronic device– LED – Colourants and pigments – Nano biotechnology – DNA chips – DNA array devices – Drug delivery systems.

v. Laser Physics

Introduction - Interaction of radiation - with matter - Spontaneous and stimulated emission - Conditions for oscillation - Frequency of oscillation of the system - Einstein co-efficient

- Possibility of amplification - Population inversion - Laser pumping Rate equations - Three level and four level system - Optical resonator - Types and modes of resonator - Oscillation - Threshold condition. The confocal resonant cavity - theory - Spot size and beam divergence - quality factor (Q) of an optical cavity.

9. CONDENSED MATTER PHYSICS

i. Crystal Physics

Types of lattices - Miller indices – symmetry elements and allowed rotations - simple crystal structures – Atomic packing factor - Crystal diffraction - Bragg's law – Scattered wave amplitude - Reciprocal lattice (sc, bcc, fcc) – Diffraction conditions - Laue equations – Brillouin Zone - Structure factor - Atomic form factor - Inert gas crystals - Cohesive energy of ionic crystals - Madelung constant - Types of crystal binding(general ideas).

ii. Lattice dynamics

Monoatomic lattices - Lattice with two atoms per primitive cell - First Brillouin zone - Group and phase velocities - Quantization of lattice vibrations - Phonon momentum - Inelastic scattering by phonons - Einstein's model and Debye's model of specific heat - thermal expansion - Thermal conductivity - Umklapp processes.

iii. Theory of metals and semiconductors

Free electron gas in three dimensions - Electronic heat capacity - Wiedmann-Franz law - Band theory of metals and semiconductors - Bloch theorem - Kronig-Penny model - Semiconductors - Intrinsic carrier concentration – Temperature dependence - Mobility - Impurity conductivity – Impurity states - Hall effect -Fermi surfaces and construction - Experimental methods in Fermi surface studies - de Haas Van Alphen effect.

iv. Magnetism

Diamagnetism - quantum theory of Paramagnetism - Rare earth ion - Hund's rule - Quenching of orbital angular momentum - Adiabatic demagnetization - Quantum theory of ferromagnetism - Curie point - Exchange integral - Heisenberg's interpretation of Weiss field - ferromagnetic domains - Bloch Wall - Spin waves - Quantization - Magnons - thermal excitation of magnons - Curie temperature and susceptibility of ferrimagnets - Theory of anti ferromagnetism - Neel temperature.

v. Super conductivity

Experimental facts: Occurrence - Effect of magnetic fields - Meissner effect – Critical field – Critical current - Entropy and heat capacity - Isotope effect - Energy gap - Type I and Type II superconductors. Theoretical explanation: Thermodynamics of super conducting transition - London equation - BCS Theory - Coherence length –- Cooper pairs - Single particle Tunneling - Josephson tunneling - DC and AC Josephson effects - High temperature super conductors - SQUIDS.

10. QUANTUM MECHANICS II

i. Scattering Theory

The scattering problem - formulation –cross sections - Scattering amplitude – Greens function approach - Born approximation and its validity - Partial wave analysis - optical theorem - Phase shifts - Scattering length and effective range - Low energy scattering - Transformation from centre of mass to laboratory frame.

ii. Perturbation Theory

Time dependent perturbation theory - Constant and harmonic perturbations - Transition probabilities – Fermi-Golden rule - Selection rules for dipole radiation - Adiabatic approximation - Sudden approximation - The density matrix - spin density matrix and magnetic resonance - Semi classical treatment of an atom with electromagnetic radiation.

iii. Relativistic Quantum Mechanics

Klein-Gordon equation - Failures - Dirac equation - Plane - wave solutions - Interpretation of negative energy states - Antiparticles - Spin of electron - Magnetic moment of an electron due to spin - Energy values in a coulomb potential.

iv. Dirac equation

Covariant form of Dirac equation - properties of gamma matrices - Traces - Separation of the equation and the Hydrogen atom problem - Invariance of Dirac equation under Lorentz transformation - T-Transformation for the Dirac equation in presence of electromagnetic field.

v. Quantisation of Fields

Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field - The Lagrangian and Hamiltonian formulations of field – Quantum equation for the field - Second quantization of Klein-Gordon field - creation and annihilation operators - Commutation relations - Quantization of electromagnetic field - Quantization of Schroedinger’s field - Quantization of Dirac field.