RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

SECOND YEAR

B.A./B.SC. THIRD SEMESTER (July – December), 2012

Mid-Semester Examination, September 2012

Date : 10/09/2012

Time : 2 pm – 4 pm

PHYSICS (Honours)

Paper : III

Full Marks : 50

Use three Answer Scripts. One for each group.

Group - A

Answer any three questions

1. Find electrostatic potential at a point $\vec{r}$ for a charge distribution $\rho(\vec{r'}) = \frac{A - B\,\mathrm{Sin}\,\theta'}{(r')^2}$, A and B are constants and $\vec{r'} = (r', \theta', \varphi')$. 5

2. A sphere of radius a centred at the origin carries charge density $\rho(r,\theta) = \rho_o \frac{a}{r^2}(a - 2r)\,\mathrm{Sin}\,\theta$. Find the first non-vanishing multipole moment and hence the potential at a distance far off from the sphere due to that multipole moment. 3+2

3. i) a point charge q is placed in a dielectric medium of dielectric constant $\in$. Apply Gauss' law to find a) $\vec{D}$, b) $\vec{P}$, c) ρ_p and σ_p 3

ii) Assume a small sphere of radius r around the point charge q. Then find the total bound charge in the limit $r \to 0$ turns out to be $[-\frac{\in -1}{\in} q]$. 2

4. Two point charges -q and +0.5q are situated at the origin and at point (a,0,0) respectively.
   a) At what point along the z-axis does the electric field vanish ?
   b) Show that the zero potential surface is a sphere in shape. 3+2

5. Given a spherical charge distribution of radius R and uniform charge density ρ_o, determine the energy of the distribution by integrating $\frac{1}{2}\int \vec{E} \cdot \vec{D}\, \mathrm{d}^3 r$. 5

Group - B

Answer any four questions

6. Starting from the expression for $\vec{B}$ given by Biot-Savart's law prove that $div\ \vec{B} = 0$. Is $\vec{B}$ a conservative field. 4+1

7. Define vector potential $\vec{A}$. Using Coulomb's gauge find out the equation satisfied by $\vec{A}$. (use also Ampere's circuital law in differential form.) 2+3

8. Using Ampere's circuital law find out $\vec{B}$ for an infinite solenoid. 5

9. Establish the continuity equation relating the charge density and current density at a point in a medium. Explain the significance of the equation. 4+1

10. State Kirchhoff's voltage law and current law. Show that the current law is consistent with the principle of conservation of charge and voltage law is consistent with the principle of conservation of energy. 5

11. State and prove maximum power transfer theorem. 5

Group - C

Answer any three questions

12. State and prove Carnot theorem. 1+4

13. A vessel contains N molecules of an ideal gas at temperature T. The number of molecules having speed lying between c and c+dc is given by

$$dn_c = n(c)dc = 4\pi N(\frac{m}{2\pi kT})^{3/2} \exp(-\frac{mc^2}{2kT})c^2 dc.$$

Find out expressions for the most probable speed c_m and the number of molecules $n(c_m)$ having speed c_m. Estimate the percentage of the total molecules whose speed lie between $c_m \pm 0.01 c_m$. 2+1+2

14. The energy distribution law for a system of perfect gas molecules at a temperature 'T' is given by the following expression

$$n(\in)d \in = AN \exp(-\frac{\in}{kT})\sqrt{\in}\, d \in,$$

where A is a constant and N is the total number of molecules. Find the value of the constant A. Hence calculate the average energy. 2+3

15. Show that in any irreversible process entropy change of the universe is always positive. Use it to prove the Clausius statement of the second law of thermodynamics. 3+2

16. Write down the combined expression of 1st and 2nd laws of thermodynamics for a gaseous system.

The entropy of n moles of an ideal gas can be written as

$$S = (n/2)[5R \ln(U/n) + 2R \ln(V/n) + S_0],$$

where U is the total internal energy of the gas, V is the volume and S_0 is a constant.

Find the expressions of the molar internal energy and pressure of the ideal gas.

Hence calculate C_P and C_V. 1+1+1+1+1