RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. THIRD SEMESTER EXAMINATION, DECEMBER 2015

SECOND YEAR [BATCH 2014-17]

Date : 15/12/2015 **PHYSICS [Hons]**

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

[Use a separate Answer Book for each group]

<u>Group – A</u>

Answer **<u>any three</u>** questions

1. a) State Coulomb's law in electrostatics in free space. How is the singularity in the equation removed? [1+3]

   b) Consider a circular disk of radius *a* having uniform surface charge density σ on it. Calculate the electric potential and field at an axial point P at a distance *x* from the centre of the disk. Show the variations of field and potential w.r.t *x* graphically. [3+1]

   c) State and explain superposition principle in electrostatics. [2]

2. a) What do you mean by flux of electric field? A point charge Q is placed at the corner of a cube. Find the flux through a surface just in front of the charge. [1+3]

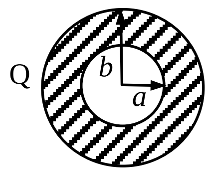
   b) Derive Poisson's equation in electrostatics from Gauss's law. [2]

   c) A spherical shell of radius *a* is maintained at a constant potential V_a. Obtain the variation of the potential outside and inside the sphere. [4]

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. [6]

   b) Show that the quadrupole moment for an arbitrary charge distribution is independent of choice of the origin provided both the dipole and monopole moments are zero. [4]

4. a) Consider a thick metallic shell of inner radius *a* and outer radius *b* with charge Q on it. A point charge q is fixed at the centre of the shell. Calculate the charge on each surface and also the potential and field everywhere. Also show the variation of potential and field with distance from centre. [1+3+2]

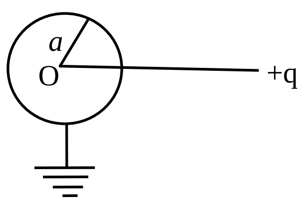


   b) A non-conducting thick spherical shell of radius $n_j (a \le r \le b)$ has a charge density $P(r) = \frac{A}{r}$, A is a constant. At the centre of the enclosed cavity a point charge Q is placed. What should be the value of A so that the field in the region $a \le r \le b$ has a constant magnitude. [4]

5. a) Establish the relation $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$ for a parallel plate capacitor with linear dielectric within it. (Symbols have their usual meaning) [2]

   b) The interior of a cylinder, defined by $x^2+y^2 = R^2$, z = 0 and z = h is occupied by a dielectric material with polarization $\vec{P} = \hat{i}x^2 + \hat{j}y^2$. Find the volume and surface charge densities due to the polarization. [3]

   c) Consider a grounded conducting sphere of radius *a* is placed in front of a point charge q as shown in figure. Calculate the potential and field at an external point $P(r, \theta)$ w.r.t. the centre of the sphere. [5]



Group – B

Answer **any four** questions

6. a) Find the expression for reluctance of a magnetic circuit. 3

   b) Investigate the discharge of a capacitor in series LCR circuit driven by a D.C. source. When is the discharge critically damped? 4+1

   c) In a series LCR circuit, L = 10 mH and C = 1μF. Calculate the value of 'R' for which the capacitor discharge is critically damped. 2

7. a) Show that the magnetic field $\vec{B}$ inside the infinitely long solenoid oriented along *z*-axis, with '*n*' turns for unit length, radius 'R' and carrying current 'I' is $\vec{B} = \mu_0 nI\hat{z}$. 4

   b) Prove that the magnetic flux $\phi = \int \vec{B}.d\vec{S} = \oint \vec{A}.d\vec{l}$ where $\vec{A}$ represents the magnetic vector potential. 2

   c) A semi-infinite conducting filament (with respect to origin) carries 3A current in *x*-direction. Find the magnetic field B at (i) (3,4,0) cm (ii) (–3,4,0) cm. 2+2

8. a) Show that a non-uniform magnetization $\vec{M}$ is equivalent to a bound current density $\vec{J} = \vec{\nabla} \times \vec{M}$ throughout the magnetized body. 5

   b) An infinitely long cylinder of radius R carries a "frozen-in" magnetization $\vec{M} = cr\hat{z}$ where *c* is a constant and *r* is the distance from the axis. There is no free current anywhere. Find the magnetization current densities and total current. 5

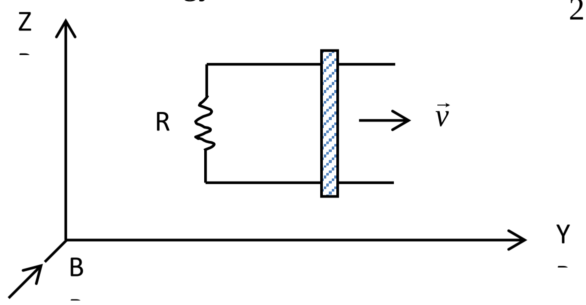
9. a) What do you mean by magnetic poles? Show that $-\vec{\nabla}.\vec{M}$ represents the magnetic pole density? 1+2

   b) A sphere of radius R is so magnetized that its magnetization at any inside point (*x*,*y*,*z*) with respect to its centre as origin is given by $\vec{M} = (a+bx)\hat{z}$. Find the magnetization current densities and magnetic pole densities. 4

   c) Show that the magnetic scalar potential satisfies Laplace's equation in the absence of free currents in a linear material and for uniform magnetization. 3

10. a) What is the difference between motional emf and transformer emf? 4

    b) A metal bar of mass *m* slides frictionlessly on two parallel conducting rails a distance *l* apart (shown in figure). A resistor *R* is connected across the rail and a uniform magnetic field $\vec{B} = B(-\hat{x})$ fills the entire region. If the bar moves at velocity $\vec{v} = v(\hat{y})$ with initial velocity v_0 at time *t* = 0, show that the energy delivered to the resistor is $\frac{1}{2}mv_0^2$. 6



11. a) Establish the following boundary condition $\frac{B_{1t}}{\mu_1} = \frac{B_{2t}}{\mu_2}$ where the symbol have their usual meanings. 5

    b) Given that $\vec{H}_1 = 10\hat{x} + 6\hat{y} - 3\hat{z}$ A/m in the region $y - x - 2 \le 0$, where $\mu_1 = 5\mu_0$ for a coil of area 10 cm^2 carrying current of 10A. Calculate (i) $\vec{M}_1$ (Magnetization) and $\vec{B}_1$ (ii) $\vec{H}_2$ in the region $y - x - 2 \ge 0$, where $\mu_2 = 2\mu_0$. 2+3

12. a) Show that the equivalent inductance of two coils of self inductance L_1 and L_2 connected in parallel is $L_{eq} = \frac{L_1L_2 - M^2}{L_1 + L_2 \mp 2M}$ where, M is the mutual inductance between the coils. 4

b) A steady current of 2A in a coil of 400 turns causes a flux of 10^{-4} Wb to link the loops of the coil. Calculate (i) the average back emf induced in the coil if the current is stopped in 0.08 sec, (ii) the inductance of the coil and (iii) the energy stored in the coil. 3

c) A capacitor of capacitance C is charged by a battery of emf E through a resistance R. Show that, half of the total energy delivered from the battery is used in charging the condenser. 3

Group – C

Answer **any three** questions

13. a) What do you mean by statistical expectation value? Distinguish among the three distributions; Binomial, Gaussian and Possion. Give examples in each case. [1+3]

b) Find the mean value and standard deviation of binomal distribution. [3]

c) The probability of molecular collision in gas over a time interval dt is αdt where α is a constant. Find the mean time interval between two successive collisions. [3]

14. a) State the fundamental postulates of statistical mechanics. What do you mean by canonical ensemble. For what type of system is it suitable? [2+2+1]

b) Define degrees of freedom of a gas molecule. Find the total Kinetic energy (U) associated with the chaotic motion of one mole of an ideal monatomic gas at absolute temperature T. How does this energy U vary with temperature if pressure is maintained constant. [1+2+2]

15. a) Define the coefficient of self diffusion (D) for an ideal gas in which concentration gradient exists only along one direction. Using the kinetic theory of gas, find an expression of 'D'. Comment on the dependence of D on pressure and temperature. [1+3+2]

b) Distinguish between thermal conductivity and thermometric conductivity. Explain their importance in heat conduction. [1+1]

c) A bar of length 30 cm and uniform area of cross-section 5 cm^2 consists of two halves of copper and iron. The end of copper side is maintained at 200°C and the end of iron side is cooled at 0°C. Assume the system is insulated. Find the rate of heat flow in steady state $K_{Cu} = 0{\cdot}9$ cgs, $K_{Fe} = 0{\cdot}12$ cgs. [2]

16. a) Find the critical constants of a real gas whose equation of state is given by $P(V-b) = RT\exp\left(-\frac{a}{RTV}\right)$ where a and b are constants.

Using above results derive the reduced equation of state. [3+2]

b) How are the values of Vander Waal's constants determined experimentally. [2]

c) Calculate the values of Vander Waal's constants for helium gas, when critical pressure is $0{\cdot}23\times10^6\,Nm^{-2}$ and critical volume is $58\times10^{-8}\,m^3mol^{-1}$. [3]

17. a) Find out the nature of speed distribution of molecules effusing through a very small hole on the surface of a container. Now estimate the mean kinetic energy per molecule of the effusing gas and show that this is greater than the mean kinetic energy per molecule of the gas within the container. [4+2+2]

b) The mean free path in a certain gas is 4·0 cm. How many are between 3·9 cm and 4·0 cm? [2]

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