Physics PhD Qualifying Exam
Paper 1 – Syllabus

Preface

This document comprises all topics relevant for Paper 1 of the Ph.D. Qualifying Exam in Physics at Eastern Mediterranean University, in accordance with the Department's Rules and Regulations for Graduate Studies (valid until the change of the Department's Rules and Regulations for Graduate Studies is made). The subjects covered in Paper 1 are from Classical Mechanics, Electrodynamics, Quantum Mechanics, and Mathematica Methods for Scientists and Engineers corresponding to the MSc courses taught in our department. The reference textbooks are indicated at the end of each subject.

Classical Mechanics

Topics covered

1. Elementary principles
   1.1 Mechanics of a particle
   1.2 Mechanics of a system of particles
   1.3 D'Alembert principle and Lagrange equations
   1.4 Conservation theorem
2. Variational principles
   2.1 Hamilton's principle
   2.2 Calculus of variations
3. The central force problem
   3.1 Two body problem and equivalent one body problem
   3.2 The Kepler problem and planetary motion
   3.3 Conserved quantities in the Kepler problem: the Laplace-Runge-Lenz vector
4. Rigid body motion
   4.1 Rotations and orthogonal transformations
   4.2 Euler angles and rotation matrices
   4.3 Mechanics of rotating systems Coriolis effect and satellite motion
   4.4 Euler's equations of motion
   4.5 The heavy symmetrical top and gyroscopes
   4.6 Inertia tensor, precession and wobbling of the Earth
5. Oscillations
   5.1 The eigenvalue equations
   5.2 Normal modes
   5.3 Application to vibrations of molecules
   5.4 Forced vibrations
6. Lagrange formulation
7. Hamilton formulation
   7.1 Hamilton's equations
   7.2 Hamilton's formulation of relativistic mechanics
   7.3 Principle of least action
8. Canonical transformations
   8.1 Canonical transformations
   8.2 Poisson brackets and relation to commutators of quantum mechanics
9. Hamilton-Jacobi theory
   9.1 Hamilton-Jacobi equations

Bibliography

Goldstein, H, Poole, C P, & John, L S (2014) *Classical Mechanics* (3rd ed) Essex, England: Pearson Education Limited

Electrodynamics

Topics covered

1. Electrostatics
   1.1 Gauss' law
   1.2 Potential
   1.3 Poisson's equation
   1.4 Surface charge distributions
   1.5 Green's function with boundary values
   1.6 Capacitance, dielectrics
2. Techniques of solutions of boundary value problems: images, separation of variables, orthogonal functions, Fourier series and integrals, spherical coordinates, spherical harmonics, Legendre functions, Bessel functions, Green's function in spherical coordinates, multipole expansions
3. Magnetostatics
   3.1 Vector potential
   3.2 Magnetic moment, torque
   3.3 Permeability
   3.4 H and B
   3.5 Boundary value problems
4. Faraday's law
   4.1 Induction
   4.2 Energy in a magnetic field
   4.3 Quasistatic fields
5. Maxwell's equations
   5.1 Gauge choices
   5.2 Retarded solutions
   5.3 Poynting's theorem

Bibliography

Jackson, J D, (1998) *Classical Electrodynamics* (3rd ed) New York, USA: Wiley

Quantum Mechanics

Topics covered

1. Quantum kinematics and dynamics
   1.1 Postulates of Quantum Mechanics
   1.2 Configuration space vs Hilbert space, wave function vs state vector
   1.3 Time evolution in Schrodinger and Heisenberg pictures
2. Simple 1-d problems
   2.1 Free particle
   2.2 Delta function potential
   2.3 Step-like potentials
   2.4 Harmonic oscillator: eigenstates and spectrum, raising and lowering operators
   2.5 Particle in a box
   2.6 Uncertainty principle
3. Continuous symmetries
   3.1 Translations
   3.2 Rotations
4. Discrete symmetries
   4.1 Parity
   4.2 Time reversal
5. Angular momentum
   5.1 Orbital angular momentum
   5.2 Spin
   5.3 Angular momentum algebra, addition of angular momentum
6. Spherical symmetry
   6.1 Spherical potentials
   6.2 Spherical harmonics
   6.3 Wigner-Eckart theorem
   6.4 Example: hydrogen atom
7. Charged particle in a magnetic field
   7.1 Electromagnetic gauge transformations
   7.2 Landau levels
   7.3 Aharanov-Bohm effect
8. Identical particles: Fermi and Bose statistics
9. Perturbation theory
   9.1 Time independent perturbation theory
   9.2 Time dependent perturbation theory
   9.3 Selection rules
10. Other approximation methods
    10.1 Born approximation
    10.2 WKB approximation
    10.3 Sudden and adiabatic approximations
11. Variational methods
12. Scattering theory
    12.1 Partial wave expansion
    12.2 Phase shifts
    12.3 Resonant scattering

Bibliography

Griffiths, D J (2014) *Introduction to Quantum Mechanics* (2nd ed) Harlow, UK: Pearson

Mathematical Methods for Scientists and Engineers

Topics covered

1. Vector Analysis
   - 1.1 Definitions, Elementary Approach
   - 1.2 Rotation of the Coordinate Axes
   - 1.3 Scalar or Dot Product
   - 1.4 Vector or Cross Product
   - 1.5 Triple Scalar Product, Triple Vector Product
   - 1.6 Gradient, ∇
   - 1.7 Divergence, ∇
   - 1.8 Curl, $\nabla\times$
   - 1.9 Successive Applications of ∇
   - 1.10 Vector Integration
   - 1.11 Gauss' Theorem
   - 1.12 Stokes' Theorem
   - 1.13 Potential Theory
   - 1.14 Gauss' Law, Poisson's Equation
   - 1.15 Dirac Delta Function
   - 1.16 Helmholtz's Theorem
2. Vector Analysis in Curved Coordinates and Tensors
   - 2.1 Orthogonal Coordinates in $\mathbb{R}^3$
   - 2.2 Differential Vector Operators
   - 2.3 Special Coordinate Systems: Introduction
   - 2.4 Circular Cylinder Coordinates
   - 2.5 Spherical Polar Coordinates
   - 2.6 Tensor Analysis
   - 2.7 Contraction, Direct Product
   - 2.8 Quotient Rule
   - 2.9 Pseudotensors, Dual Tensors
   - 2.10 General Tensors
   - 2.11 Tensor Derivative Operators
3. Functions of Complex Variable I Analytic Properties, Mapping
   - 3.1 Complex Algebra
   - 3.2 Cauchy-Riemann Conditions
   - 3.3 Cauchy's Integral Theorem
   - 3.4 Cauchy's Integral Formula
   - 3.5 Laurent Expansion
   - 3.6 Singularities
   - 3.7 Mapping
   - 3.8 Conformal Mapping
4. Functions of Complex Variable II
   - 4.1 Calculus of Residues
   - 4.2 Dispersion Relations
   - 4.3 Method of Steepest Descents
5. The Gamma Function (Factorial Function)
   - 5.1 Definitions, Simple Properties
   - 5.2 Digamma and Polygamma Functions
   - 5.3 Stirling's Series
   - 5.4 The Beta Function
   - 5.5 Incomplete Gamma Function
6. Differential Equations

6.1 Partial Differential Equations
6.2 First-Order Differential Equations
6.3 Separation of Variables
6.4 Singular Points
6.5 Series Solutions - Frobenius' Method
6.6 A Second Solution
6.7 Nonhomogeneous Equation – Green's Function
6.8 Heat Flow, or Diffusion, PDE

7. Calculus of Variations
   7.1 A Dependent and an Independent Variable
   7.2 Applications of Euler Equations
   7.3 Several Dependent Variables
   7.4 Several Independent Variables
   7.5 Several Dependent and Independent Variables
   7.6 Lagrangian Multipliers
   7.7 Variation with Constraints
   7.8 Rayleigh Ritz Variational Technique

Bibliography

Arfken, G. B., Weber, H. J., & Harris, F. E. (2005). *Mathematical Methods for Physicists,* (6th ed.). Academic Press.