RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. THIRD SEMESTER EXAMINATION, DECEMBER 2017

SECOND YEAR [BATCH 2016-19]

Date : 12/12/2017 **PHYSICS [Honours]**

Time : 11 am – 3 pm **Paper : III** Full Marks : 100

Group – A

(*Answer <u>any three</u> questions*) [3×10]

1. a) Define the electrostatic energy. Derive an expression of the electrostatic energy of a point charge distribution. [1+3]

   b) Find an expression for electrostatic energy in a region of space where the field is $\vec{E}$ and permittivity of space is $\in$. Three point charges are located at three vertices of an equilateral triangle of side *a*. Assuming the magnitude of charge q find the electrostatic energy of the system. [3+1]

   c) Find the energy of uniformly charged spherical shell of total charge q and radius R. [2]

2. a) Consider a uniformly charged sphere of radius *a* and charge density ρ. Show that the electric potential ϕ at any internal point with distance *r* from centre is given by $\phi(r) = \frac{\rho a^3}{6 \in_0}\left(3 - \frac{r^2}{a^2}\right)$. [3]

   b) Consider a spherical shell carrying a total charge Q is cut into two equal halves. What is the force of repulsion between the two halves. [4]

   c) Determine the polar equation of a equipotential surface for a dipole. [3]

3. a) Show that the electrostatic potential due to an arbitrary charge distribution may be considered as the sum of potentials due to a monopole, a dipole, a quadrupole and higher order multipoles. [4]

   b) Show that if the total charge vanishes, the dipole moment is independent of the choice of origin. [2]

   c) Three point charges $-q(-a,0,0), +2q(0,0,0)$ and $-q(a,0,0)$ are placed on x-axis at the locations mentioned. Find an expression for the quadrupole moment for the given charge distribution. Hence find the potential for the system at any point $P(r,\theta)$. [3+1]

4. a) Establish the relation $\vec{D} = \in_0 \vec{E} + \vec{P}$ for a parallel plate capacitor with linear dielectric within it. (Symbols have their usual meaning). [3]

   b) At the plane interface between two dielectrics with K_1 = 3 and K_2 = 2, electric field $E_1 = 1200\,v/m$ in the upper medium makes an angle $\theta_1 = 45°$ with the normal to the interface. Find the electric field in the lower medium and also the polarization charge density on the interface. [4]

   c) A metal sphere of radius *a* carries a charge Q. It is surrounded out to radius *b*, by linear dielectric material of permittivity $\in$. Find the potential at the centre of the sphere. [3]

5. a) Consider a point charge q is placed at the front of a conducting sphere of radius *a* at a distance *d*. Calculate the induced charge density on the surface of the sphere. [4]

   b) Show that the ratio if charge densities at two extreme ends ($\theta = 0°$ and $\theta = 180°$) of the sphere is $\frac{\sigma_1}{\sigma_2} = \left(\frac{d+a}{d-a}\right)^3$. [2]

   c) The potential $V_0(\theta)$ is specified on the surface of a hollow sphere of radius R. Find the potential inside the sphere. [Assume the solution of Laplau's equation if necessary] [4]

Group – B

(*Answer <u>any four</u> questions*) [4×10]

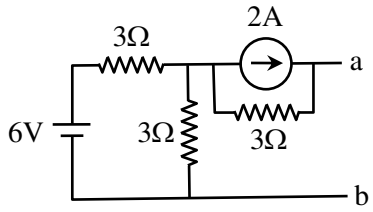
6. a) What is magnetic vector potential? Is the choice of magnetic vector potential unique? Justify. [1+2]

   b) An electron moves in a circular orbit of radius 5·1 nm around a nucleus at a frequency of $6\cdot8\times10^{15}$ Hz. Find the magnetic field at the centre of the nucleus. [2]

   c) A standard solenoid of length 1m and radius 3 cm has 1000 turns is carrying current of 500mA along $\hat{\phi}$. Find the magnetic field at (i) (0,0,0) cm, (ii) (25,0,0)cm and (iii) (100,0,0)cm. [5]

7. a) Express the principle of conservation of charge in differential form. [4]

   b) In the following circuit, a load R is connected between the terminals ab. What should be the value of R such that maximum power is dissipated in it. Also, find the maximum power. [1+3]



   c) Discuss the analogy between electric and magnetic circuits. [2]

8. a) An infinite current sheet of infinitesimal thickness lies in the z = 0 plane with surface current density $\vec{K} = K\hat{x}$. Show that the magnetic field can be written as

$$\vec{B} = \begin{cases} -\frac{\mu_0}{2}K\hat{y} & \text{for} \quad z > 0 \\ +\frac{\mu_0}{2}K\hat{y} & \text{for} \quad z < 0 \end{cases}$$

   Hence deduce the magnetic vector potential. [4+2]

   b) Find an expression for torque acting on a square current coil placed in a uniform magnetic field. [4]

9. a) Explain what do you mean by free current and bound current in connection with magnetization of matter. [1]

   b) Show that magnetic field due to an object of magnetization $\vec{M}$ is equivalent to sum of bound current densities $\vec{K}_b = \vec{M}\times\hat{n}$ on the surface and $\vec{J}_b = \vec{\nabla}\times\vec{M}$ within the volume of the object. [5]

   c) In a magnetic material for which $\mu = 5\cdot5\mu_0$ and $\vec{B} = 2\hat{x} + 10\hat{y} - 4\hat{z}\,\text{mWb.m}^{-2}$. Find (i) the magnetization M, (ii) the bound current density and conduction current density, (iii) the surface current density. [1+1+2]

10. a) Two magnetic media of relative permeability μ_1 and μ_2 are separated by a plane interface. Show normal component of B field satisfy the relation $B_{1n} = B_{2n}$. [3]

    b) Show that magnetic scalar potential satisfied Laplace's equation in absence of conduction current in a material of uniform magnetization. [3]

    c) The toroid of iron $(\mu_r = 5000)$ having mean diameter 20 cm and cross sectional area $\pi\,\text{cm}^2$ to produce a flux of $12\cdot57\times10^{-4}\,\text{Wb}$ in the ring. If a air gap of 8mm length is cut in the ring then calculate the current required to maintain the same flux. [The number of turns of the wire is 400]. [4]

11. a) A DC emf is applied to a circuit consisting of resistor R and a inductor L in series. Find the instantaneous current in the circuit. Show graphically how two voltages across L and R vary with time. [3+2]

b) Calculate the self inductance (internal inductance) per unit length of a solid cylindrical conductor of radius *a*. [3]

c) A solid cylindrical conductor of length 1m, radius 5cm carrying current 1A with uniform current distribution over its cross-section. Find the energy stored only within the material of the conductor. Assume the permeability of the material to be equal to μ_0. [2]

12. a) State Faraday's law of induction. Express the integral and differential form of Faraday's law of induction and explain their significance. [1+3]

b) A metal rod of length ℓ is placed on two rails with one end is connected with conducting wire. A uniform magnetic field *B* is applied perpendicular to the plane of the rail. The rod is given a push towards right with velocity v_0. The rod moves on rails. Assume that there is no friction, find the distance before which the rod comes to rest. [3]

c) Prove the Neumann's formula for the mutual inductance for two arbitrary loops. [3]

Group – C

(*Answer <u>any three</u> questions*) [3×10]

13. a) Five independent shots are fired at a target. The probability of a hit in each short is 0·25. Three hits suffice to destroy the target. Determine the probability of target destruction. [4]

b) What do you mean by most probable macrostate? What is its role in determining the behaviour of a system in equilibrium? [2]

c) Write down the expression of partition function (Z) of a system in thermal equilibrium at a temperature T. What is its significance? How can it be used to find the mean energy of the system? [1+1+2]

14. a) What are virial coefficients? Write down vander Waal's equation of state. Hence find virial coefficients. Find the expression for Boyle temperature in terms of virial coefficient *a* and *b* of vander Waal's gas? Show that vander Waal gas differ from ideal gas by 62·5%? [1+1+2+1+2]

b) What is the mean inter molecular separation and the mean free path in a van der Waals gas at its critical point? Express your answers in terms of the molecular diameter *d*. [3]

15. a) Write down the expression of coefficient of viscosity (η) of an ideal gas. Show that $\eta \propto \frac{1}{d^2}$, where d is the molecular diameter. [2]

b) Define the coefficient of self diffusion (D) for an ideal gas in which concentration gradient exists only along one direction. Write down the expression of D and relate it with η. [3]

c) Deduce the expression of molecular effusion and obtain the nature of speed distribution of molecules effusing through the hole. [3+2]

16. a) Explain the thermodynamic limit. What is the importance of thermodynamic limit? [2]

b) Find the expression for average velocity, root mean square velocity and most probable velocity according to Maxwell's velocity distribution. [2+2+2]

c) "Atmosphere has no sharp boundaries". Explain. [1]

d) Explain the absence of hydrogen (H_2) gas in Earth's atmosphere. [1]

17. a) Explain the difference between thermal conductivity and thermometric conductivity with example. [3]

b) Deduce an expression for the rate of radial flow of heat under steady state per unit length of an infinite annular conducting cylinder heated uniformly along the axis. [4]

c) The temperature of H_2 and He mixture is T = 300K. At what value of molecular velocity *v* will the Maxwell distribution function F(v) yield the same magnitude for both gases. [3]

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