GENERAL PHYSICS 2 - PEQ

MIDTERM 1

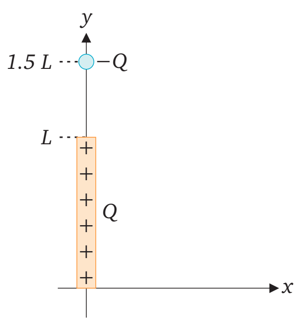
watch video

1. As shown in the figure, there is a rod with total charge $+Q$ placed on the y-axis between the points $y = 0$ and $y = L$. The thickness of the rod is negligible, and the charge is distributed uniformly along the rod. At the point $y = 1.5L$, a point particle with charge $-Q$ is fixed.

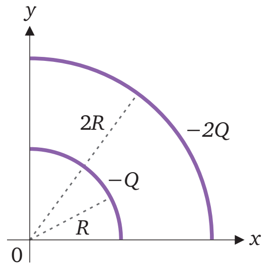
a. Find the electric field produced by the rod at the location of the $-Q$ charged particle in terms of Q, L, ϵ_0, and unit vectors.

b. Find the electric force acting on the $-Q$ charged particle in terms of unit vectors.

c. Find the total force exerted by the $-Q$ charged particle on the charged rod in terms of unit vectors.



2. In the system shown, there are two quarter-circle arcs: one with radius R and charge $-Q$, and the other with radius $2R$ and charge $-2Q$. The charge distributions on the arcs are uniform. Find the total electric field vector at point O in terms of k, Q, R, and unit vectors.



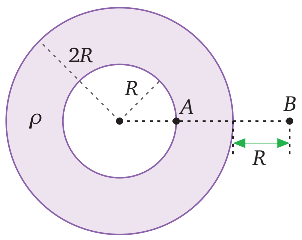
3. In the figure, the cross section of an infinitely long, hollow, insulating cylinder with inner radius R and outer radius $2R$ is shown. In the filled part of the cylinder ($R < r < 2R$), the volume charge density is given by ρ. Here, ρ is constant and positive. The distance of any point from the cylinder axis is denoted by r.

a. Find the magnitude and direction of the electric field in the hollow region inside the cylinder ($r < R$).

b. Find the magnitude and direction of the electric field in the charged region of the cylinder ($R < r < 2R$).

c. Find the magnitude and direction of the electric field in the exterior region of the cylinder ($r > 2R$).

d. Find the potential difference ($V_A - V_B$) between point A, which is at a distance R from the cylinder axis, and point B, which is at a distance $3R$.

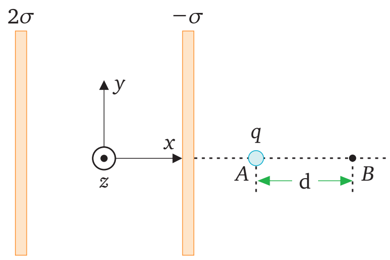


4. Two infinitely wide insulating parallel plates are placed parallel to the yz-plane as shown in the figure. The left plate has surface charge density $\sigma_1 = 2\sigma$ and the right plate has surface charge density $\sigma_2 = -\sigma$. Here, σ is a positive quantity, and the distance between points A and B on the x-axis is d.

a. Find the electric field vector in the region where points A and B are located, in terms of σ, ϵ_0, and unit vectors.

b. Find the potential difference ($V_A - V_B$) between points A and B.

c. A charged particle of mass m located at point A is released from rest. If its speed is v when it reaches point B, find the expression for the magnitude of the particle's charge.



5. The electric potential in the xy plane is given by $V(x, y) = 30x - 40y$. Here, V is in volts, and x and y are in meters. An electric dipole with magnitude $p = 5.0 \times 10^{-4}$ C · m is held in the xy plane such that the vector $\vec{p}$ makes an angle of 53° with the positive y axis. This dipole is brought from its initial position to a position where the dipole moment vector is parallel to the positive y axis by applying an external force.

a. Find the electric field vector in the region in standard unit-vector notation.

b. Find the electric torque acting on the dipole in its initial position in unit-vector notation.

c. Find the work that must be done by the external force to bring the dipole from its initial orientation to the final orientation in which the dipole moment vector is parallel to the positive y axis.

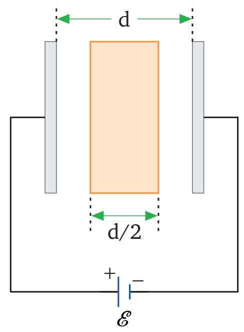
6. A capacitor in air with plate separation d is connected to a source with voltage $\mathscr{E}$. Initially, the capacitance of the capacitor is measured as C_0, the charge accumulated on one plate as Q_0, and the stored energy as U_0. After the charging process is completed, while the source remains connected, an insulating material of thickness $d/2$ and dielectric constant $\kappa = 3.0$ is inserted between the plates.

a. Find the capacitance of the capacitor in the final state in terms of C_0.

b. Find the charge accumulated on one plate in the final state in terms of Q_0.

c. Find the ratio of the final energy stored in the capacitor to the initial energy, U_{son}/U_0.

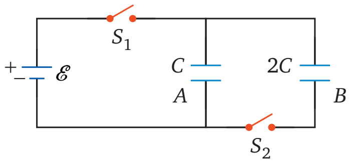
d. Find the magnitude of the electric field inside the dielectric material in the final state in terms of $\mathscr{E}$ and d.



7. In the circuit shown, there are two capacitors with capacitances $C_A = C$ and $C_B = 2C$, a source with negligible internal resistance, and switches S_1, S_2. The capacitors are initially completely uncharged.

a. When switch S_1 is closed and sufficient time has passed, find the charges accumulated on the plates of capacitors A and B and the potential differences across the capacitors in terms of the given quantities.

b. Then, switch S_1 is opened and switch S_2 is closed, and the system is allowed to reach equilibrium again. In this final state, find the charges on capacitors A and B and the potential differences across the capacitors.



Answers

1	a. $\vec{E} = \dfrac{Q}{3\pi\epsilon_0 L^2}\hat{j}$ b. $\vec{F} = -\dfrac{Q^2}{3\pi\epsilon_0 L^2}\hat{j}$ c. $\vec{F}_{\text{rod}} = \dfrac{Q^2}{3\pi\epsilon_0 L^2}\hat{j}$
2	$\vec{E}_{tot} = \dfrac{3kQ}{\pi R^2}(\hat{\imath} + \hat{\jmath})$
3	a. $E = 0$ b. $E = \dfrac{\rho(r^2 - R^2)}{2\epsilon_0 r}$, in the radially outward direction c. $E = \dfrac{3\rho R^2}{2\epsilon_0 r}$, in the radially outward direction d. $V_A - V_B = \frac{\rho R^2}{2\epsilon_0}\left[\frac{3}{2} + \ln\left(\frac{27}{16}\right)\right]$
4	a. $\vec{E} = \dfrac{\sigma}{2\epsilon_0}\hat{\imath}$ b. $V_A - V_B = \dfrac{\sigma d}{2\epsilon_0}$ c. $q = \dfrac{mv^2\epsilon_0}{\sigma d}$
5	a. $\vec{E} = -30\hat{\imath} + 40\hat{\jmath}$ V/m b. $\vec{\tau} = 2.5 \times 10^{-2}\hat{k}$ N·m c. $W_{\text{ext}} = -2.0 \times 10^{-2}$ J
6	a. $C = 1.5C_0$ b. $Q = 1.5Q_0$ c. $U_{\text{final}}/U_0 = 1.5$ d. $E = \dfrac{\mathscr{E}}{2d}$
7	a. $Q_A = C\mathscr{E}$, $V_A = \varepsilon$; $Q_B = 0$, $V_B = 0$ b. $Q'_A = \dfrac{C\mathscr{E}}{3}$, $V'_A = \dfrac{\mathscr{E}}{3}$; $Q'_B = \dfrac{2C\mathscr{E}}{3}$, $V'_B = \dfrac{\mathscr{E}}{3}$