KING FHAD UNIVERSITY OF PETROLEUM & MINERALS
DEPARTMENT OF PHYSICS

PHYSICS 102 (992)
SOLUTION (CHAPTER 24)

Q.1 In Figure 24.1, a butterfly net is in a uniform electric field of magnitude E. The rim, a circle of radius a, is aligned perpendicular to the field. Find the electric flux through the netting.

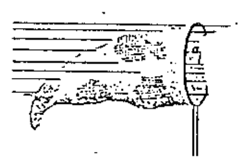


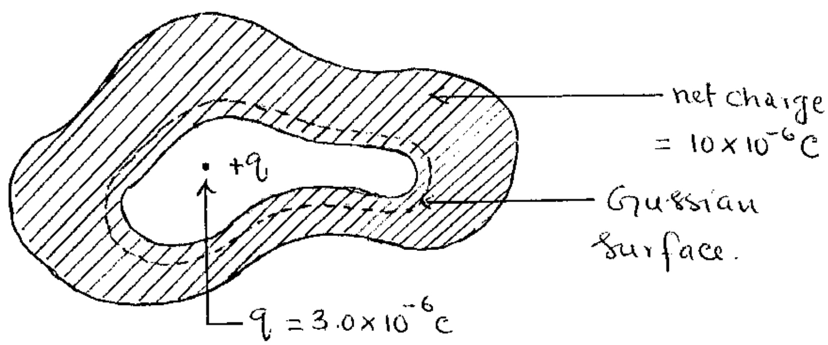
FIGURE 24.1

$$\Phi = \Phi_{netting} + \Phi_{circular\ opening} = 0$$

$$\Phi_{netting} = -\Phi_{circular\ opening} = -E\pi a^2$$

$$\boxed{\Phi_{netting} = -E\pi a^2}$$

Q.2 An isolated conductor of arbitrary shape has a net charge of $+10\times10^{-6}$ C. Inside the conductor is a cavity within which is a point charge $q = +3\times10^{-6}$ C. What is the charge (a) on the cavity wall and (b) on the outer surface of the conductor?



$$\oint \vec{E}\cdot d\vec{a} = \frac{q_{enclosed}}{\epsilon_0}$$

(a) $$\underbrace{0}_{\text{Since } \vec{E} \text{ inside a conductor is zero.}} = \frac{\text{Charge on the Cavity wall} + 3.0\times10^{-6}}{\epsilon_0}$$

$$\boxed{\text{Charge on the Cavity wall} = -3.0\times10^{-6}\text{C.}}$$

(b) Charge on the cavity wall + Charge on the outer surface $= 10\times10^{-6}$ C.

charge on the outer surface $= 10.0\times10^{-6} - (-3\times10^{-6})$

$= \boxed{13.0\times10^{-6}\text{C.}}$

Q.3 A very long conducting cylindrical rod of length L with a total charge +q is surrounded by a conducting cylindrical shell (also of length L) with total charge –2q, as shown in figure 24.3. Use Gauss' law to find (a) the electric field at points outside the conducting shell, (b) the distribution of charge on the conducting shell, and (c) the electric field in the region between the shell and rod.

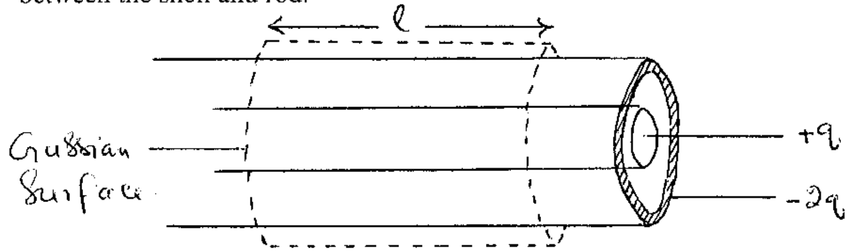
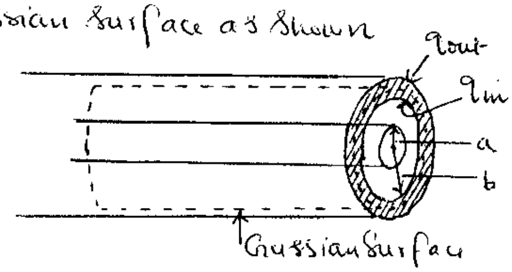


FIGURE 24.3

$$\oint \vec{E}\cdot d\vec{a} = \frac{q_{encl}}{\epsilon_0}, \quad E \cdot 2\pi r l = \frac{\frac{(q-2q)}{L}\cdot l}{\epsilon_0}$$

(a) $\boxed{E = \frac{-q}{2\pi \epsilon_0 r L}}$, negative sign means the field is inward, towards the axis of the cylinder

(b) take a cylindrical Gussian surface as shown



$$\oint \vec{E}\cdot d\vec{a} = \frac{q_{encl}}{\epsilon_0}$$

$$0 = \frac{q + q_{in}}{\epsilon_0}$$

$$q_{in} = -q$$

$$q_{in} + q_{out} = -2q, \quad q_{out} = -2q - (-q) = -q$$

$$\boxed{\sigma_{in} = \frac{-q}{2\pi a L}}, \quad \boxed{\sigma_{out} = \frac{-q}{2\pi b L}}$$

q_{in} = charge on the inside wall of the shell.

q_{out} = charge on the outside wall of the shell.

(c) $\boxed{E = \frac{q}{\pi \epsilon_0 r L}}$, outward

Q.4 In Figure 24.4, a small, non-conducting ball of mass m = 1.0 mg and charge $q = 2.0 \times 10^{-8}$ C (distributed uniformly through its volume) hangs from an insulating thread that makes an angle $\theta = 30^{\circ}$ with a vertical, uniformly charged non-conducting sheet (shown in cross section). Considering the weight of the ball and assuming that the sheet extends far vertically and into and out of the page, calculate the surface charge density σ of the sheet.

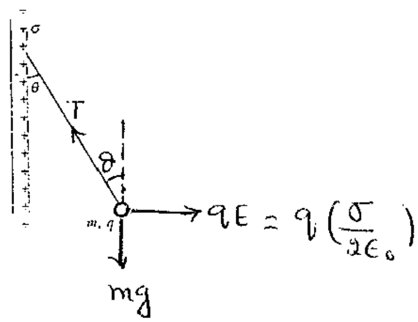


FIGURE 24.4.

$$q = 2.0 \times 10^{-8}\ C.$$

$$m = 1.0 \times 10^{-3} g$$

$$\theta = 30^{0}$$

$$T \sin\theta = q\left(\frac{\sigma}{2\epsilon_0}\right), \quad T \cos\theta = mg$$

$$\tan\theta = q\,\frac{\sigma}{2\epsilon_0 mg}$$

$$\sigma = \frac{(\tan 30^{\circ})(2)(8.85\times10^{-12})(1\times10^{-3}\times10^{-3})(9.8)}{2.0\times10^{-8}}$$

$$\boxed{\sigma = 5.0\times10^{-9}\ C/m^2}$$

Q.5 In Figure 24.5 a sphere, of radius a and charge +q uniformly distributed throughout its volume, is concentric with a spherical conducting shell of inner radius b and outer radius c. This shell has a net charge of –q. Find expressions for the electric field, as function of the radius r, (a) within the sphere (r < a); (b) between the sphere and the shell (a < r < b); (c) inside the shell (b < r < c); and (d) outside the shell (r > c). (e) What are the charges on the inner and outer surfaces of the shell?

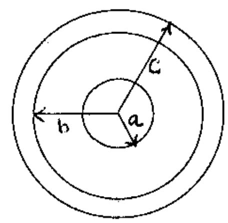


FIGURE 24.5

(a) $r < a$

$$\oint \vec{E} \cdot d\vec{a} = \frac{q_{encl}}{\epsilon_0}$$

$$E \cdot 4\pi r^2 = \frac{1}{\epsilon_0} \frac{q}{\frac{4}{3}\pi a^3} \cdot \frac{4}{3}\pi r^3$$

$$E = \left(\frac{q}{4\pi\epsilon_0 a^3} \right) r.$$

(b) $a < r < b$

$$E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}, \quad \boxed{E = \frac{q}{4\pi\epsilon_0 r^2}}$$

(c) $\boxed{E = 0}$, inside a Conductor.

(d) $\boxed{E = 0}$, $q_{encl} = 0$

(e) $\underline{-q}$ on the inner surface, $\underline{\text{zero}}$ on the outer surface