Open Book Examination, January/February 2021

First semester M.Sc. Physics

Course: MP 1.1 – Mathematical Methods of Physics

Time: 3 Hours | Maximum Marks: 80

Instruction: Answer ***all*** questions.

1. (a) Let V be the vector space of all (2 × 2) matrices over the real field **R**. Show that W is not a subspace of V where: (i) W consists of all matrices with zero determinant, and (ii) W consists of all matrices A for which $A^2 = A$. (10)

   (b) Let $e_1, e_2, ...e_n$ be a basis of V. Then for any linear operators $S, T \in A(V)$, show that $\left[ST\right]_e = \left[S\right]_e \left[T\right]_e$. (5)

OR

2. (a) Calculate the Fourier transform (inverse transform) of $F(k) = \frac{N}{\sqrt{2\alpha}} e^{-\left(k^2/4\alpha\right)}$.

   Sketch an appropriate diagram for f(x) and F(k). (10)

   (b) Check whether the (3 × 3) rotation matrix can be diagonalized. (5)

3. (a) Show that the partial derivative of a covariant tensor is not a tensor. (10)

   (b) Explain transformation rules for contravariant, covariant and mixed tensors for rank 2. (5)

OR

4. (a) Determine the conjugate metric tensor in spherical coordinate system. (10)

   (b) Express grad, div and curl in spherical polar coordinate system. (5)

5. (a) Separate the Helmholtz equation $(\nabla^2 + k^2)\psi = 0$, in cylindrical coordinates and identify the corresponding ordinary differential equations. (10)

   (b) Find the singular points of the differential equation (5)

$$2x^2 + \frac{d^2y}{dx^2} + 3x\frac{dy}{dx} + (x^2 - 4)y = 0$$

OR

6. (a) Solve the integral equation $\varphi(x) = x + \frac{1}{2}\int_{-1}^{+1}(t-x)\varphi(t)dt$ using the Neumann series method. (10)

(b) Transform the following differential equation into an integral equation

$y''(x) + p^2 y = 0;$ given that $y(0) = y(1) = 0$ (5)

7. (a) Obtain any one of the recurrence relations of Legendre polynomial starting from its generating function. (5)

(b) State and prove the Orthogonality relation for Legendre polynomials. (10)

OR

8. (a) Obtain Bessel's function from its differential equation by Frobenius' method. (10)

(b) Define gamma and beta functions. (5)

9. Answer **any four** of the following. (4x5=20)

(a) Find the co-ordinate of the vector **V** relative to the basis (1,1,1), (1,1,0), (1,0,0) of R^3 where **V** = (4, -3, 2)

(b) Prove that the eigenvalues of a Hermitian matrix are real.

(c) Prove that the following is a tensor of rank 2 in 2 dimensional space

$$\bar{A} = \begin{pmatrix} y^2 & -xy \\ -xy & x^2 \end{pmatrix}.$$

(d) Show that (y, x) are the components of a tensor of rank 1 in two dimensions.

(e) Define the Wronskian determinant. Check whether the following solutions are linearly independent or not: $e^x \cos x$, $e^x \sin x$.

(f) Determine the eigenvalues and eigenfunctions of the homogeneous Fredholm equation $\varphi(x) = \lambda\int_{-1}^{+1}(t+x)\varphi(t)dt$.

(g) Prove that $xL_n'(x) = nL_n(x) - nL_{n-1}(x)$.

(h) Deduce $P_0(x), P_2(x)$ and $P_4(x)$ from Rodrigue's formula.

Open Book Examination, January/February 2021

First semester M.Sc. Physics

Course: MP 1.2 – Classical Mechanics

Time: 3 Hours Maximum Marks: 80

Instruction: Answer ***all*** questions.

1. (a) Prove that if the net force acting on a system of particles is zero, then the linear momentum of the system is constant. (8)

(b) Show that the sum of kinetic energy and potential energy for a system of particles moving under the action of an external force remains constant throughout its motion. (7)

OR

2. (a) Based on the concept of D' Alembert's principle, obtain Lagrange's equations of motion. (10)

(b) Setup the Lagrangian and hence obtain the equation of motion for the Atwood machine. (5)

3 .(a) Setup the Hamiltonian and Hamilton's equation of motion for simple pendulum and simple harmonic oscillator. (7)

(b) State Hamilton's principle of least action. Derive Hamilton's equations from the Variational Principle. (8)

OR

4 .(a) Define canonical transformations in Hamiltonian mechanics. Obtain the basic relations of canonical transformation in terms of the generating function F. (8)

(b) Express the total time derivative $\frac{dA}{dt}$ of a function $A\left(p_k, q_k, t\right)$ in terms of the Poisson bracket of A with the Hamiltonian H. (7)

5. (a) A rigid body is rotating about an axis through the origin. Deduce the relations connecting the components of total angular momentum with the components of angular velocity. (10)

(b) How will you assign the generalized coordinates for the motion of a rigid body? (5)

OR

6 .(a) Obtain Euler's equations of motion for a rotating rigid body with one point fixed. (8)

(b) Explain the force-free motion of a symmetrical top. (7)

7. (a) A body of rest mass m_0 moving at speed v collides and sticks to an identical body at rest. What is the mass and momentum of the final lump? (5)

(b) An atomic clock is placed in a jet airplane. The clock measures a time interval of 3600s when the jet moves with a speed of 400ms^{-1}. Find out the time interval measured by a clock on the ground. (5)

(c) Deduce the energy-momentum relation $E^2 = p^2c^2 + m_0^2c^4$ (5)

OR

8. (a) Describe the Eötvös experiment and its importance. (10)

(b) Arrive at the Newtonian limit of Einstein's field equations. (5)

9. Answer **any four** of the following: (4X5=20)

(a) A system of particles consists of three particles of masses 5 g, 3 g and 2 g located at the points (1,0,-1), (-2,1,3) and (3,-1,1) respectively. Find the coordinates of the centre of mass.

(b) If $\vec{F} = x^2yz\,\hat{i} - xyz^2\,\hat{k}$, find out the nature of the force $\vec{F}$.

(c) Starting from the Lagrangian, obtain the Hamiltonian for electron in hydrogen atom.

(d) Show that the transformation $Q_1 = q_1, Q_2 = p_2, P_1 = p_1 - 2p_2, P_2 = -2q_1 - q_2$ is canonical.

(e) Evaluate the Poisson bracket $\left[L_x, P_y\right]$ and $\left[L_x, L_y\right]$.

(f) Show that the kinetic energy of a rotating rigid body can be expressed as $T = \frac{1}{2}\omega J$.

(g) At what speed does a meter stick move if its length is observed to have shrunk to 0.5 m?

(h) The momentum of a body quadruples when its speed doubles. What was the initial speed in the units of c?

Open Book Examination, January/February 2021

First semester M.Sc. Physics

Course: MP 1.3- Atomic and Molecular Physics

Time: 3 Hours Max. Marks: 80

***Instructions**: Answer **all** questions.*

1. (a) What is rotational spectrum and how do we identify it in electromagnetic spectrum? Discuss the theory of rotational spectrum of a rigid diatomic molecule. (10)

(b) Write a note on Born-Oppenheimer approximation. (5)

OR

2. (a) Discuss quantum mechanical treatment of intensities of transition among various vibrational energy levels and obtain an expression for Franck-Condon factor. (10)

(b) What are 'P', 'Q' and 'R' branches of rotational spectrum? Explain their characteristics with necessary theory. (5)

3.(a) What is the essential idea behind the formation of molecules or solids through chemical bonding? Explain in detail with examples. (8)

(b) What is lattice energy? Explain the procedure to determine lattice energy theoretically and experimentally. (7)

OR

4. (a) What is a covalent bond? Explain the formation of σ and π bonds with examples. Describe the atomic and molecular orbitals resulting in these bonds. (10)

(b) What is hybridization of atomic orbitals? Describe the formation of sp^2 and sp^3 orbitals. (5)

5. (a) Describe various characteristics of LASERs. (8)

(b) Discuss Einstein's theory of various transitions (spontaneous and induced) and obtain the expressions for Einstein's coefficients. (7)

OR

6.(a) What is an optical cavity? Describe various modes of oscillations in a rectangular cavity. (10)

(b) Write a note on holography and its applications. (5)

7. (a) Discuss Raman spectroscopy and its applications. (5)

(b) Give an account for the difference in the intensities of Stokes lines and anti-Stokes lines of Raman spectrum. (5)

(c) Write notes on non-linear optical properties and higher harmonic generations. (5)

OR

8. (a) Explain the process of mode locking in LASERs. (5)

(b) Write a note on time profile of pulsed LASERs. (5)

(c) Explain how LASER spectroscopy has found application in medicine and diagnostics. (5)

9. Answer **any four** of the following: (4x5=20)

(a) Write a note on progression and sequences in rotational-vibrational spectra.

(b) What is a 'band head'? Explain the relationship between band head and rotational constants $B_v^{'}$ and $B_v^{''}$.

(c) What are unit cells in crystals? Are they unique? Justify.

(d) Write a note on metals and metallic bond.

(e) What is population inversion? Explain various methods to achieve population inversion.

(f) What is a MASER? Explain the construction and working of ammonia MASER.

(g) Discuss multi-photon excitations.

(h) Write a note on optical fiber communication and its consequences.

Open Book Examination, January/February 2021

First semester M.Sc. Physics

Course: MP 1.4 - Solid State Physics and Electronic Devices

Time: 3 Hours Max. Marks: 80

***Instructions**: Answer **all** questions.*

1. (a) Using tight binding approximation show the formation of energy bands in a simple cubic crystal. Show from the calculations that for small values of *k*, electron will behave like a free particle. (10)

(b) Prove that the reciprocal lattice of a bcc lattice is fcc lattice. (5)

OR

2. (a) What are Brillouin zones? Explain the motion of electrons in one – dimensional and two- dimensional lattices. (10)

(b) Discuss a method of determining Fermi surface of a metal experimentally. (5)

3 .(a) Explain the electrical conductivity using band theory of solids for metals and semiconductors. (10)

(b) Explain the Schottky effect. (5)

OR

4. (a) Discuss the Sommerfeld's theory of free electrons. (10)

(b) Discuss magnetoresistance in metals. (5)

5. (a) Discuss in detail the thermo-luminescence and glow curves. (10)

(b) Write a note on Destriau effect. (5)

OR

6 .(a) Obtain an expression for Fermi energy in case of an extrinsic semiconductor. (10)

(b) Explain the effect of doping on Fermi level in semiconductors. (5)

7. (a) With suitable diagram, explain the formation of junction in a p-n junction diode and obtain the expression for contact potential. (10)

(b) Obtain the expression for current in a reverse biased p-n junction diode. (5)

OR

8. (a) Explain with a neat diagram, the construction and working of:

(i) Phototransistor

(ii) Silicon Controlled Rectifier. (10)

(b) Distinguish between BJT and JFET. (5)

9. Answer any **four** of the following: (4X5=20)

(a) Prove that for the Kronig-Penny potential with P<<1, the energy of the lowest energy band at $k = 0$ is $E \frac{h^2 P}{4\pi^2 m a^2}$.

(b) Calculate the electrical conductivity of copper if the Fermi energy and electron concentration of copper are 7.05eV and 2.68X10^{28} m^{-3} respectively.

(c) Write a note on mean free path and importance.

(d) A photon of energy 1.2 MeV gets backscattered by an electron. Calculate the wavelength of the scattered photon.

(e) Describe the process of electro-luminescence.

(f) Calculate the carrier concentration at 300 K for an intrinsic semiconductor with a band gap of 1.1 eV.

(g) With a neat diagram explain the working of relaxation oscillator using UJT.

(h) The intrinsic stand-off ratio for a UJT is 0.6. If the inter-base resistance is 10 kΩ, find R_{B_1} and R_{B_2} .