City College

Internal Examination 2020

Physics (Hons.) CBCS Semester 2

Paper: CC-3: Electricity and Magnetism

Time: 2 Hours; Full Marks: 50

Group A

1. Answer any five questions from the following: $[5 \times 2 = 10]$

(a) From the relation $\int \delta(\omega) d\omega = 1$, where the integration is over all ω-space, find out the dimension of $\delta(\omega)$, where $\delta(\omega)$ is the 1-dimensional Dirac δ-function, and ω has dimension of frequency.

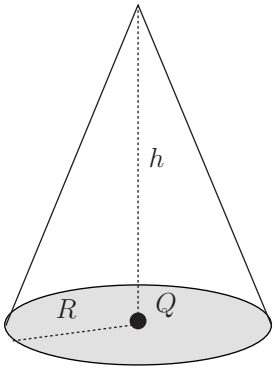
(b) A charge Q is placed at the origin of the 3-dimensional coordinate system. Find the flux of the electric field through the curved surface of a cone of height h and circular base of radius R (as shown in the figure).

(c) A cube has a constant potential Φ on its surfaces. If there are no charges inside the cube, find the potential at the center of the cube.

(d) Write down the equation of motion of a particle of mass m and charge q moving in an electric field $\vec{E}$ and magnetic field $\vec{B}$.

(e) What is the physical significance of the equation $\vec{\nabla} \cdot \vec{B} = 0$?

(f) Show that magnetic force is a no-work force.



Group B

Answer any five questions $[5 \times 5 = 25]$

2. (a) Consider a circular ring of radius ρ_0 and carrying a charge q. The ring is centered at $(0, 0, z_0)$ and lies normal to the z-axis. Write down the line charge density and the volume charge density. Relate the two. How will the volume density change if the center of the ring is shifted to $(0, 0, -z_0)$, other conditions remaining same? (b) In a strange world, the Coulombic force between two point charges varies as $\frac{1}{r^3}$. Will the electrostatic force still be conservative? Will Gauss' law hold for such a Coulombic force? $[3 + 2 = 5]$

3. (a) Consider the interface of two media A and B where the electric fields are respectively $\vec{E}_A$ and $\vec{E}_B$. The unit normal $\hat{n}$ points from A to B. If $\vec{E}_A$ and $\vec{E}_B$ make angles α and β respectively with $\hat{n}$, show that

$$\tan\beta = \frac{\tan\alpha}{1 + \frac{\sigma}{\epsilon_0 E_A \cos\alpha}},$$

where σ is the surface charge density at the interface. How are the angles related when E_A becomes very large? (b) Three equal charges are successively brought from infinity and each is placed at one of the three vertices of an equilateral triangle. Assuming the rest of the Universe as a whole to be neutral, the energy E_0 of the electrostatic field increases successively to $E_0 + \Delta_1, E_0 + \Delta_1 + \Delta_2, E_0 + \Delta_1 + \Delta_2 + \Delta_3$. Find $\Delta_1 : \Delta_2 : \Delta_3$. $[3 + 2 = 5]$

4. (a) A long, solid dielectric cylinder of radius a is permanently polarized so that the polarization is everywhere radially outward, with a magnitude proportional to the distance from the axis of the cylinder, i.e., $\vec{P} = \frac{1}{2}P_0\vec{r}$. What is the bound charge density in the cylinder? (b) Identical charges q are placed at five vertices of a regular hexagon of side a. Find the magnitude of the electric field and the electrostatic potential at the center of the hexagon. $[3 + 2 = 5]$

5. (a) Starting from Biot-Savart law for volume current distribution, show that $\vec{\nabla} \times \vec{B} = \mu_0\vec{J}$, where $\vec{B}$ is the magnetic field and $\vec{J}$ is the current density. (b) Find the magnetic field at a height h on the axis of a circular loop of radius a, and carrying current I. $[3 + 2 = 5]$

6. (a) Find the magnetic vector potential for an infinite solenoid of radius a, carrying current I and having n turns per unit length. (b) If the vector potential, $\vec{A} = \alpha x\hat{i} + 2y\hat{j} - 3z\hat{k}$, satisfies $\vec{\nabla} \cdot \vec{A} = 0$, find the value of the constant α. $[3 + 2 = 5]$

7. (a) Define the terms magnetic susceptibility and permeability and establish the relation between them. (b) A uniform magnetic field in the positive z-direction passes through a circular wire loop of radius 1 cm and resistance 1 Ω lying in the x-y plane. The field strength is reduced from 10 tesla to 9 tesla in 1 s. Find the charge transferred across any point in the wire. $[3 + 2 = 5]$

Group C

Answer any five questions $[5 \times 3 = 15]$

8. What are the three elements of Earth's magnetic field? Are they constant at all places?

9. Briefly explain the working principle of a Wheatstone bridge with relevant circuit diagram.

10. Define the coefficients of mutual inductance and self inductance. What is the unit of magnetic flux?

11. Consider two alternating signals: $V_1(t) = V_0 \sin\omega t$ and $V_2(t) = V_0 \cos 2\omega t$. Plot $V_1(t)$ and $V_2(t)$ against time t in the same graph.

12. In a LCR experiment, it is found that resonance occurs at $\omega_0 = 5$ kHz. Plot the current-vs-frequency curve taking the range of frequency to be 0 to 10 kHz clearly indicating the resonance frequency.

13. What do you mean by quality factor of a series LCR circuit? Consider two LCR circuits having the following circuit parameters: $R_1 = r, L_1 = \ell, C_1 = c$ and $R_2 = 4r, L_2 = \ell, C_2 = c$. Plot the current-vs-frequency curves for both sets of parameters on the same graph.

Answer scripts must be emailed to ***sem2hcityphysics@gmail.com*** *within 15 minutes of the end of the examination.*