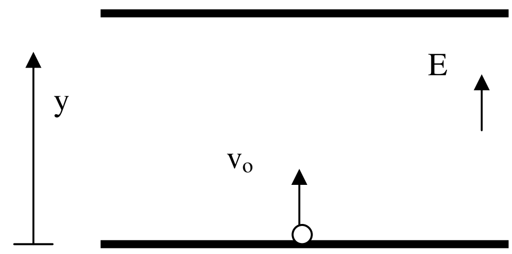
1. The uniform electric field between two conducting charged plates shown in the figure has a magnitude of E = 28.40 N/C. The plate separation is 1 m, and we launch an electron from the bottom plate directly upward with $v_o = 3\times10^6$ m/s. Will the electron reach the top plate? Justify your answer by providing numerical data.



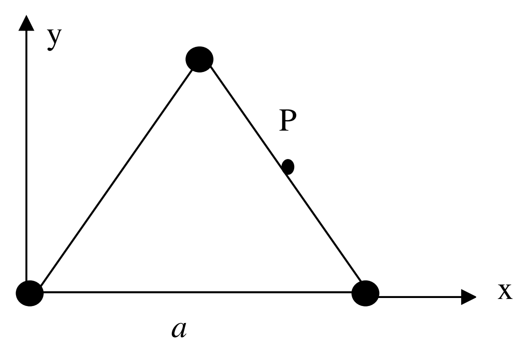
* $a_y = \frac{qE_y}{m} = \frac{-1.6\times10^{-19}\times28.40}{9.11\times10^{-31}} = -5.0\times10^{12}\ m/s^2$

* $v_y^2 - v_{oy}^2 = 2a_y(y-y_o)$

$0 - 9\times10^{12} = -2\times5.0\times10^{12}\ H \rightarrow H = 0.90\,m$

* Since H < 1m, the electron does not reach to the top plate.

2. Three point charges, 1 μC each, are placed on three corners of an equilateral triangle with side a = 1 m. Write the net electric field at the middle point P, in terms of unit vectors.



$r^2 = a^2 - a^2/4 = 0.75\,m^2$

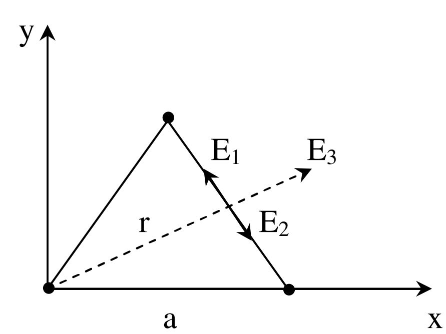
* $E_3 = k\frac{|q|}{r^2} = 12\,k\ N/C$

and $\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 = \vec{E}_1 - \vec{E}_1 + \vec{E}_3 = \vec{E}_3$

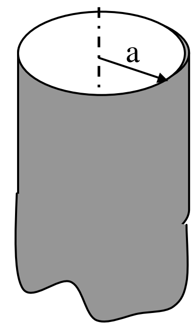
* $E_x = E_{3x} = 12\times\cos30 = 10.4\,k\ N/C$

* $E_y = E_{3y} = 12\times\sin30 = 6.0\,k\ N/C$

* $\vec{E} = 10.4(k\ N/C)\hat{\imath} + 6.0(k\ N/C)\hat{\jmath}$



3. A long non-conducting cylinder with radius a = 0.5 m has a volume charge density ρ = -5 nC/m³. Find the magnitude of electric field (in N/C) at a distance r = 0.2 m from its axis.

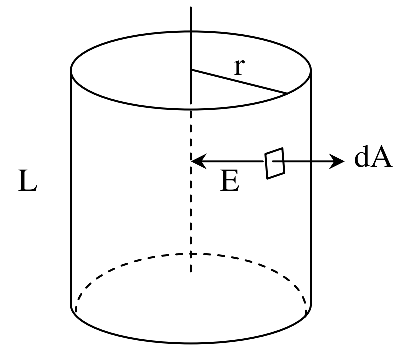


$$\oint \vec{E}\cdot\overrightarrow{dA}=\frac{q_{enc}}{\varepsilon_o}$$

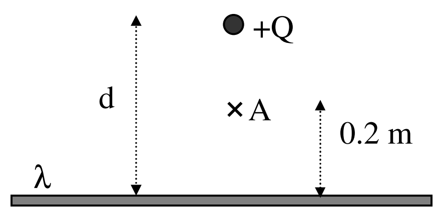
$$\oint \vec{E}\,\overrightarrow{dA}=-2\pi rLE$$

$$q_{enc}=\pi r^2\,LP$$

$$E=-\frac{\rho}{2\varepsilon_o}r=-\frac{-5\times10^{-9}\times0.2}{2\times8.85\times10^{-12}}\rightarrow E=56.5\,N/C$$



4. A very long line of charge having a uniform charge density λ is at a distance of d = 0.4 m from a positive point charge (Q = 4 μC) as shown in the figure. If the net electric field at point A is zero, find the value of λ (sign and magnitude).

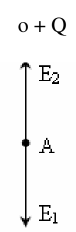


$\vec{E}_2$ (due to the charged bar) must be upward to cancel the downward field $\vec{E}_1$ (due to +Q).

Thus, λ should have a positive value.

$$k\frac{|Q|}{r_1^2}=\frac{2k|\lambda|}{r_2}\rightarrow|\lambda|=\frac{|Q|\,r_2}{2\,r_1^2}$$

$$r_1=r_2=0.2m\rightarrow|\lambda|=10\,\mu C/m\rightarrow\lambda=+10\,\mu C/m$$



5. A solid ball of radius R has a uniform volume charge density ρ and produces a certain electric field with magnitude E_1 at point P, which is at a distance 2R from the ball's centre (fig.1). If a core of radius R/2 is removed from the ball (fig.2), the field magnitude at point P changes to E_2. What is the ratio E_2/E_1?

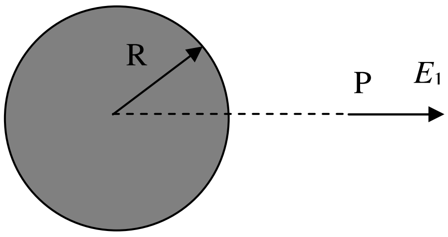


Fig. 1

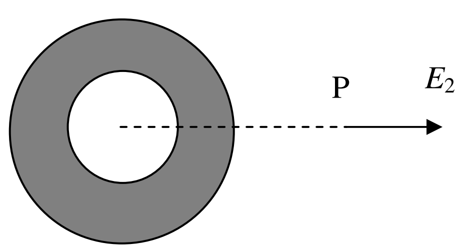


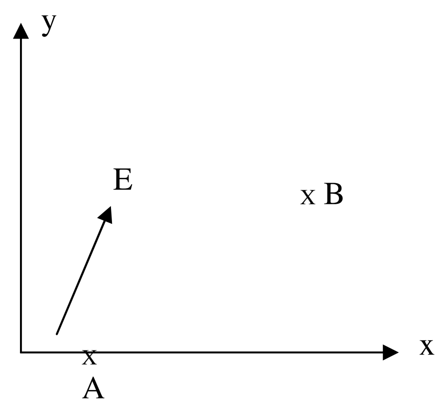
Fig. 2

Solution:

$$E_1=\frac{k|q_1|}{r^2},\ E_2=\frac{k|q_2|}{r^2}$$

$$\frac{E_2}{E_1}=\frac{|q_2|}{|q1|}=\frac{\frac{4}{3}\pi\left[R^3-\left(R/2\right)^3\right]\rho}{\frac{4}{3}\pi R^3.\rho}=\frac{7}{8}=0.875$$

6. Points A (x = 2 m, y = 0 m) and B (x = 6 m, y = 3 m) are in a uniform electric field $\vec{E} = 200(N/C)\hat{i} + 500(N/C)\hat{j}$. Calculate the potential difference $V_A - V_B$.



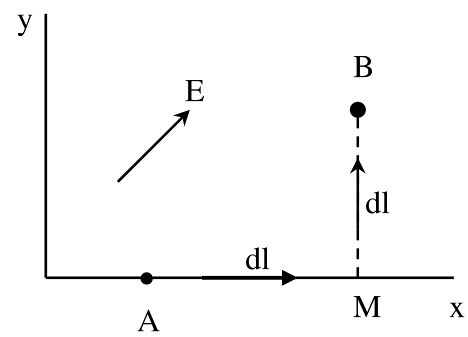
Solution:

$$V_A - V_B = \int_A^M \vec{E}\cdot\vec{dl} + \int_M^B \vec{E}\cdot\vec{dl}$$

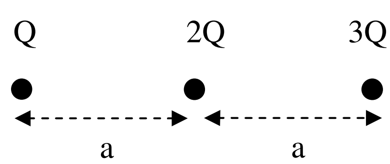
$$= \int_2^6 200\,dx + \int_0^3 500\,dy$$

$$= 800 + 1500 = 2300\ V$$

$$V_A - V_B = 2.3\,kV$$



7. Three particles with equal mass but different charge are released from their positions shown below (Q = -2 μC, a = 9 cm). What is the highest kinetic energy the particle with charge Q can obtain?



Solution:

$$U_i = k\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)$$

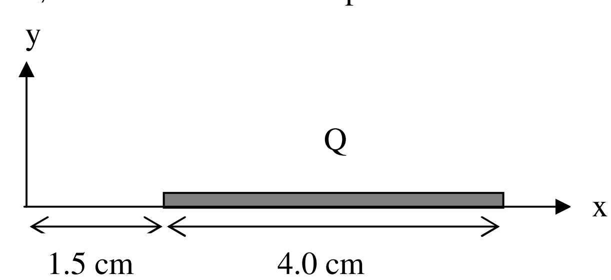
$$= kQ^2\left(\frac{2}{a} + \frac{3}{2a} + \frac{6}{a}\right) = 19\frac{kQ^2}{2a} = 3.8\,J$$

$$U_i + K_i = U_f + K_f$$

$$3.8 + 0 = 0 + K_f \rightarrow K_f = 3.8J$$

*Since the particles have the same mass $\rightarrow K_Q = \frac{1}{3}K_f$ = 1.27 J

8. Electric charge Q = 8 nC is distributed uniformly along a thin rod of length 4 cm, as shown in the figure. Take the electric potential to be zero at infinity. Calculate the electric potential at the origin.

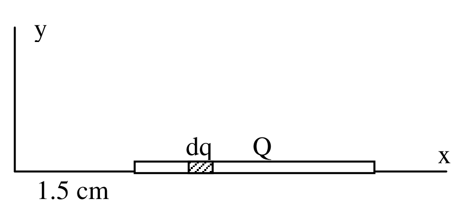


Solution:

$$dV = \frac{k\,dq}{x} = k\lambda\frac{dx}{x}$$

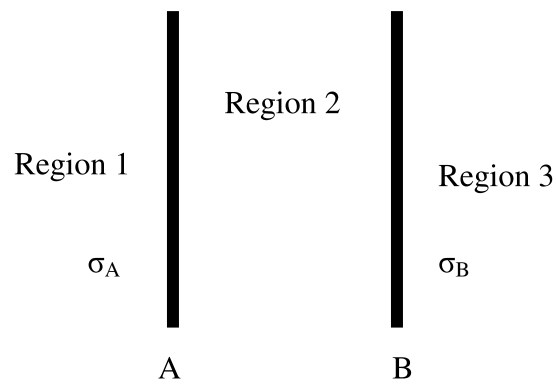
$$V = k\lambda\int_{0.015}^{0.055}\frac{dx}{x} = k\lambda\ln\left(\frac{0.055}{0.015}\right)$$

$$V = 9\times10^9\times\frac{8\times10^{-9}}{0.04}\ln\left(\frac{0.055}{0.015}\right) = 2.34\,kV$$



Multiple-Choice Questions

1. Two infinitely large conducting plates are positively charged so that the surface charge density of A is twice that of B ($\sigma_A = 2\sigma_B$). Which of the following statements is correct?

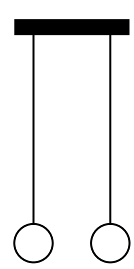


a) The net electric field in region 2 is zero.
b) The net electric field in regions 1 and 3 is zero.
c) The directions of net electric field in regions 1 and 3 are the same.
d) The magnitudes of the net electric field in regions 1 and 3 are equal.

2. A point charge of mass *m* and charge *Q* and another point charge of mass *m* and charge 2*Q* are released on a frictionless table. If the charge *Q* has an initial acceleration of *a*, what will be the initial acceleration of 2*Q*?

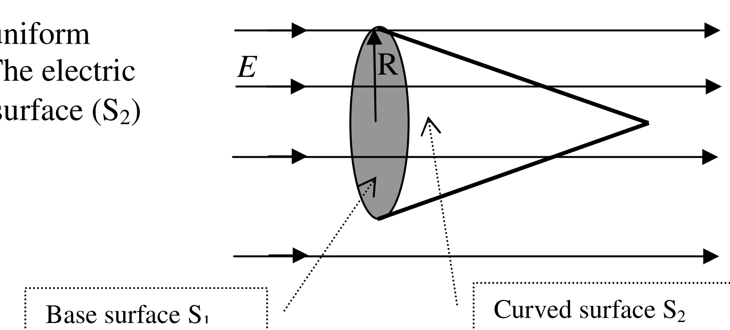
a) *a*
b) 2*a*
c) *a*/2
d) 4*a*

3. The two metal spheres shown in the figure hang from nylon threads close to each other. The charge of one sphere is – Q, and the other is uncharged. If the spheres are released from rest, which of the following statements is true:



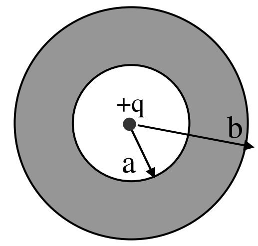
a) They attract, touch each other, and stay in touch.
b) They attract, touch each other, and then repel
c) They do not attract or repel each other.
d) They repeal each other until they stop at a greater distance.

4. An empty cone is placed inside a uniform electric field as shown in the figure. The electric flux, Φ_E, passing through the curved surface (S_2) of the cone is:



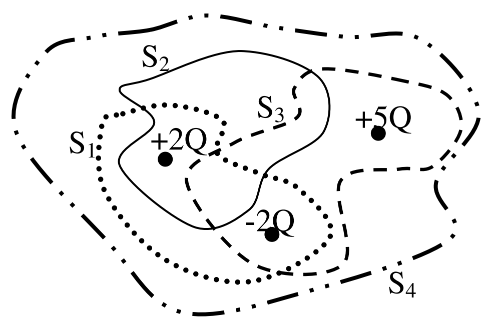
a) Zero
b) $\pi R^2 E$
c) $4\pi R^2 E$
d) $2\pi R^2 E$

5. A charged conducting spherical shell with a net charge of -2q has radii a and b. If a point charge of +q is placed at the centre, then the surface charge density on the outer surface of the conducting shell is:



a) Zero
b) $-2q/(4\pi b^2)$
c) $-q/(4\pi b^2)$
d) $-3q/(4\pi b^2)$

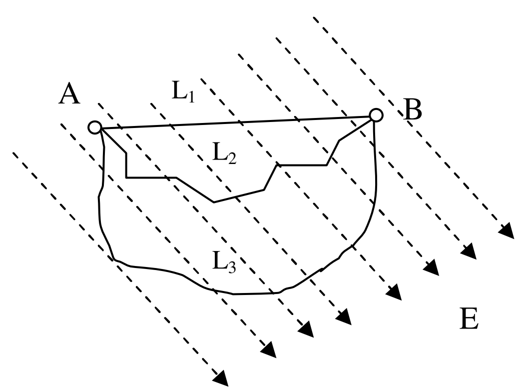
6. Four Closed surfaces S_1, S_2, S_3 and S_4 together with the charges +2Q, +5Q and -2Q are sketched as shown in the figure. If Q = 8.85 pC then the net electric flux (in Nm^2/C) through the surface S3 is:



a) 0
b) 2
c) 3
d) 4

7. The work done by the electric field $\vec{E}$ to move charge Q from point A to point B along three different paths with length L_1, L_2 and L_3 is denoted by W_1, W_2 and W_3, respectively. If $L_3 = 2L_2 = 3L_1$, then:

a) $W_3 = 2W_2 = 3W_1$
b) $W_2 = 1.5\ W_1$
c) $W_1 = W_2 = W_3$
d) $W_3 = W_1 + W_2$



8. A conducting spherical shell with inner radius *a* and outer radius *b* carries charge *Q*. The electric potential (with respect to infinity) at the center of the shell is:

a) *kQ/(b-a)*
b) Zero
c) *kQ/ a*
d) *kQ/b*