Electrodynamics (H2) (SC1.102a)

IIIT-H, Semester Winter 24, Quiz 2

Full Marks: 30, Duration: 45min, April 2, 2024

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1. Consider a straight line segment of length $2L$, which carries a uniform line charge density λ. Show that the electric potential at a distance $z >> L$ above the mid point of the line is approximately

$$V \approx \frac{1}{4\pi\epsilon_0}\frac{2\lambda L}{z}.$$

Hint: Write dV for small line elements at both sides and equal distance from the midpoint. Integrate it. Appropriately use the $z >> L$ approximation. **[9]**

2. Consider a hollow spherical shell of inner radius a and outer radius b. The shell carries charge density $\rho = k/r^2$, where k is a constant and r is the distance from the center of the sphere. Using Gauss's law find the electric field in three regions, *i)* $r < a$, *ii)* $a < r < b$, and *iii)* $r > b$. **[7]**

3. One of these is not an electrostatic field. Prove which one.

(a) $\vec{E} = k\Big(xy\hat{x} + 2yz\hat{y} + 3xz\hat{z}\Big)$

(b) $\vec{E} = k\Big(y^2\hat{x} + (2xy + z^2)\hat{y} + 2yz\hat{z}\Big)$

where k is a constant, and $\hat{x}, \hat{y}, \hat{z}$ are unit vectors. *This is not a MCQ. No credit for choosing the correct answer without proof.* **[4]**

4. A negatively charge particle $-q$ moves in a circular orbit in a horizontal plane where there is a uniform magnetic field $\vec{B}$ that makes an angle θ with the unit vector normal to the plane. If R is the radius of the circle, m is the mass of the particle, and ω is the angular velocity, what is the magnitude $|\vec{B}|$?. *Hint: Easy.* **[4]**

5. A steady current I flows down a long cylindrical wire of radius a. Find the magnetic field both inside and outside the wire if the current is uniformly distributed over the outside surface of the cylinder. *Hint: Apply Ampere's law.* **[6]**

Electrodynamics(H2) (SC1.102a)

IIIT-H, Semester Spring 24, Final Exam

Duration 3 hours, Full Marks: 55

There are 10 questions. Only handwritten cheat sheet (max 3 A4 size pages) allowed.

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1. Suppose the Coulomb's law of force between two charges q_1 and q_2 is found to be

$$\vec{F} = \frac{q_1 q_2}{4\pi\epsilon_0} \frac{1 - \sqrt{\alpha r}}{r^2} \hat{r},$$

where α is constant, and r is the distance between the charges. Find the electric field of a charge Q at a point $\vec{r}$. **[2]**

2. A conducting sphere has charge Q_1. A point charge Q_2 is kept at a height h from the surface of the sphere at a point A. The point charge moves to a new location B that is diametrically opposite to A. If the height h is constant through the journey, what is the work done by the electric field of the sphere. **[2]**

3. The speed of light is constant. But is it same in all medium? Explain. **[1+2]**

4. Two infinite sheets with uniform electric charge densities $+\sigma$ and $-\sigma$ intersect at a right angles. Find the magnitude and direction of the electric field everywhere. Sketch the electric field lines. **[4+2]**

5. Consider two concentric spherical shells (hollow sphere). The inner sphere is of radius R_1 and the outer one is of radius $R_2 > R_1$. We put a charge $+Q$ on the inner sphere and $-Q$ on the outer. Calculate the potential difference between the spheres and the capacitance of the system. **[4+2]**

6. A parallel-plate capacitor consists of two conducting parallel plates of same area A kept at a distance d apart. Suppose the capacitor is charged to a potential V and then disconnected from the charging circuit. How much work is done by slowly changing the separation of the plates from d to $d' \neq d$. *Hint: Think about the energy stored in a capacitor. While the separation changes, the charge remains constant.* **[6]**

7. A solid sphere of radius R carries a polarization $\vec{P}(\vec{r}) = k\vec{r}$, where k is a constant and $\vec{r}$ is the vector from the center. Find the field inside and outside the sphere. **[6]**

8. An atom consists of a point nucleus of charge $+q$, surrounded by a cloud of negative charge $-q$ that is uniformly spread over a radius r. Find the dipole moment when it is placed in an electric field $\vec{E}$. **[7]**

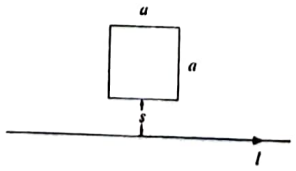

Figure 1:

9. A square loop of sides a lies on a table, a distance s from a very long straight wire, which carries a current I, as shown in figure 1. *a)* Find the flux $\vec{B}$ through the loop. *b)* If the loop is pulled directly away from the

wire, at a speed v, what is the electromotive force that is generated, and in which direction (clockwise or anticlockwise) does the current flow? *c)* Which direction the current flows if the wire is pulled to the right and parallel to the wire at the same speed? **[4+3+2]**

10. The electric field of an electromagnetic wave in vacuum is given as

$$E_x = 0\,, \quad E_y = 30\cos\left(2\pi 10^8 t - \frac{2\pi}{3}x\right), \quad E_z = 0\,,$$

where $E_{x,y,z}$ are in volts/meter, t in seconds, and x meters. Determine *i)* the frequency, *ii)* the wavelength, *iii)* the direction of propagation of the wave, *iv)* the direction of magnetic field, and *v)* calculate the average energy per unit area per unit time transported by this wave. *Write answers in proper units.* **[1+1+1+2+3]**