

1. Humid air breaks down (its molecules become ionized) in an electric field $3.0 \times 10^6 \text{ N/C}$. In that field, what is the magnitude of the electrostatic force on
 (a) an electron
 (b) an ion with a single electron missing

Solution

(a) $F = Ee = (3.0 \times 10^6 \text{ N/C}) (1.6 \times 10^{-19} \text{ C})$
 $= 4.8 \times 10^{-13} \text{ N}$

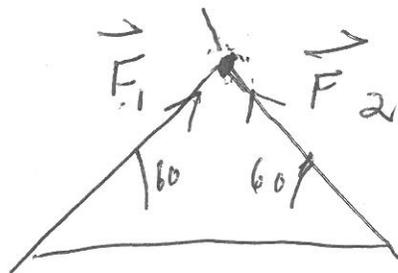
(b) $F = Ee = (3.0 \times 10^6 \text{ N/C}) (1.6 \times 10^{-19} \text{ C})$
 $= 4.8 \times 10^{-13} \text{ N}$



2 Two particles, each with a charge of magnitude $q = 12 \text{ nC}$, are at two of the vertices of an equilateral triangle of edge length $L = 2.0 \text{ m}$. What is the magnitude of the electric field at the third vertex if

- (a) both charges are positive
 and (b) one charge is positive and the other is negative.

Solution



$$(a) \quad \vec{F}_1 = \frac{q}{4\pi\epsilon_0} \frac{1}{L^2} (\cos 60^\circ \hat{i} + \sin 60^\circ \hat{j})$$

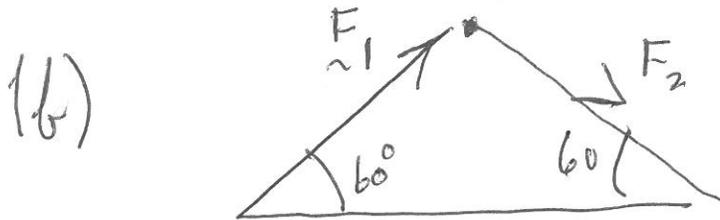
$$\vec{F}_2 = \frac{q}{4\pi\epsilon_0} \frac{1}{L^2} (-\cos 60^\circ \hat{i} + \sin 60^\circ \hat{j})$$

Total F :

3

$$\vec{F} = \vec{F}_1 + \vec{F}_2 = 2 \cdot \frac{q}{4\pi\epsilon_0} \frac{1}{L^2} \sin 60^\circ \hat{j}$$
$$= 2 (12 \times 10^{-9} \text{C}) \left(8.99 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2} \right) \left(\frac{\sqrt{3}}{2} \right)$$

$$= 12 \times 8.99 \times \frac{\sqrt{3}}{4} \text{ N/C} = 46 \text{ N/C}$$



$$\vec{F}_1 = \frac{q}{4\pi\epsilon_0} \frac{1}{L^2} (\cos 60^\circ \hat{i} + \sin 60^\circ \hat{j})$$

$$\vec{F}_2 = \frac{q}{4\pi\epsilon_0} \frac{1}{L^2} (\cos 60^\circ \hat{i} - \sin 60^\circ \hat{j})$$

$$\vec{F}_{\text{total}} = \vec{F}_1 + \vec{F}_2 = 2 \cdot \frac{q}{4\pi\epsilon_0} \frac{1}{L^2} \cos 60^\circ \hat{i}$$

$$= 9 \times 10^{-9} \times 8.99 \times 10^9 \times \frac{1}{4} \times 2 \times \cos 60^\circ$$

$$= 26.7 \text{ N/C}$$

#3 Find the electrostatic field established by two long hollow concentric cylinders having radii a and b bearing respective surface charge densities σ_a and σ_b in the region inside the inner cylinder, between the cylinders, and outside the two cylinders

Solution



(a) Inside the inner cylinder, $E_1 = 0$

$$(b) \text{ For } a < r < b : E_2 (2\pi r) L = \frac{\sigma_a L (2\pi a^2)}{\epsilon_0}$$

$$\rightarrow E_2 = \frac{\sigma_a}{\epsilon_0} \frac{a}{r}$$

(c) For $r > b$:

$$E_3 (2\pi r) L = \frac{\sigma_a L (2\pi a^2)}{\epsilon_0} + \frac{\sigma_b L (2\pi b^2)}{\epsilon_0}$$

$$\rightarrow E_3 = \frac{1}{\epsilon_0} \left\{ \sigma_a a + \sigma_b b \right\} \frac{1}{r} \quad \underline{5.}$$

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#4 Consider a sphere of radius a with a spherical charge density distribution

$$\rho(r) = \rho_0 e^{-Kr} \quad , 0 < r < a$$

$$= 0$$

where K, ρ_0 are constants. Find the electrostatic field produced by the charge density

(a) for $r < a$ and (b) $r > a$

Solution (a) $E (4\pi r^2) = \frac{Q}{\epsilon_0}$

where

$$\begin{aligned} Q &= \int_0^r dR (4\pi R^2) \rho_0 e^{-KR} \\ &= 4\pi \rho_0 \int_0^r dR \cdot R^2 e^{-KR} \end{aligned}$$

$$= 4\pi \rho_0 \frac{\partial^2}{\partial k^2} \int_0^r uR e^{-kR}$$

$$= 4\pi \rho_0 \frac{\partial^2}{\partial k^2} \left[-\frac{1}{k} e^{-kR} \right]_0^r$$

$$= 4\pi \rho_0 \frac{\partial^2}{\partial k^2} \left\{ \frac{1}{k} [1 - e^{-kr}] \right\}$$

$$= 4\pi \rho_0 \left\{ \frac{2}{k^3} + 2 \left(-\frac{r}{k^2} \right) \right\}$$

$$= 4\pi \rho_0 \left\{ \frac{2}{k^3} [1 - e^{-kr}] + 2 \left(-\frac{1}{k^2} \right) (-1) e^{-kr} + \frac{1}{k} \cdot 1^2 (-1) e^{-kr} \right\}$$

$$= 4\pi \rho_0 \left\{ \frac{2}{k^3} - \left(\frac{2r}{k^2} + \frac{2}{k^3} + \frac{r^2}{k} \right) e^{-kr} \right\}$$

$$\rightarrow E = \frac{\rho_0}{\epsilon_0} \frac{1}{r^2} \left\{ \frac{2}{k^3} - \left(\frac{2r}{k^2} + \frac{2}{k^3} + \frac{r^2}{k} \right) e^{-kr} \right\}$$

for $r < a$