

[This question paper contains 4 printed pages.]

(27)

Your Roll No. 2024

Sr. No. of Question Paper : 4388

G

Unique Paper Code : 32221502

Name of the Paper : Solid State Physics

Name of the Course : B.Sc. (Hons.) Physics

Semester : V

Duration : 3 Hours

Maximum Marks : 75

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt any **five** of the following questions.
3. Question no. 1 is compulsory.



1. Attempt any **Five** of the following : (3×5=15)

(a) What are point groups. Mention which are the two symmetry operations permissible in 2-D lattice? How many point groups are possible in 2-D lattice?

(b) What type of lattice and basis do the following structures have: (a) Sodium Chloride (b) Diamond Cubic (c) Zinc sulphide?

- (c) What is Ewald's construction? Give its significance.
- (d) For Cu, Einstein's temperature is 230°K . Calculate Einstein's frequencies of atoms in the solids. that $h = 6.6 \times 10^{-34}\text{Js}$ and $k_B = 1.38 \times 10^{-23}\text{J/K}$.
- (e) What are phonons? Mention one experiment which suggests the existence of phonons.
- (f) How does the Debye model differ from Einstein's model of specific heat?
- (g) What are the shortcomings of the free electron theory? Does this theory account for the variation of ohm's law?
- (h) What is ferroelectricity? Draw the graph showing variation of polarization with electric field for ferroelectric materials. Give one example compound / element which shows ferroelectricity.

2. (a) The primitive translation lattice vectors of a crystal are :

$$\vec{a} = \frac{a}{2}(\hat{i} + \hat{j} - \hat{k}), \vec{b} = \frac{a}{2}(-\hat{i} + \hat{j} + \hat{k}) \text{ and}$$

$$\vec{c} = \frac{a}{2}(\hat{i} - \hat{j} + \hat{k})$$

Determine the reciprocal lattice vectors and the structure obtained.

- (b) What are Miller Indices? What is the purpose of taking reciprocal of intercepts in order to find out Miller indices? (5)
- (c) Sketch (120), (101) and [100] in a cubic crystal. (5)
3. (a) Derive an expression for the dispersion relation for a mono-atomic lattice vibration in one dimension. Draw the dispersion curve for wave vector k lying between $-\pi/a$ to $+\pi/a$. (5)
- (b) Show that for very long wavelength limit, crystal behave as a continuous medium. (5)
- (c) Prove that crystal medium behave as low pass filter. (5)
4. (a) Derive Clausius-Mossotti relation between polarizability and dielectric constant of the dielectric material and discuss the significance of this relation. (8)
- (b) Draw a diagram showing variation of total polarizability with frequency ranging from static to ultraviolet and explain why the dielectric constant of water is 81 at zero frequency while it is 1.8 at optical frequencies. (7)
5. (a) Discuss difference between Type I and Type II superconductors using Meissner's effect. (5)

- (b) Write short notes on (i) Critical temperature (ii) Critical magnetic field and its variation with temperature. (5)
- (c) The penetration depth for lead is $396 \text{ \AA}$ and $1730 \text{ \AA}$ at 3 K and 7.1 K respectively. Calculate the critical temperature for lead. (5)
6. (a) Discuss the Langevin's theory of para-magnetism. How does the quantum theory remove the shortcomings of classical Langevin's theory. (8)
- (b) A paramagnetic salt contains 10^{28} ions/m^3 with magnetic moment of one Bohr magneton. Calculate the paramagnetic susceptibility and the magnetization produced in a uniform magnetic field of 10^6 A/m at room temperature (Given 1 bohr magneton $= 9.27 \times 10^{-24} \text{ A/m}^2$). (7)
7. (a) Discuss the formation of allowed and forbidden energy band gap on the basis of Kronig-Penny model. (10)
- (b) The energy near the valence band edge of a crystal is given by: $E = -A K^2$ where $A = 10^{-19} \text{ Jm}^2$. An electron with wave vector $k = 10^{10} \text{ m}^{-1}$ is removed from an orbital in a completely filled valence band. Determine the effective mass and energy of the electron. (5)

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Your Roll No. 2024

Sr. No. of Question Paper : 4477

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Unique Paper Code : 32227502

Name of the Paper : Advanced Mathematical
Physics – I (DSE)

Name of the Course : B.Sc. (Hons.) Physics

Semester : V

Duration : 3 Hours

Maximum Marks : 75

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **five** questions in all taking at least **two** questions from each section.
3. All questions carry equal marks.



Section-A

1. (a) Prove that the set Q_{-1} of all rational numbers other than -1 with the binary operation $*$ defined by $a * b = a + b + ab$ form a group. (5)

P.T.O.

- (b) If V be the set of all ordered triples of reals, with addition and scalar multiplication defined as follows :-

$$(x_1, y_1, z_1) + (x_2, y_2, z_2) = (3y_1 + 3y_2, -x_1 - x_2, z_1 + z_2)$$

$$\text{and } \alpha(x_1, y_1, z_1) = (3\alpha y_1, -\alpha x_1, \alpha z_1) \forall \alpha \in \mathbb{R}$$

then show that V is not a vector space. (5)

- (c) Determine whether or not the vector $\xi = (2, -5, 3)$ belonging to the subspace of $\mathbb{R}^3$ spanned by $\alpha_1 = (1, -3, 2)$, $\alpha_2 = (2, -4, 1)$ and $\alpha_3 = (1, -5, 7)$. (5)

2. (a) Verify that the vectors $(1, 3, 2)$, $(1, -7, -8)$, $(2, 1, -1)$ of v_3 space are linearly dependent. (5)

- (b) Consider $T : \mathbb{R}^3 \rightarrow \mathbb{R}^2$ defined by $T(x, y, z) = (2x + 7y, 5y - 3z)$. Determine whether T is a linear transform or not. (5)

- (c) If H is a Hermitian matrix, prove that e^{iH} is a unitary matrix ($i = \sqrt{-1}$). (5)

3. (a) Find the eigenvalues and eigenvectors of the matrix

$$A = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 3 & 2 \\ 0 & 0 & 2 \end{pmatrix}$$

Can A be diagonalized? If yes, find a diagonalizing matrix P and verify that P diagonalizes A . (10)

- (b) Write Cayley-Hamilton theorem and verify it for the matrix

$$A = \begin{pmatrix} 3 & -4 \\ 1 & 5 \end{pmatrix} \quad (1,4)$$

- (a) Solve the following system of differential equations using matrix method

$$y_1' = -y_1 + 4y_2$$

$$y_2' = 3y_1 - 2y_2$$

$$\text{subject to } y_1(0) = 3, y_2(0) = 4. \quad (10)$$

- (b) Find e^A for the matrix $A = \begin{pmatrix} 3 & -1 \\ 4 & -2 \end{pmatrix}$. (5)

Section-B

- (a) Obtain an expression of pure stress tensor and prove that it is symmetric tensor of order (rank) two. (6)
- (b) Show that $\vec{A} = \vec{B} \times \vec{C}$ transforms like a tensor of order (rank) one. (6)
- (c) Prove that ε_{ijk} (in Cartesian Co-ordinates) is an isotopic tensor of order three. (3)

- (a) Using Cartesian tensors, prove that

$$\nabla \cdot (\vec{A} \times \vec{B}) = (\nabla \times \vec{A}) \cdot \vec{B} - (\nabla \times \vec{B}) \cdot \vec{A} \quad (7)$$

(b) Show that $u_i v_j$ (in Cartesian Co-ordinates) is a tensor of order (rank) two. (3)

(c) By using the expression of Moment of Inertia of an asymmetric object

$$I_{ik} = \sum_{\text{all particles}} m (r^2 \delta_{ik} - r_i r_k),$$

from a matrix of all components. What is the all meaning of I_{xy} ? (4,1)

7. (a) A covariant tensor has components xy , $2y - z^2$, xz in Cartesian Co-ordinates. Find its covariant components in cylindrical co-ordinates. (12)

(b) Determine the metric tensor in Spherical Co-ordinates. (3)

8. (a) If A_k^{ij} and B_q^p are general tensors, show that $A_k^{ij} B_q^i$ is not a tensor. (6)

(b) Show that the outer product of two contravariant vectors A^μ and B^ν results in a contravariant tensor of rank two. (4)

(c) Show that every covariant tensor of order two can be expressed as the sum of two tensors, one of which is symmetric and the other skew-symmetric. (5)

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Your Roll No. 2024

Sr. No. of Question Paper : 4479

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Unique Paper Code : 32227504

Name of the Paper : Nuclear and Particle Physics

Name of the Course : B.Sc. (Hons.) Physics_DCS

Semester : V

Duration : 3 Hours

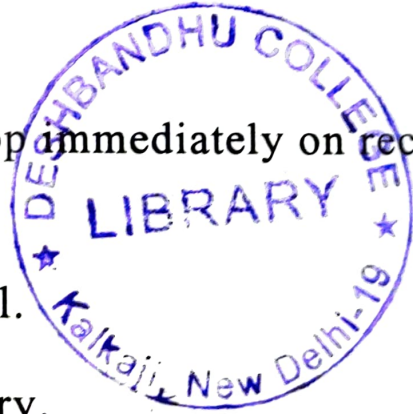
Maximum Marks : 75

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **five** questions in all.
3. Question No. 1 is compulsory.
4. Use of scientific calculators is allowed.
5. Some useful data is given at the end.

1. Attempt any **five** of the following :

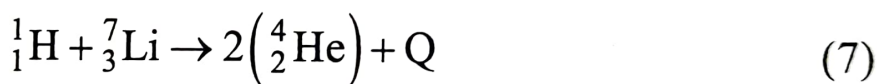
(a) Distinguish between the Bremsstrahlung radiation and Cerenkov radiation.



P.T.O.

- (b) Give the Lepton and Baryon numbers for electrons, protons and neutrons.
- (c) What is the basic difference between alpha decay spectrum and beta decay spectrum?
- (d) Why are even-even nuclei most stable?
- (e) Find the binding energy ${}^{56}_{26}\text{Fe}$ in MeV.
- (f) State four quantities that are conserved in a nuclear reaction.
- (g) Why do stable nuclei have more neutrons than protons? $(3 \times 5 = 15)$
2. (a) Discuss the basic assumptions of Liquid Drop model of nucleus. Explain how the model is used to estimate the semiempirical mass formula. (10)
- (b) Use the semiempirical mass formula to calculate the binding energy of ${}^{40}_{20}\text{Ca}$. (5)
3. (a) Explain in brief, the Fermi gas model for nuclei. (10)
- (b) Which isobar of A (atomic mass number) = 75 does the liquid drop model suggest to be the most stable nucleus? (5)

4. (a) Consider the successive nuclear decay of $A \rightarrow B \rightarrow C$. Assuming that the initial number of nuclei of A is N_{0A} and the initial number of nuclei B and C are 0, derive an expression for the number of nuclei $N_B(t)$ present at any instant of time. Assume the probability of decay per unit time for nuclei A and nuclei B are λ_A and λ_B respectively. (8)
- (b) For the following nuclear reaction, determine the energy released (Q) in MeV if protons are incident on the Lithium target.



5. (a) In the alpha decay of ${}_{94}^{238}\text{Pu}$ into the ground state and excited states of ${}_{92}^{234}\text{U}$, the energies of the alpha particles in MeV are 5.59, 5.546 and 5.447. Draw a schematic diagram of the transitions and determine the energies of γ rays emitted by the daughter nuclei. (8)
- (b) Give an example each of β^+ , β^- and electron capture. State three differences between decays by positron emission and the process of electron capture. (7)

6. (a) Explain the construction and working of an ionization chamber for nuclear radiation detection. (10)
- (b) Alpha particle of energy 10 MeV produces 3×10^5 ion pairs on being completely stopped in an ionization chamber. Calculate the pulse height and current in the output circuit if total capacitance of the ionization chamber and the resistance in the output circuit is 50 μF and 10 $\text{K}\Omega$ respectively. (5)
7. (a) Distinguish between Baryons and Mesons. (5)
- (b) Describe briefly the Quark model of elementary particles. Write down the quark contents of proton, neutron, neutral pion and charged pion. (5+5)

Some useful data

1 amu = 931.5 MeV

Masses:

Atomic mass of proton (m_p)	= 1.007825 amu,
Atomic mass of neutron (m_n)	= 1.008665 amu
Atomic mass of Hydrogen (^1_1H)	= 1.007825 amu
Atomic mass of Helium (^4_2He)	= 4.002603 amu
Atomic mass of Lithium (^7_3Li)	= 7.01603 amu
Atomic mass of Calcium ($^{40}_{20}\text{Ca}$)	= 40.078 amu
Atomic mass of Iron ($^{56}_{26}\text{Fe}$)	= 55.934939 amu
Atomic mass of Uranium ($^{238}_{92}\text{U}$)	= 238.040904 amu
Atomic mass of Plutonium ($^{238}_{94}\text{Pu}$)	= 238.049511 amu

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Your Roll No. 2024

Sr. No. of Question Paper : 4481

Unique Paper Code : 32227506

Name of the Paper : Astronomy & Astrophysics

Name of the Course : **B.Sc. (Hons.) Physics – DSE**

Semester : V

Duration : 3 Hours

Maximum Marks : 75

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **Five** questions in all.
3. Question No. **1** is compulsory.
4. Use of non-programmable scientific calculator is allowed.

1. Attempt any **five** of the following : (5×3)

- (a) Balmer lines are not seen in the spectra of either O stars or K stars. Explain.
- (b) What is the Sun's approximate RA on the following dates: June 7, Jan. 22 & Sept. 28.
- (c) What is the approximate LST at noon on July 22?
- (d) The star system 61 Cygni has a radial velocity of 64 km/sec, a proper motion of 5.28"/yr, and a distance of 3.498 pc. What is its space velocity?
- (e) What is Olber's paradox? How is it resolved?
- (f) For a spherical galaxy, determine the density profile $\rho(r)$ for which rotational velocity, $v_c(r)$ is independent of r . (r is the distance from the center of galaxy).

- (a) (i) Define apparent magnitude (m) and absolute magnitude (M). Show that $m = M + 5 \log_{10} D + 25$, where D is the distance measured in Mpc.
- (ii) The angular diameter of star A with apparent bolometric magnitude of 2 is 2.5 times greater than the angular diameter of star B with apparent bolometric magnitude of 7. What is the ratio of temperature of star A to that of star B.
- (b) Draw HR (Hertzsprung-Russell) diagram for classification of stars by incorporating Luminosity, temperature, absolute magnitude and spectral type. (10,5)
- (a) (i) Suppose an astronomer wants to observe the star on celestial meridian with declination $\delta = -60^\circ$. Which observatory should an

astronomer choose : Lick Observatory at latitude = 37° N or Keck observatory at latitude = 20° N (Explain with suitable diagram).

(ii) What are the advantages of reflecting type telescope over refracting type?

(b) For a gas of neutral hydrogen atoms, at what temperature is the number of atoms in the first excited state only 1% of the number of atoms in the ground state? (10,5)

4. (a) Consider a star with mass M and radius R . Assume that the star's density varies as a function of radius r according to the equation :

$$\rho = \rho_c [1 - (r / R)]$$

where ρ_c is the density at the center of the star.

- (i) Calculate ρ_c in terms of M and R .
- (ii) Calculate the mass of the star interior to radius r , $M(r)$, as function of total mass M and radius R .
- (iii) Using hydrostatic equilibrium, obtain an expression for the pressure, $P(r)$ at radius r in terms of G , M and R . (Assume that $P(R) = 0$, the pressure drops to zero at the outer boundary)
- (b) A globular cluster contain 10^6 stars, Assume that they all have same mass ($1 M_\odot$) and same speed (10 km/s). Use the virial theorem to estimate the characteristic size of the cluster.

5. (a) Using Maxwell equations, derive the induction equation having both the convective and diffusive term. Discuss the importance of both the terms.
- (b) The radius of the sunspot is $l = 10^4$ km and magnetic diffusivity $\eta = 10^3 \text{ m}^2 \text{ s}^{-1}$. Calculate the magnetic Reynold number if the velocity of the conducting fluid is 10^3 m s^{-1} . Explain the significance of the result obtained. (10,5)
6. (a) Derive an expression of radial velocity of a star in the neighbourhood of a sun as function of galactic longitude (l), distance between the star and the sun, d , and Oort's constant A .
- (b) Assume the Oort constants A and B are $+15 \text{ km/s/kpc}$ and -10 km/s/kpc respectively. Calculate the rotational velocity of the sun if it is 8.5 kpc away from the galactic center. (10,5)

- (a) Describe a method for obtaining a distance estimate for :
- (i) a galaxy whose approximate distance is 20 Mpc and
 - (ii) a star at a distance of 10 kpc.
- (b) Suppose a quasar shows absorption from a Lyman-alpha cloud at an observed wavelength $\lambda_0 = 183 \text{ nm}$.
- (i) Given that Lyman-alpha has a rest wavelength of about $\lambda = 122 \text{ nm}$, what is the redshift z for this cloud.
 - (ii) For a Hubble constant $H_0 = 67 \text{ km/s/Mpc}$, what is its distance, in Mpc? (10,5)

Useful constants :

$$G = 6.67 \times 10^{-11} \text{ m}^{-3} \text{ kg}^{-1} \text{ s}^{-2}$$

$$k_B = 1.38 \times 10^{-23} \text{ J/K}$$

$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

$$M_{\text{sun}} = 1.99 \times 10^{30} \text{ kg}$$

$$R_{\text{sun}} = 6.96 \times 10^8 \text{ m}$$

$$L_{\text{sun}} = 3.86 \times 10^{26} \text{ W}$$

$$1 \text{ A. U.} = 1.5 \times 10^{11} \text{ m}$$