#7, #20, #24, #38, #44

Saturday, 19 February 2022 7:22 PM

Chapter 21: Coulomb's Law

13

••13 In Fig. 21-26, particle 1 of charge $+1.0\ \mu C$ and particle 2 of charge $-3.0\ \mu C$ are held at separation $L = 10.0$ cm on an x axis. If particle 3 of unknown charge q_3 is to be located such that the net electrostatic force on it from particles 1 and 2 is zero, what must be the (a) x and (b) y coordinates of particle 3?

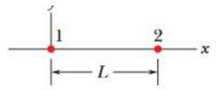
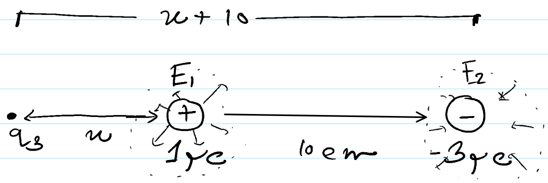


Figure 21-26 Problems 13, 19, 30, 58, and 67.



(a) Net force on q_3 would have to be equal to zero

So we can say,

$$|E_1| - |E_2| = 0$$

$$\text{or, } \frac{|q_1|}{4\pi\epsilon_0 r_1^2} - \frac{|q_2|}{4\pi\epsilon_0 r_2^2} = 0$$

$$\text{or, } \frac{1}{4\pi\epsilon_0}\left(\frac{|1\times10^{-6}|}{x^2} - \frac{|-3\times10^{-6}|}{(x+\frac{10}{100})^2}\right) = 0$$

$$\text{or, } \frac{1\times\cancel{10^{-6}}}{x^2} = \frac{3\times\cancel{10^{-6}}}{x^2 + 2\frac{1}{10}\cdot x + \frac{1}{100}}$$

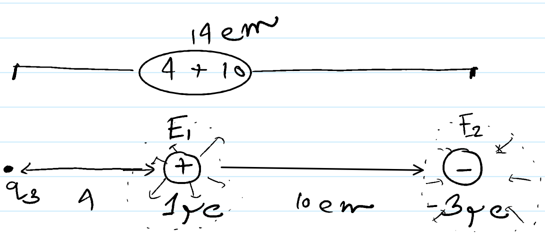
$$\text{or, } x^2 + 0.2x + 0.01 = 3x^2$$

$$\text{or, } x^2 - 0.2x - 0.01 = 0$$

$$\text{or, } x = 0.24, -0.04$$

[x can't be positive as it would result in attraction toward q_2]

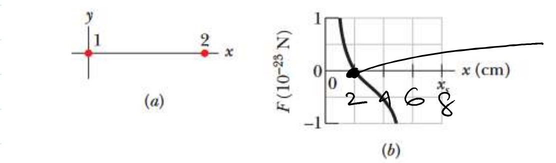
$$x = 0.04 \text{ m}$$



(b) if charges are not placed in parrall the charge effection on q3 would eventually drop the charge in one of those charge So as both charge are placed in y=0 the q_3 charge also need to be placed on y=0

16

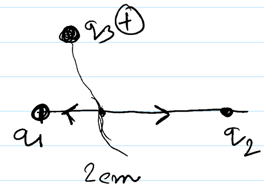
••16 In Fig. 21-27*a*, particle 1 (of charge q_1) and particle 2 (of charge q_2) are fixed in place on an x axis, 8.00 cm apart. Particle 3 (of



2cm

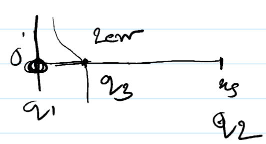
charge $q_3 = +8.00 \times 10^{-19}$ C) is to be placed on the line between particles 1 and 2 so that they produce a net electrostatic force $\vec{F}_{3,net}$ on it. Figure 21-27*b* gives the x component of that force versus the coordinate x at which particle 3 is placed. The scale of the x axis is set by x_s = 8.0 cm. What are (a) the sign of charge q_1 and (b) the ratio q_2/q_1?

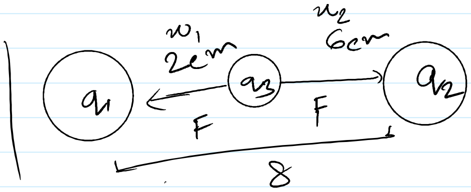
(a)



as we can notice the q_3 charge has rippled q_2 and q_1 has also mad q_3 meaning they must have same charge. As q_3 is positive other charge must be positive in order to ripple the charge.

(b)





As the charge q_3 effecting q_1 and q_2 with same force

$$F_1 = F_2$$

or, $$\frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_3}{x_1^2} = \frac{1}{4\pi\epsilon_0} \frac{q_3 q_2}{x_2^2}$$

or, $$\frac{q_1}{2^2} = \frac{q_2}{6^2} \Rightarrow \frac{q_1}{q_2} = \frac{4}{36}$$

or, $$\frac{q_1}{q_2} = \frac{1}{9}$$

or, $q_2 / q_1 = 9$ (Ans)

$q_2/q_1 = 9$ (Ans.)

23

•••23 In Fig. 21-32, particles 1 and 2 of charge $q_1 = q_2 = +3.20 \times 10^{-19}$ C are on a y axis at distance $d = 17.0$ cm from the origin. Particle 3 of charge $q_3 = +6.40 \times 10^{-19}$ C is moved gradually along the x axis from $x = 0$ to $x = +5.0$ m. At what values of x will the magnitude of the electrostatic force on the third particle from the other two particles be (a) minimum and (b) maximum? What are the (c) minimum and (d) maximum magnitudes?

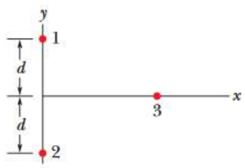
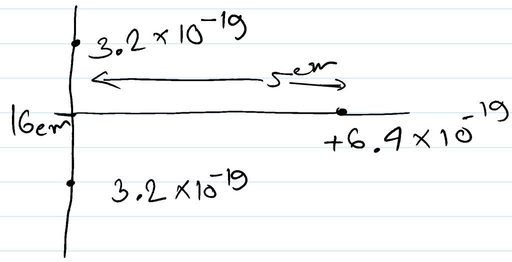
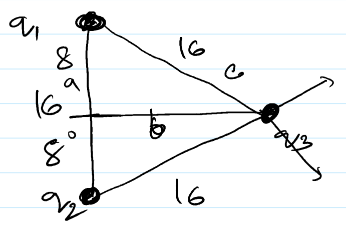


Figure 21-32 Problem 23.



(a) to get lowest magnatudes a charge should placed perpendueler between charges then at $x=0$ the charge is lowest.

(b) the maximum we would get when all the points are same distence to eachother as



we know

$b = \sqrt{c^2 - a^2}$

$x = 8\sqrt{3}$

(c) The value of net force $F = 0$ as they push eachother to a equlibium point resting

(d) maximum magnitude of charge would be at $x = 8\sqrt{3}$

equal angle triangle

$$F_{net} = F_3 \cos\theta + F_3 \cos\theta = 2 \frac{1}{4\pi\epsilon_0} \frac{3.2 \times 10^{-9} \times 6.4 \times 10^{-19}}{(8\sqrt{3})^2} \cos(60^\circ)$$

$$= 4.9 \times 10^{-26}\ \text{N}$$

32

••32 Figure 21-34a shows charged particles 1 and 2 that are fixed in place on an x axis. Particle 1 has a charge with a magnitude of $|q_1| = 8.00e$. Particle 3 of charge $q_3 = +8.00e$ is initially on the x axis near particle 2. Then particle 3 is gradually moved in the positive direction of the x axis. As a result, the magnitude of the net electrostatic force $\vec{F}_{2,net}$ on particle 2 due to particles 1 and 3 changes. Figure 21-34b gives the x component of that net force as a function of the position x of particle 3. The scale of the x axis is set by $x_s = 0.80$ m. The plot has an asymptote of $F_{2,net} = 1.5 \times 10^{-25}$ N as $x \to \infty$. As a multiple of e and including the sign, what is the charge q_2 of particle 2?

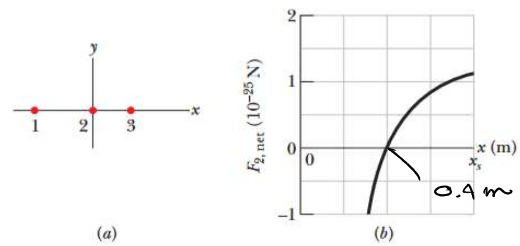


Figure 21-34 Problem 32.

$$F_{2net} = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{r^2}$$

$$1.5\times10^{-25} = \frac{1}{4\pi\epsilon_0} \cdot \frac{8\times q_2}{0.4^2}$$

$$q_2 = \frac{1.5\times10^{-25}}{8.99\times10^{-9}} \times 0.4^2$$

$$q_2 = 2.67\times10^{-18}\ C$$

$$q_2 = \frac{2.67\times10^{-18}}{1.602\times10^{-19}}\ C$$

$$= 13e$$

(Ans)

42 (a)

$$\tan\theta = \frac{x/2}{\sqrt{L^2 - \left(\frac{x}{2}\right)^2}}$$

$$\tan\theta = \frac{x}{2l}$$

$$F_e = \frac{q^2}{4\pi\epsilon_0 x^2}$$

$$\frac{mgx}{2l} = \frac{q^2}{\cancel{4}_{2}\pi\epsilon_0 x^2}$$

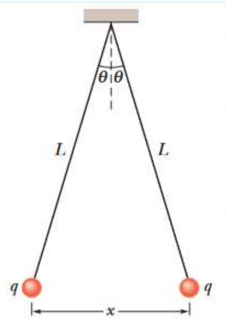
$$x^3 = \left(\frac{l q^2}{2\pi\epsilon_0 mg}\right)$$

$$x = \sqrt[3]{\frac{q^2 l}{2\pi\epsilon_0 mg}}$$

42 In Fig. 21-39, two tiny conducting balls of identical mass m and identical charge q hang from nonconducting threads of length L. Assume that θ is so small that $\tan\theta$ can be replaced by its approximate equal, $\sin\theta$. (a) Show that

$$x = \left(\frac{q^2 L}{2\pi\epsilon_0 mg}\right)^{1/3}$$

gives the equilibrium separation x of the balls. (b) If $L = 120$ cm, $m = 10$ g, and $x = 5.0$ cm, what is $|q|$?



(b)

$$\frac{mg}{\cancel{2}l} = \frac{q^2}{\cancel{4}_{2}\pi\epsilon_0 x^2}$$

$$q^2 = \frac{mgx^3}{2KL}$$

$$q = \sqrt{\frac{mgx^3}{2Kl}}$$

$$q = \sqrt{\frac{10\times10^{-3}\times9.8\times(0.5\times10^{-2})^3}{2KL}}$$

$$q = \pm 2.4\times10^{-8}\ C$$

(Ans)

8

••8 In Fig. 22-36, the four particles are fixed in place and have charges $q_1 = q_2 = +5e$, $q_3 = +3e$, and $q_4 = -12e$. Distance $d = 5.0\ \mu m$. What is the magnitude of the net electric field at point P due to the particles?

••9 Figure 22-37 shows two charged particles on an x axis: $-q = -3.20 \times 10^{-19}$ C at $x = -3.00$ m and $q = 3.20 \times 10^{-19}$ C at $x = +3.00$ m. What are the (a) magnitude and

Figure 22-35 Problem 7.

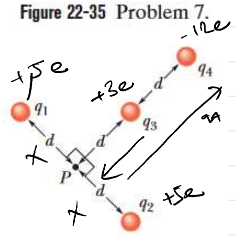


Figure 22-36 Problem 8.

As $E_1 = E_2$ they cancel each other

$E_P = -E_3 + E_5$

$= \frac{1}{4\pi\epsilon_0}\left(-\frac{3q}{d^2} + \frac{12q}{(2d)^2}\right)$

$= \frac{1}{4\pi\epsilon_0}\left(\frac{-12q + 12q}{4d^2}\right)$

$= 0$ J

10

••10 Figure 22-38a shows two charged particles fixed in place on an x axis with separation L. The ratio q_1/q_2 of their charge magnitudes is 4.00. Figure 22-38b shows the x component $E_{net,x}$ of their net electric field along the x axis just to the right of particle 2. The x axis scale is set by $x_s = 30.0$ cm. (a) At what value of $x > 0$ is $E_{net,x}$ maximum? (b) If particle 2 has charge $-q_2 = -3e$, what is the value of that maximum?

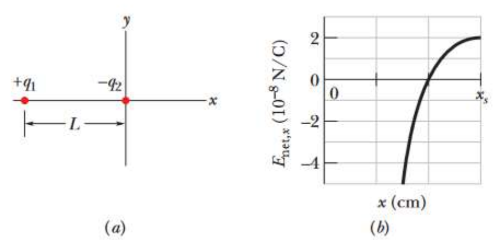


Figure 22-38 Problem 10.

(a) $E_{net} = E_1 + E_2 = \frac{4q}{4\pi\epsilon_0 (L+x)^2} - \frac{q}{4\pi\epsilon_0 x^2}$

$E_{net} = 0$ at (x)

$\frac{4\cancel{q}}{\cancel{4\pi\epsilon_0}(L+x)^2} = \frac{\cancel{q}}{\cancel{4\pi\epsilon_0} x^2}$

$4x^2 = l^2 + x^2 + 2lx$

or, $3x^2 = l^2 + 2lx$

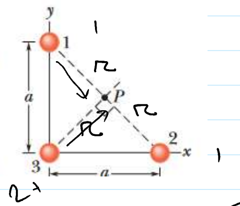
or $x = 34$ m

(b) $E_{net} = \frac{4q}{4\pi\epsilon_0 (L+x^2)} - \frac{q}{4\pi\epsilon_0 x^2}$ | $q = 3e \times 1.6 \times 10^{-19}$

$= 2.2 \times 10^{-8}$ NC^{-1}

(15)

••15 In Fig. 22-42, the three particles are fixed in place and have charges $q_1 = q_2 = +e$ and $q_3 = +2e$. Distance $a = 6.00\ \mu m$. What are the (a) magnitude and (b) direction of the net electric field at point P due to the particles?



•••16 Figure 22-43 shows a plastic ring of

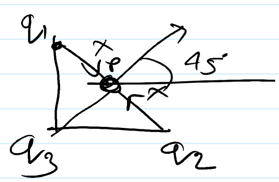
$$E = \frac{1}{4\pi\epsilon_0}\left|\frac{(q_1 - q_2 + q_3)}{r^2}\right| \quad [\text{as } q_1 = q_2]$$

$$= \frac{1}{4\pi\epsilon_0}\frac{(q_3)}{(4.24\times10^{-6})^2}$$

$$= 160\,N/C$$

$$d = r^2 + r^2$$
$$a^2 = 2r^2$$
$$r = \frac{a}{\sqrt{2}} = 4.24\times10^{-6}$$

(6)



(Ans) 45° from x axis

(24)

••24 A thin nonconducting rod with a uniform distribution of positive charge Q is bent into a complete circle of radius R (Fig. 22-48). The central perpendicular axis through the ring is a z axis, with the origin at the center of the ring. What is the magnitude of the electric field due to the rod at (a) $z = 0$ and (b) $z = \infty$? (c) In terms of R, at what positive value of z is that magnitude maximum? (d) If $R = 2.00$ cm and $Q = 4.00\ \mu C$, what is the maximum magnitude?

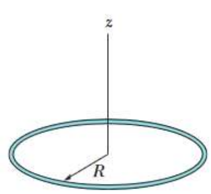


Figure 22-48 Problem 24.

(a) $E = \frac{qz}{4\pi\epsilon_0(z^2+R^2)}$ [at $z = 0$]

$$E = \frac{0}{4\pi\epsilon_0 R^2} = 0$$

(b) $E = \frac{qz}{4\pi\epsilon_0(z^2+R^2)}$

$$= \frac{q\frac{1}{0}}{4\pi\epsilon_0(\frac{1}{0}+R^2)} \quad [\text{at } z = \infty]$$

$$= \frac{q}{0(\frac{1}{0})} = 0$$

(c) to find maxima $\frac{d}{dz}\left(\frac{qz}{4\pi\epsilon_0(z^2+R^2)^{3/2}}\right) = 0$

$$q(R^2 - 2z^2)$$

$$dz \quad 4\pi\epsilon_0 (z^2+R^2)^{5/2})$$

$$\text{or,} \quad \frac{q\,(R^2-2z^2)}{4\pi\epsilon_0\,(z^2+R^2)^{5/2}} = 0$$

$$\text{or,} \quad q(R^2-2z^2) = 0$$

$$\text{or,} \quad z^2 = \frac{R^2}{2}$$

$$\text{or,} \quad z = \frac{R}{\sqrt{2}}$$

(d)

$$E_{max} = \frac{qz}{4\pi\epsilon_0 (z^2+R^2)^{3/2}}$$

$$E_{max} = \frac{qz}{4\pi\epsilon_0 \left(z^2+\frac{R^2}{2}\right)^{3/2}} = 3.46\times10^{7}\ \text{N/C}$$

(32)

rod? (At that distance, the rod "looks" like a particle.)

•••32 GO In Fig. 22-55, positive charge $q = 7.81$ pC is spread uniformly along a thin nonconducting rod of length $L = 14.5$ cm. What are the (a) magnitude and (b) direction (relative to the positive direction of the x axis) of the electric field produced at point P, at distance $R = 6.00$ cm from the rod along its perpendicular bisector?

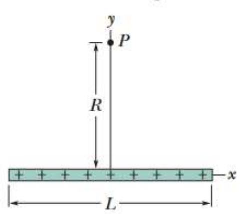
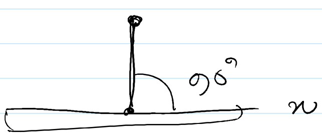


Figure 22-55 Problem 32.

(a)
$$|\vec{E}| = 2\int_0^{L/2} \frac{dq}{4\pi\epsilon_0 r^2}\sin\theta$$

$$= \frac{q}{2\pi\epsilon_0 L R}\,\frac{L/2}{\sqrt{(L/2)^2+R^2}}$$

(b)

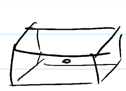


(Ans) 90°

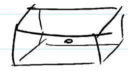
Chapter 23: Gauss' Law

(7)

•7 A particle of charge 1.8 μC is at the center of a Gaussian cube 55 cm on edge. What is the net electric flux through the surface?



•7 A particle of charge 1.8 μC is at the center of a Gaussian cube 55 cm on edge. What is the net electric flux through the surface?



$$\phi = \frac{q}{\epsilon_0} = \frac{1.8 \times 10^{-6}}{8.85 \times 10^{-12}} = 2 \times 10^{5}\, N/m^2/C$$

20

•20 Flux and conducting shells. A charged particle is held at the center of two concentric conducting spherical shells. Figure 23-39*a* shows a cross section. Figure 23-39*b* gives the net flux Φ through a Gaussian sphere centered on the particle, as a function of the radius r of the sphere. The scale of the vertical axis is set by $\Phi_s = 5.0 \times 10^5\ N \cdot m^2/C$. What are (a) the charge of the central particle and the net charges of (b) shell *A* and (c) shell *B*?

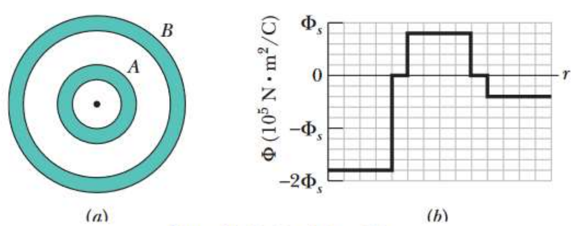


Figure 23-39 Problem 20.

(a) $\phi = \frac{q}{\epsilon_0}$

$q = -9 \times 10^5 \times \epsilon_0$

$= -8 \times 10^{-6}\ C$

(b) $q_A = q_{top} - q_{central}$

$= (4 \times 10^5 \times \epsilon_0 - 8)\ \mu C$

$= 11.5\ \mu C$

(c) $\phi_{total} = -2 \times 10^5\ N m^2/C$

$q_{total} = \phi\, \epsilon_0$

$= -1.77 \times 10^{-6}\ C$

$q_{total} = q_B + q_{central}$

$q_B = +1.77 \times 10^{-6} - 8 \times 10^{-6}$

$= 5.3 \times 10^{-6}\ C$

24

•24 Figure 23-40 shows a section of a long, thin-walled metal tube of radius $R = 3.00$ cm, with a charge per unit length of $\lambda = 2.00 \times 10^{-8}$ C/m. What is the magnitude E of the electric field at radial distance (a) $r = R/2.00$ and (b) $r = 2.00R$? (c) Graph E versus r for the range $r = 0$ to $2.00R$.

•25 SSM An infinite line of charge produces a field of magnitude 4.5×10^4 N/C at distance 2.0 m. Find the

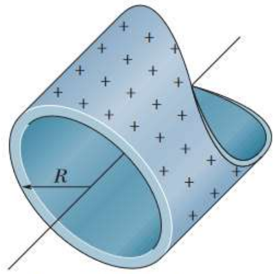


Figure 23-40 Problem 24.

(a) for $r < R$, $q_{enc} = 0$, $E = 0$

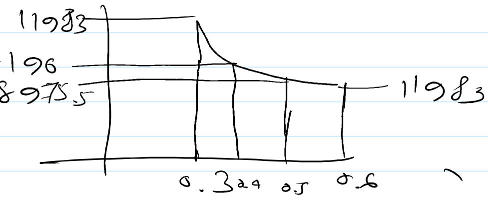
(b) $r > R$, $q_{enc} = \lambda$

$$E = \frac{\lambda}{2\pi r \epsilon_0} = \frac{2 \times 10^{-8}}{2\pi\,(0.06 \times \epsilon_0)}$$

$$E = 5.99 \times 10^{-3}\ \text{N/C}$$

(c) $E = \dfrac{\lambda}{2\pi r \epsilon_0}$

r	E N/C
0.06	5991.7
0.05	7190
0.04	8987.5
0.03	11983



(38)

••38 GO In Fig. 23-48a, an electron is shot directly away from a uniformly charged plastic sheet, at speed $v_s = 2.0 \times 10^5$ m/s. The sheet is nonconducting, flat, and very large. Figure 23-48b gives the electron's vertical velocity component v versus time t until the return to the launch point. What is the sheet's surface charge density?

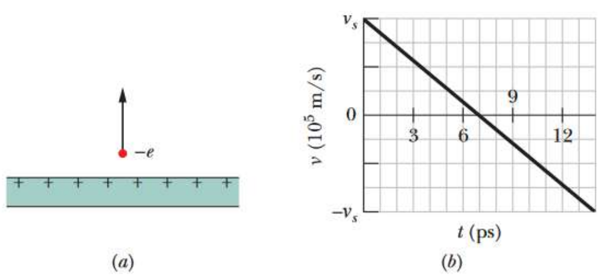


Figure 23-48 Problem 38.

$$E = \frac{\sigma}{2\epsilon_0}$$

$$\frac{F}{e} = \frac{\sigma}{2\epsilon_0}$$

$$\frac{ma}{e} = \frac{\sigma}{2\epsilon_0}$$

$$a = \frac{\sigma e}{2\epsilon_0 m} = \frac{2 \times 10^5}{7 \times 10^{-12}}$$

$$a = 29 \times 10^6\ \text{C/m}^2$$

(44)

Module 23-6 Applying Gauss' Law: Spherical Symmetry

•44 Figure 23-52 gives the magnitude of the electric field inside and outside a sphere with a positive charge distributed uniformly throughout its volume. The scale of the vertical axis is set by $E_s = 5.0 \times 10^7$ N/C. What is the charge on the sphere?

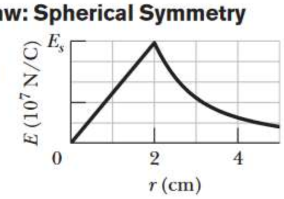


Figure 23-52 Problem 44.

$$E = \frac{q}{4\pi\epsilon_0 r^2}$$

$$q = 4\pi\epsilon_0 E r^2$$

$$= \left(\frac{2}{100}\right)^2 \times 4\pi\epsilon_0 \times 5 \times 10^7$$

$= 2.2 \times 10^{-6} C$