2016

PHYSICS

(Major)

Paper : 6.2

(Theory)

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

GROUP—A

(MATHEMATICAL METHODS)

(*Marks* : 15)

1. Answer any *two* from the following : 1×2=2

(a) Which of the following quantities is a tensor of rank 1?

$$\sum_{i=0}^{3} a_i b^i, \quad \sum_{k=0}^{3} a_{ik} b^k, \quad \sum_{i,k=0}^{3} P_{ik} \xi^i \xi^k$$

(b) A covariant tensor of rank 2 and a contravariant tensor of rank 1 are given by $g_{\mu\nu}$ and A^{α} respectively. How can you obtain a tensor of rank 1 by combining them?

(c) If W_{pm} is an antisymmetric tensor, show that

$$(\delta^i_m \delta^k_p + \delta^i_p \delta^k_m) W_{ik} = 0$$

2. Answer any *four* from the following : 2×4=8

(a) Show that $F_{ij} = \frac{\partial a_i}{\partial x^j} - \frac{\partial a_j}{\partial x^i}$ is an anti-symmetric tensor.

(b) A vector $\vec{X}$ has components (x^1, x^2). If the coordinate system is rotated counter-clockwise by an angle θ, the components are transformed into $(\bar{x}^1, \bar{x}^2)$. From the transformation rule

$$\bar{x}^i = \sum_{j=1}^{2} \frac{\partial \bar{x}^i}{\partial x^j} x^j$$

obtain the matrix form $\left(\frac{\partial \bar{x}^i}{\partial x^j} \right)$.

(c) If a_{ik} and b_{ik} are two symmetric tensors satisfying the equation

$$a_{ij} b_{kl} - a_{il} b_{jk} + a_{jk} b_{il} - a_{kl} b_{ij} = 0$$

show that $a_{ij} = \rho b_{ij}$ is a solution of the above equation where ρ is a constant.

(d) Show that $\delta^i_j U^i U^j$ represents square of the magnitude of the vector

$$\vec{U} = U^1 \hat{i} + U^2 \hat{j} + U^3 \hat{k}$$

(e) If a tensor of rank N is contracted 2 times, what would be its final rank? Obtain a zero rank tensor from the 4th rank tensor R^{ij}_{kl}.

3. Answer any *one* from the following : 5

(a) If G^{ij} and T^{ij} are two contravariant tensors of rank 2 and satisfy the equation

$$G^{ij} - kT^{ij} = 0$$

in coordinate system x^i, show that they satisfy same form of equation

$$\overline{G}^{ij} - k\overline{T}^{ij} = 0$$

under coordinate transformation $x^i \to \overline{x}^i$. Here k is an invariant.

(b) If g_{ij} is a second rank covariant tensor and A^i and B^j are two contravariant tensors of rank 1, show that the quantity $g_{ij}A^iB^j$ remains invariant under coordinate transformation $x^i \to \overline{x}^i$.

(c) If I^{ij} is a contravariant tensor of rank 2 and ω_j is covariant tensor of rank 1, show that $L^i = I^{ij}\omega_j$ transforms like a contravariant tensor of rank 1.

GROUP—B

(SOLID-STATE PHYSICS)

(*Marks* : 45)

4. Choose the correct answer from the following : 1×7=7

(a) The number of atoms per unit cell in an f.c.c. lattice is

(i) 1

(ii) 2

(iii) 3

(iv) 4

(b) The type of bonding between layers of graphite is

(i) van der Waals

(ii) hydrogen bond

(iii) ionic

(iv) covalent

(c) Near to absolute zero temperature, silicon is a/an

(i) metal

(ii) semimetal

(iii) insulator

(iv) semiconductor

(d) Intrinsic germanium can be made *p*-type semiconductor by doping with

(i) phosphorous

(ii) aluminium

(iii) sulphur

(iv) carbon

(e) Donor level in an extrinsic semiconductor lies

(i) near to valence band

(ii) at the middle of the band gap

(iii) near to conduction band

(iv) anywhere in the band gap

(f) The very first superconductor discovered was

(i) Hg

(ii) Nb

(iii) Pb

(iv) Bi

(g) Above Curie temperature a ferromagnetic material becomes

(i) antiferromagnetic

(ii) paramagnetic

(iii) diamagnetic

(iv) ferrimagnetic

5. Give very short answers of the following questions : 2×4=8

(a) What are primitive and non-primitive unit cells?

(b) Write the first two terms in the Madelung constant of NaCl.

(c) Write the expression relating electrical and thermal conductivity of metals and explain the terms used.

(d) What are ferromagnetic domains?

6. Give short answers on any *two* of the following questions : 5×2=10

(a) What are Miller indices and how are they determined? What are the Miller indices of faces of a cubic lattice? 1+2+2=5

(b) Illustrate on covalent bonding of solids. What are the characteristic properties of covalent solids? 3+2=5

(c) Assuming kinetic theory of gases to be applicable to free electron gas, obtain expression for thermal conductivity of free electrons. 5

(d) Illustrate briefly on Kronig-Penney model. 5

7. Answer any *two* questions from the following : 10×2=20

(a) Obtain the values of packing fractions of f.c.c. and b.c.c. lattices in closed packed structure. What is the reason that most of the metals crystallize in f.c.c. form? 4+4+2=10

(b) Illustrate on Boltzmann transport equation. How is it used to determine electrical conductivity for a free electron gas? 4+6=10

(c) Explain classical theory of paramagnetism. What are the drawbacks of this theory? 7+3=10

(d) How is permeability related to magnetization? From *B-H* curve of a ferromagnet, explain the phenomena of energy loss. An electromagnet produces 1 tesla magnetic field (H). Show that at a temperature (T) of 300 K the approximation $\mu H / k_B T$ is valid. (Where μ = Bohr magneton and k_B = Boltzmann constant.) 2+5+3=10

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