'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours Part-III Examination, 2022

PHYSICS

PAPER-VIII

Time Allotted: 4 Hours | Full Marks: 90

The figures in the margin indicate full marks.
All symbols are of usual significance.

Answer question no. 1 and *five* from the rest, taking at least *one* but not more than *two* from each group

1. (a) KBr crystal has a cubic structure. If its density is 2.75×10^3 kg m^{-3} and molecular weight is 119.01 a.m.u., calculate the lattice constant. 3

   (b) An alien spaceship is being followed by a rocket launched from the earth. The speed of the rocket as observed from the Earth is 2.5×10^8 ms^{-1} and that of the alien spaceship is 2×10^8 ms^{-1}. What is the speed of the alien spaceship with respect to the rocket? 3

   (c) In a medium of dielectric constant 5, the maximum displacement current is equal to the maximum conduction current at a frequency of 1 MHz. Find out the conductivity of the medium. 3

   (d) Describe the state of polarization of the wave 3

$$\vec{E}(z,t) = \hat{i}E_0\cos(kz-\omega t) - \hat{j}E_0\sin(kz-\omega t)$$

   (e) Estimate the diamagnetic susceptibility per mole of hydrogen. Assume $\langle r_0^2\rangle = 3a_0^2$ where the atomic radius $a_0 = 0.5$Å. 3

GROUP-A

(PHYSICAL OPTICS II)

2. (a) Describe the phenomenon of double refraction in a uniaxial crystal. How is double refraction explained by Huygen's theory? 2+2

   (b) If n_0 is the refractive index for the O-ray, and n_e is the refractive index for the E-ray, then show that the refractive index n_θ for the E-ray in the direction θ with the optical axis is given by, 4

$$\frac{1}{n_\theta^2} = \frac{\cos^2\theta}{n_0^2} + \frac{\sin^2\theta}{n_e^2}$$

   (c) How can you convert 4

   (i) an elliptically polarised light into a circularly polarized light?

   (ii) a circularly polarised light into an elliptically polarized light?

   (d) For calcite, $\mu_e = 1.486$ and $\mu_0 = 1.658$ for the sodium light. Calculate the minimum thickness of a quarter wave plate made out of calcite. 3

3. (a) Explain the working principle of the optical fibre as a waveguide for light. 3
   (b) Deduce the threshold condition for a Laser action. 4
   (c) Explain the concept of temporal and spatial coherence. Discuss how the visibility of fringes depend on the degree of coherence. 3+2
   (d) Calculate the numerical aperture and acceptance angle of an optical fibre for which μ_1 (core) = 1.55 and μ_2 (cladding) = 1.50 3

4. (a) What is optical activity? Discuss Fresnel's theory of optical activity and obtain an expression for the rotation. 1+5
   (b) A 20 cm long tube containing 48 cc of sugar solution produces an optical rotation of 11°. If the specific rotation of sugar solution is 66°, determine the amount of sugar present in the solution contained in the tube. 3
   (c) Discuss the four-level pumping scheme for a Laser action. 3
   (d) State the basic principles of holography. 3

GROUP-B

(ELECTROMAGNETIC THEORY AND SPECIAL THEORY OF RELATIVITY)

5. (a) Derive the electromagnetic wave equations from Maxwell's field equations and show that the electric and magnetic fields are in phase in a homogeneous isotropic dielectric medium. 2+3
   (b) What is the Poynting vector? Determine the Poynting vector at the surface of the Sun if the power radiated by the Sun is 3.8×10^{26} W while its radius is 7×10^{8} m. 2+2
   (c) Explain the concept of displacement current. 2
   (d) Using Maxwell's equations show that the velocity of propagation of electromagnetic waves in free space is $c = 1/\sqrt{\mu_0\varepsilon_0}$ 4

6. (a) Define the scattering cross-section. Assuming the formula for the time average power radiated per unit solid angle by an oscillating dipole, obtain an expression for the scattering cross-section for Rayleigh scattering. 1+4
   (b) Show that the Brewster's law of polarisation is a direct consequence of the Fresnel's law of reflection. 3
   (c) Verify whether $\vec{E} = \cos(y-t)\hat{k}$ and $\vec{B} = \cos(y-t)\hat{i}$ may constitute an electromagnetic wave. 3
   (d) Show that 4

$$\frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)$$

   remains invariant under Lorentz transformation.

7. (a) Show that, $\frac{\partial U}{\partial L} + \nabla \cdot \vec{S} = 0$, where $\vec{S} = \frac{1}{\mu_0}(\vec{E}\times\vec{B})$ and U is the energy density. 4
   (b) What do you mean by a proper length? Using Lorentz transformation equations show that proper length is the highest length of an object. 1+3

(c) Show that a particle of zero rest mass, must travel with the speed of light. Calculate the relativistic mass and momentum of a photon of energy 6.2×10^{-19} J. $1\frac{1}{2}+1\frac{1}{2}$

(d) Find out the speed of a 1 MeV electron both classically and relativistically. 2+2

GROUP-C
(SOLID STATE PHYSICS)

8. (a) Define the 'packing fraction' for a lattice structure. Calculate the packing fraction and density of sodium chloride from the following data: 1+3

Radius of sodium ion = 0.98Å

Radius of chlorine ion = 1.81Å

Atomic mass of sodium = 22.99 amu

Atomic mass of chlorine = 35.45 amu

(b) Derive an expression for the interplanar spacing of the (hkl) planes of a simple cubic structure. 3

(c) The distance between the (100) planes (d_{100}) in a bcc structure is 0.232 nm. Determine the lattice constant. 2

(d) All primitive cells are unit cells, but all unit cells may or may not be primitive cells. — Justify. 2

(e) Prove that the reciprocal lattice vector is normal to a lattice plane of the crystal lattice. 4

9. (a) What is the Hall-coefficient? Discuss how the Hall-coefficient is experimentally determined. 1+3

(b) State Wiedemann-Franz's law. How can you prove it on the basis of Drude model of free electrons? 2+5

(c) The Curie temperature of iron is 1043 K. If each Fe atom has a magnetic moment $\mu = 2\mu_B$ where μ_B is the Bohr magneton, calculate the following: 2+2

(i) Saturation magnetization

(ii) Weiss field constant for iron.

Assume, that iron has a bcc structure with lattice constant $a = 0.286\,\text{nm}$. Given that $\mu_B = 9.27\times10^{-24}\,\text{Am}^2$.

10. (a) What do you mean by the effective mass of an electron? 2

(b) What do you understand by a Fermi gas? Can a metal be associated with two Fermi temperatures? 2+1

(c) What is the Fermi surface? Determine the Fermi temperature of lithium with an electron density $5\times10^{29}\,\text{m}^{-3}$. 1+3

(d) Distinguish between dia-, para-, ferro- and antiferro- magnetic materials on the basis of the variation of magnetic susceptibility with temperature. 4

(e) What are ferrites? Discuss some of its uses. 1+1

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