RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

B.A./B.SC. THIRD SEMESTER EXAMINATION, DECEMBER 2013

SECOND YEAR

Date : 14/12/2013 **PHYSICS (Honours)**

Time : 11 am – 3 pm Paper : III Full Marks : 75

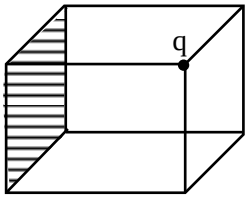
[Use Separate Answer Scripts for each group]

Group – A

(*Answer **any five** of the following*)

1. a) Find the potential at a distance r from an infinitely long straight wire that carries a uniform linear charge density λ. [3]

   b) A charge q sits at the corner of a cube as shown, what's the flux of $\vec{E}$ through the shaded side of the given figure? [2]



   c) A conducting sphere of radius R in vacuum carries a charge Q on it. What is the radius R_0 of a spherical surface such that half of the electrostatic energy lies within it? [5]

2. 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. [5]

   b) Four point charges +60, –60, +60, –60 esu are placed respectively at the corners of a square ABCD of side 12 cm. Calculate the quadrupole moment of this charge distribution. [5]

3. a) State— i) Gauss' Law for dielectrics [1]

   ii) Boundary conditions for Dielectric media. [1+1]

   b) Obtain the expression for the potential of a polarized dielectric as the sum of two integrals, one due to volume charge distribution and the other due to surface charge distribution. [3]

   c) Find the capacitance per unit length of a cylindrical cable of outer radius 4 mm and inner radius 0·5mm if the dielectric constant of the material of the cable is 5·0. [4]

4. a) Two identical point charges are separated by a distance 2d in air, and an insulated uncharged conducting sphere of radius a is positioned midway between them. If a <<d, prove that the introduction of the sphere reduces the force experienced by either point charge to $\left[1-\left(24a^5/d^5\right)\right]$ of its original value. [5]

   b) Consider a long dielectric cylinder of permitivity $\in$ placed in a uniform electric field that is normal to its axis. Find the potential inside and outside the cylinder. [5]

5. a) Define self-inductance and mutual inductance. [1+1]

   b) A circular coil of radius 0·1m and 10 turns is allowed to rotate in a static magnetic field of 0·1 T with a frequency of 50 rad/sec. The axis of rotation is perpendicular to the magnetic field. Find the magnitude of the electric field generated. [4]

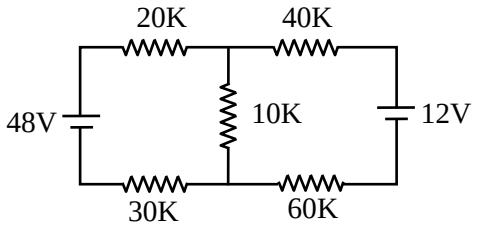
   c) Two coils of self inductance L_1 and L_2 respectively and of negligible resistance are arranged in parallel. M is their mutual indirectance. Show that the equivalent inductance of the system is

$$\frac{L_1L_2-M^2}{L_1+L_2-2M}$$ [4]

6. a) Starting from Kirchoff's laws for distribution of current in a network of conductors. Show that the first law is consistent with the principle of change conservation and the second law is consistent with the principle of energy conservation. [4]

   b) An electron (of mass $9{\cdot}1\times10^{-31}$ kg and charge $1{\cdot}6\times10^{-19}$ C) moving with an uniform velocity of 1km/sec is placed in a magnetic field of 20T applied normally to the direction of motion of the electron. Calculate the radius of the orbit of the electron. [3]

   c) Using superposition theorem, find the current through the 10K resistance in the following circuit. [3]



7. a) State Biot-Savart's law. Hence prove that (i) $\vec{\nabla}\times\vec{B}=\mu_0\vec{J}$, (ii) $\vec{\nabla}\cdot\vec{B}=0$. What is the physical significance of the expression (ii) ? [Where the symbols have their usual meanings] [1+4+2+1]

   b) Verify that the vector potential $\vec{A}$ due to a uniform magnetic induction $\vec{B}$ is given by $\vec{A}=\frac{1}{2}(\vec{B}\times\vec{r})$, where $\vec{r}$ is the position vector of the point in question. [2]

8. a) What is magnetic circuit? Establish a relation between the magnetomotive force, the reluctance and magnetic flux. [1+2]

   b) Find the vector potential inside and outside of an infinite solenoid with n turns per unit length, radius R and current I. [3]

   c) Show that in inhomogeneous magnetization gives rise to bound volume current density $\vec{J}_b=\vec{\nabla}\times\vec{M}$ within the matter. [4]

Group – B

Answer **any two** questions from Question No. 9-12 :

9. a) Maxwell's speed distribution law for a two dimensional perfect gas is given by

   $dn(u,v)dudv=n\frac{m}{2\pi kT}\exp\left[-\frac{m(u^2+v^2)}{2kT}\right]dudv$, where n is the number of molecules per unit area; u and v are the two perpendicular components of the velocity.

   i) Find the expression for the number of molecules per unit area having speed between c to c+dc, where $c=\sqrt{u^2+v^2}$

   ii) Find also the average energy of a molecule and show that the result is consistent with the eqipartition law. [3+4]

   b) During a hailstorm, hailstones with an average mass of 3 gm and a speed of 15m/s strike a window pane at a 45° angle. The area of the window is $0{\cdot}5$ n^2 and the hailstones hit at a rate of 25 per second. What average pressure do they exert on the window? [3]

10. a) What is meant by state function? What are its mathematical characteristics? [2]

   b) Show that the work done by a gm-mole of a perfect gas in an adiabatic reversible expansion is $R\frac{T_1-T_2}{1-\gamma}$, where the temperature falls from T_1 to T_2, other terms have their usual meaning. [4]

   c) An approximate equation of state of a real gas at moderate pressure is given by $PV=RT(1+B/V)$, where B is a function of temperature only. Find the values of B_T and β_P, where B_T = isothermal bulk modulus and β_P = volume coefficient of expansion. [4]

11. a) Derive a relation between P and T of an ideal gas undergoing reversible adiabatic transformation. [3]

b) A compressor designed to compress air is used instead to compress Helium. It is found that the compressor overheats. Explain this effect, assuming the compression is approximately adiabatic and the initial pressure and temperature are same for both the gases. [3]

c) Prove that the efficiency of a reversible engine is maximum for a fixed source and sink temperature. [4]

12. a) Give the mathematical formulation of the First law of thermodynamics. Starting from the law derive the relation between pressure and volume of an ideal gas in an adiabatic process. [2+2]

b) i) Show that the entropy of one mole of an ideal gas is given by $S(T, V) = C_v \ln T + R \ln V + S_0$

ii) A mixture of 1 mole of helium and 2 mole of nitrogen is considered as an ideal gas mixture. Find out an expression of entropy of the mixture as a function of V and T.

iii) Initially the gas-mixture is at a temperature T_1 and occupies a volume V_1. The gas is then compressed quasistatically and adiabatically to volume V_2 and temperature T_2. Show that $\left(T_2 / T_1\right) = \left(V_1 / V_2\right)^g$, where 'g' is a constant. [2+2+2]

Answer **<u>any one</u>** questions from Question No. 13-14 :

13. A system of n particles in thermal equilibrium at temperature T, has four available states having energy 0, kT, 2kT and 3kT. The total energy of the system is 1500 kT. Calculate the value of n. [5]

14. Show that the speed distribution of molecules effusing through a small hole is proportional to $v^3 \exp\left(-\frac{mv^2}{2k_B T}\right)$, where all the notations have the usual significance. Calculate the most probable speed of the above distribution. [3+2]