Indian Institute of Technology Jodhpur
1st Mid Sem PHL1010 Examination 09 February 2024
(10 AM – 11 AM) Marks: 10

The **bold** letters represent vector quantity.

Q1. There is a square dielectric plate of thickness t and is polarized over its entire volume according to equation **P** = (a y³ + b) **j**, where a and b are constants. Find out: length = ℓ

(a) the polarization surface charge density and the polarization volume charge density. 2.0

(b) Also find out the total polarization charge. 2.0

Q2. (a) Calculate the electric field produced at point P in Figure Q2(a) by the cylinder with volumetric uniform density ρ, whose height is H, inner radius Ri and outer radius Ro. 2.0

(b) Two straight conductors, parallel and infinite, with respective density charge $\lambda_1 = \lambda$ and $\lambda_2 = -\lambda$ are separated by a distance d. Calculate the potential difference between points A and B in Figure Q2(b). 2.0

$Q = \rho \cdot H \, \pi (R_o^2 - R_i^2)$

$E = \frac{1}{4\pi\epsilon_0} \int \frac{dq}{r^2}$

$V(r) = ?$

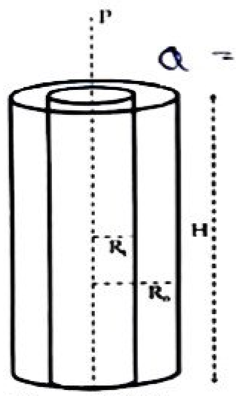


Figure Q2(a)

$V(r) = ?$

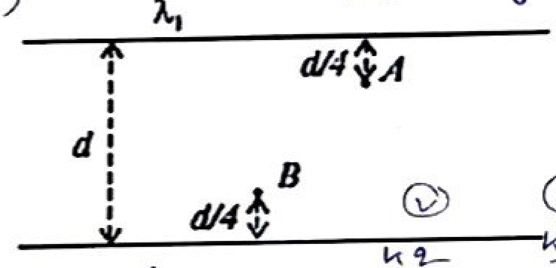


Figure Q2(b)

$E_A = \frac{2k\lambda}{r} = \frac{\lambda}{2\pi\epsilon_0 r}$

$\frac{kq}{r}$ $\frac{kq}{r^2}$

$V_A = \int \frac{k\,dq}{r}$

$V_A = \frac{1}{4\pi\epsilon_0} \int \frac{\lambda \cdot dr}{r}$

$\frac{\lambda \ln(r)}{4\pi\epsilon_0}$

$\left(\frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial z}\hat{z} \right) \cdot$

$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ F_x & F_y & F_z \end{vmatrix}$

Q3. Given a scalar field $\phi(r)$ and a vector field **F**(r), Find out: 1.0+1.0

(a) $\nabla \times (\nabla\phi(r))$ $\rightarrow 0$

(b) $\nabla \cdot (\nabla \times \mathbf{F}(r)))$ $\rightarrow$ curl.
→ Divergence of curl.
(vol.)

$\left(\frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial z}\hat{z} \right) \hat{x}\left(\frac{\partial F_z}{\partial y} - \frac{\partial}{\partial z}F_y \right) - \hat{y}\left(\frac{\partial F_z}{\partial x} - \frac{\partial}{\partial z}F_x \right) + \hat{z}\left(\frac{\partial F_y}{\partial x} - \frac{\partial}{\partial y}F_x \right)$

y

$\boxed{p = q \cdot d}$

$P = \left(\frac{4}{3}\pi R^3 \right) \rho$

$\boxed{\rho = \frac{P}{\text{vol.}}}$

$P = (ay^3 + b)\hat{j}$

$\rho =$

$\boxed{\bar{P} = (ay^3 + b)\ell^2 t}$

$\nabla \times (\nabla\phi) \rightarrow$ curl of gradient.

$\nabla \times \left(\frac{\partial\phi}{\partial x}\hat{i} + \frac{\partial\phi}{\partial y}\hat{j} + \frac{\partial\phi}{\partial z}\hat{z} \right)$

$\begin{vmatrix} \hat{i} & \hat{j} & \hat{z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ \partial\phi/\partial x & \partial\phi/\partial y & \partial\phi/\partial z \end{vmatrix} = 0\hat{x} \left(\frac{\partial}{\partial y} \cdot \frac{\partial\phi}{\partial z} - \frac{\partial}{\partial z}\frac{\partial}{\partial y}\phi \right) -$

Minor -I Examination

PHL1010: **Electromagnetism & Optics**

Time: 1 Hour | Date: 09.09.2023 | Maximum Marks: 30

General Instructions

- In **Section A: Very short answer type of Questions**, you may write final answer without explanation or reasoning.
- But in **Section B: Short Answer Type of Questions**, you **MUST** show all the steps in your calculation or derivation. Simply writing final answer in Section B will attract *strictly* 0 marks even if the answer is correct.

Section A: Very short Answer Type of Questions [1× 5 = 5 Marks]

1. Plot the electric field lines for two positive charges of equal magnitude fixed at x = 0 and x = 1cm.
2. Which quantity among the three follow the superposition principle (Electrostatic field, Electrostatic potential and Electrostatic energy)?
3. Violet and X-ray beams are incident on a metal plate at normal incidence angle, whose plasma frequency is 10^{16} Hz (Ultraviolet). Which beam will be reflected and which one will penetrate the metal?
4. An uncharged spherical conductor has an arbitrary shape cavity inside containing charge q. What is the electric field outside the conductor?
5. Write the first Maxwell's equation inside a conductor.

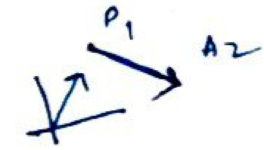
Section B: Short Answer Type of Questions

6. Two points in Cartesian coordinate system are defined by P_1 (0, 0, 1) and P_2 (2, 1, 3). A vector $\vec{B}$ connects P_1 (tail) to P_2 (head). Find the unit vector in the direction of $\vec{B}$ in Spherical and Cylindrical coordinate system. **[5 Marks]**
7. A sphere of radius R carries a charge density $\rho(r) = kr$, where k is constant.

(a) What is the SI unit of k?

(b) Calculate the electric field everywhere.

(c) Find the energy of the configuration. **[1+2+2 Marks]**

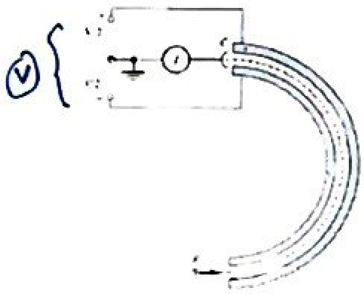


r θ z

$\frac{3}{5}\frac{kQ^2}{2R}$ $\rho = \frac{M}{V}$ $\frac{Q}{V}$ $\frac{1}{s}$

L^3 [t $\frac{Q}{t} = ?t$

8. The figure below shows a particle analyzer where a charge particle P (charge Q, mass m) enters into the analyzer. The analyzer consists of cylindrical conductors of radius **R**. The separation between the metal plates is **a**. Show that the velocity of the particle collected at point C is $v = \sqrt{\dfrac{QVR}{ma}}$, where V is the voltage across the plates. **[3 marks]**



9. Calculate the x and y component of the force acting on charge -Q for the configuration shown in the figure below (Conductor is grounded). **[3 marks]**

10. (a) Two conducting spheres of radii R_a and R_b ($R_a > R_b$) are carrying charges Q and q, respectively and are connected by a conducting wire. Find the ratio of electric fields at the surface of the spheres. **[2 Marks]**

(b) You have a suspension of protein molecules in water. What would you do in order to collect the protein molecules from water? Justify your answer. **[2 Marks]**

(c) Evaluate the integral $J = \int_{Volume} (r^2 + 2)\vec{\nabla}.\left(\dfrac{\hat{r}}{r^2}\right) d\tau$. The volume is a sphere of radius R centered at origin. **[2 Marks]**

11. Prove that one of vector field below can not be an electrostatic field. **[3 Marks]**

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

(b) $\vec{E} = k[y^2\hat{x} + (2xy + z^2)\hat{y} + 2yz\hat{z}]$, where k is constant

--- End of the Sheet ---