THE EGYPTIAN E-LEARNING UNIVERSITY

Section 3
Physics (ii)

MCQ:

1. In uniform fields, all points have _________ field strength.
   a. Zero
   b. Same
   c. Infinity
   d. Different

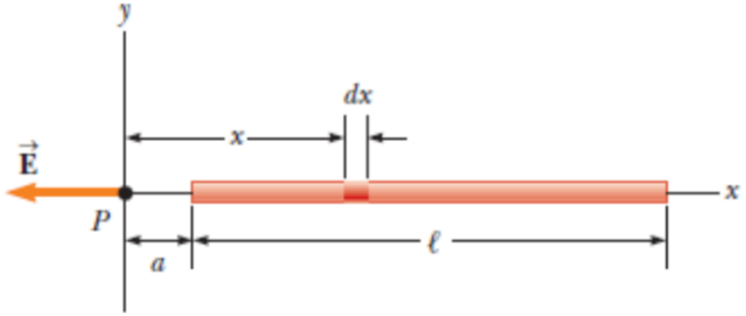
   Answer : b
2. The force per unit charge is known as
   a. electric flux
   b. electric field
   c. electric potential
   d. electric current

   Answer : b

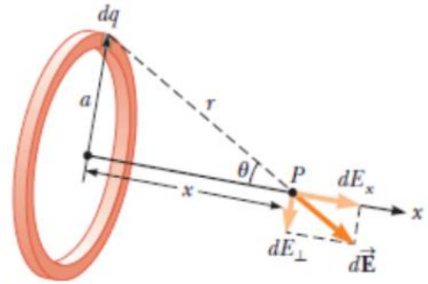
Electric Field of a Continuous Charge Distribution

- The Electric Field Due to a Charged Rod

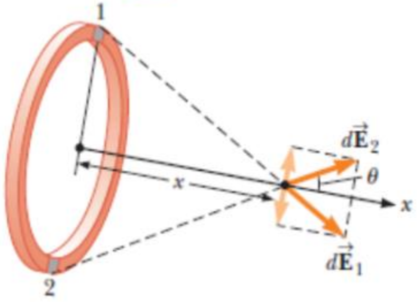
$$E = \frac{k_e Q}{a(a+l)}$$



- The Electric Field of a Uniform Ring of Charge

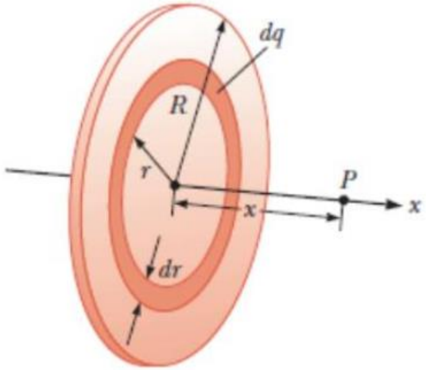


$$E = \frac{k_e x}{(a^2+x^2)^{3/2}} Q$$



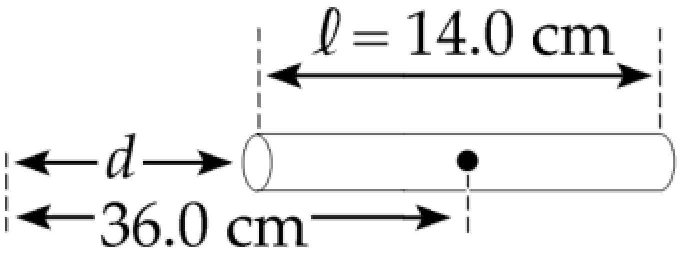
- The Electric Field of a Uniformly Charged Disk

$$E_x = 2k_e\pi\sigma\left[1 - \frac{x}{\sqrt{R^2 + x^2}}\right]$$



Example 1:

A rod 14.0 cm long is uniformly charged and has a total charge of -22.0 uC. Determine the magnitude and direction of the electric field along the axis of the rod at a point 36.0 cm from its center.



Solution

$$E = \frac{k_e \lambda l}{d(l+d)} = \frac{k_e Q}{d(l+d)} = \frac{(8.99 \times 10^9)(22.0 \times 10^{-6})}{(0.290)(0.140 + 0.290)}$$

$E = 1.59 \times 10^6$ N/C , directed toward the rod

Example 2:

A uniformly charged ring of radius 10.0 cm has a total charge of 75.0 uC. Find the electric field on the axis of the ring at

(a) 1.00 cm

(b) 30.0 cm

Solution

$$E = \frac{k_e x Q}{\left(x^2 + a^2\right)^{3/2}} = \frac{\left(8.99 \times 10^9\right)\left(75.0 \times 10^{-6}\right)x}{\left(x^2 + 0.100^2\right)^{3/2}} = \frac{6.74 \times 10^5 x}{\left(x^2 + 0.010\,0\right)^{3/2}}$$

(a) At $x = 0.010\,0$ m, $\mathbf{E} = 6.64 \times 10^6 \hat{\mathbf{i}}$ N/C $= \boxed{6.64\hat{\mathbf{i}} \text{ MN/C}}$

(b) At $x = 0.300$ m, $\mathbf{E} = 6.40 \times 10^6 \hat{\mathbf{i}}$ N/C $= \boxed{6.40\hat{\mathbf{i}} \text{ MN/C}}$

Example 3:

A uniformly charged disk of radius 35.0 cm carries charge with a density of $\mathbf{7.90 \times 10^{-3}}\ \boldsymbol{C/m^2}$ Calculate the electric field on the axis of the disk at

(a) 5.00 cm

(b) 50.0 cm

Solution

$$E = 2\pi k_e \sigma \left(1 - \frac{x}{\sqrt{x^2 + R^2}} \right)$$

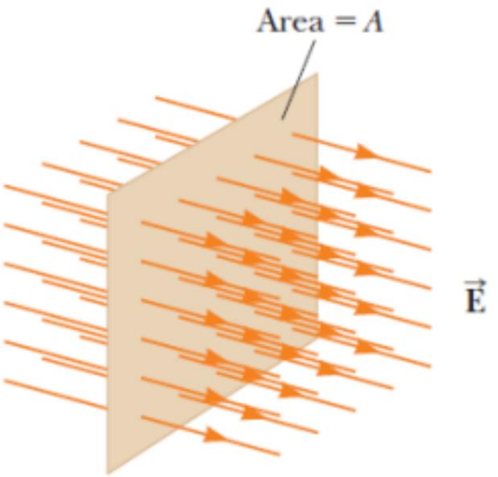
$$E = 2\pi \left(8.99 \times 10^9\right)\left(7.90 \times 10^{-3}\right)\left(1 - \frac{x}{\sqrt{x^2 + (0.350)^2}} \right) = 4.46 \times 10^8 \left(1 - \frac{x}{\sqrt{x^2 + 0.123}} \right)$$

(a) At $x = 0.050\,0 \text{ m}$, $E = 3.83 \times 10^8 \text{ N/C} = \boxed{383 \text{ MN/C}}$

(b) At $x = 0.500 \text{ m}$, $E = 8.07 \times 10^7 \text{ N/C} = \boxed{80.7 \text{ MN/C}}$

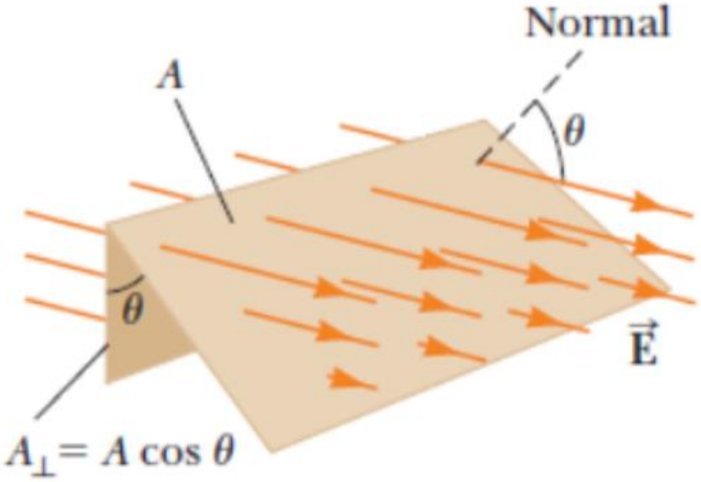
Electric Flux

$$\Phi_E = EA \ \ (\mathrm{N.m^2/C})$$



$$A_{\perp} = A \ \cos\theta$$

$$\Phi_E = EA_{\perp} = EA\cos\theta$$



Example 3:

An electric field with a magnitude of 3.50 kN/C is applied along the *x* axis. Calculate the electric flux through a rectangular plane 0.350 m wide and 0.700 m long assuming that (a) the plane is parallel to the *yz* plane; (b) the plane is parallel to the *xy* plane; (c) the plane contains the *y* axis, and its normal makes an angle of 40.0° with the *x* axis.

Solution

(a) $$\Phi_E = EA\cos\theta = \left(3.50\times10^3\right)(0.350\times0.700)\cos 0^\circ = \boxed{858\ \mathrm{N\cdot m^2/C}}$$

(b) $$\theta = 90.0^\circ \qquad \boxed{\Phi_E = 0}$$

(c) $$\Phi_E = \left(3.50\times10^3\right)(0.350\times0.700)\cos 40.0^\circ = \boxed{657\ \mathrm{N\cdot m^2/C}}$$

Example 4:

Consider a closed triangular box resting within a horizontal electric field of magnitude $E = 7.80 \times 10^4$ N/C as shown in Figure P24.4. Calculate the electric flux through (a) the vertical rectangular surface, (b) the slanted surface, and (c) the entire surface of the box.

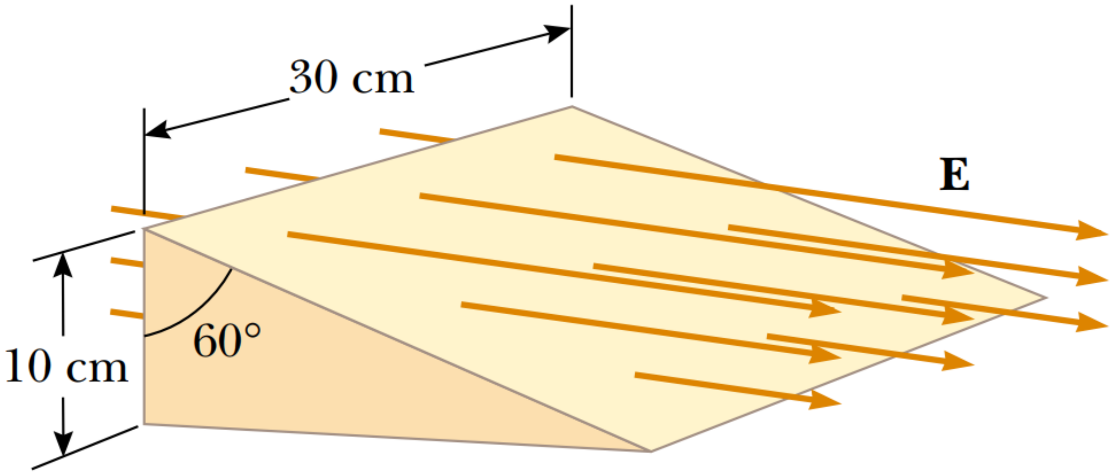


Figure P24.4

Solution

(a)
$$A' = (10.0 \text{ cm})(30.0 \text{ cm})$$
$$A' = 300 \text{ cm}^2 = 0.030\,0 \text{ m}^2$$
$$\Phi_{E,\,A'} = EA'\cos\theta$$
$$\Phi_{E,\,A'} = \left(7.80\times10^4\right)(0.030\,0)\cos 180°$$
$$\Phi_{E,\,A'} = \boxed{-2.34 \text{ kN}\cdot\text{m}^2/\text{C}}$$

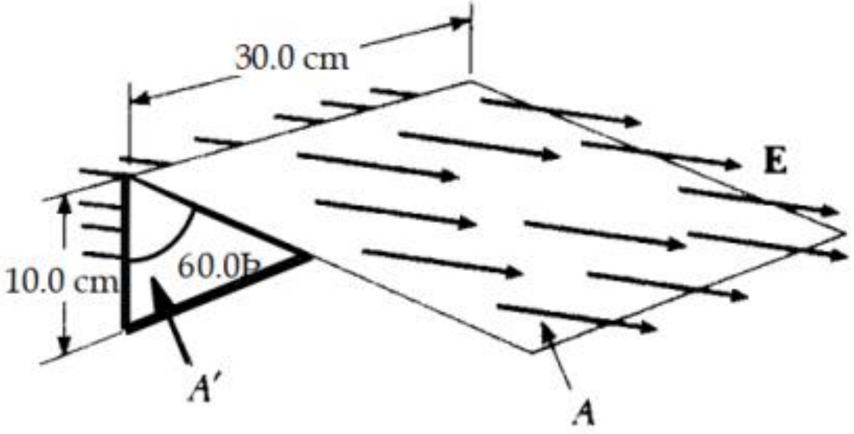


FIG. P24.4

(b)
$$\Phi_{E,\,A} = EA\cos\theta = \left(7.80\times10^4\right)(A)\cos 60.0°$$
$$A = (30.0 \text{ cm})(w) = (30.0 \text{ cm})\left(\frac{10.0 \text{ cm}}{\cos 60.0°}\right) = 600 \text{ cm}^2 = 0.060\,0 \text{ m}^2$$
$$\Phi_{E,\,A} = \left(7.80\times10^4\right)(0.060\,0)\cos 60.0° = \boxed{+2.34 \text{ kN}\cdot\text{m}^2/\text{C}}$$

(c) The bottom and the two triangular sides all lie *parallel* to **E**, so $\Phi_E = 0$ for each of these. Thus,

$$\Phi_{E,\,\text{total}} = -2.34 \text{ kN}\cdot\text{m}^2/\text{C} + 2.34 \text{ kN}\cdot\text{m}^2/\text{C} + 0 + 0 + 0 = \boxed{0}.$$

MCQ:

1. When is the flux on a surface zero?
   a. When it is perpendicular to an electric field
   b. When it is at an angle to an electric field
   c. When it is parallel to an electric field
   d. It is never zero in an electric field

   Answer : c