Chapter 16 | Phys 104 | HW #1

3. A balloon, initially neutral, is rubbed with fur until it acquires a net charge of −0.60 nC. (a) Assuming that only electrons are transferred, were electrons removed from the balloon or added to it? (b) How many electrons were transferred?

$-0.6\ nC = Q$

a) since the charge on the balloon is negative, electron were <u>added</u>

b) $Q = ne \qquad n = \frac{Q}{e} = \frac{0.6\times10^{-9}C}{1.6\times10^{-19}C} = 3.75\times10^{9}$ electrons

13. A +2.0-nC point charge is 3.0 cm away from a −3.0-nC point charge. (a) What are the magnitude and direction of the electric force acting on the +2.0-nC charge? (b) What are the magnitude and direction of the electric force acting on the −3.0-nC charge?

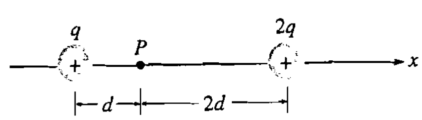
a) $F = \frac{kq_1q_2}{r^2} = \frac{\left(8.99\times10^{9}\frac{Nm^2}{C^2}\right)\left(2\times10^{-9}C\right)\left(3\times10^{-9}C\right)}{(0.03m)^2}$

$|F| = 6\times10^{-5}N$

The force on the +2.0 nC charge is directed towards the −3,0 nC charge

b) The magnitude of the force on the −3.0 nC charge is the same as on the +2.0 nC charge but it is in the opposite direction → towards the 2.0 nC charge.

15. In the figure, a third point charge −q is placed at point P. What is the electric force on −q due to the other two point charges?



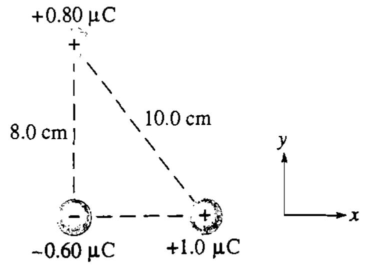
$\vec{F} = \vec{F_1} + \vec{F_2}$

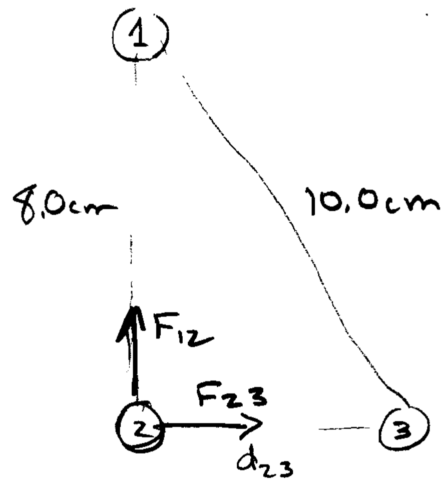
$F_1 = \frac{kq^2}{d^2}$ to the left

$F_2 = \frac{k(2q^2)}{(2d)^2} = \frac{2kq^2}{4d^2} = \frac{kq^2}{2d^2}$ to the right

$F = \frac{kq^2}{2d^2} - \frac{2kq^2}{2d^2} = -\frac{kq^2}{2d^2}$ or $\boxed{\frac{kq^2}{2d^2} \text{ to the left}}$

18. Three point charges are fixed in place in a right triangle. What is the electric force on the –0.60-μC charge due to the other two charges?





$q_1 = +0.8\mu C$

$q_2 = -0.6\mu C$

$q_3 = +1.0\mu C$

$d_{23} = \sqrt{10^2 - 8^2}$

$= 6.0\,cm$

$$F_{12} = \frac{k|q_1||q_2|}{d_{12}^2} = \frac{\left(8.99\times10^9 \frac{Nm^2}{C^2}\right)(0.8\times10^{-6}C)(0.6\times10^{-6}C)}{(0.08m)^2}$$

$= 0.67\,N$ up

$$F_{23} = \frac{k|q_2||q_3|}{d_{23}^2} = \frac{\left(8.99\times10^9 \frac{Nm^2}{C^2}\right)(0.6\times10^{-6}C)(1\times10^{-6}C)}{(0.06m)^2}$$

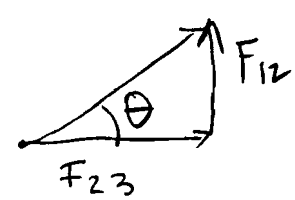
$= 1.5\,N$ to the right

since $F_{12} \perp$ to F_{23}

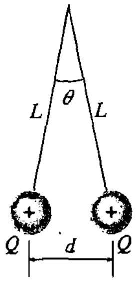
$$|F| = \sqrt{F_{12}^2 + F_{23}^2} = \sqrt{(0.67)^2 + (1.5)^2} = 1.64\,N$$

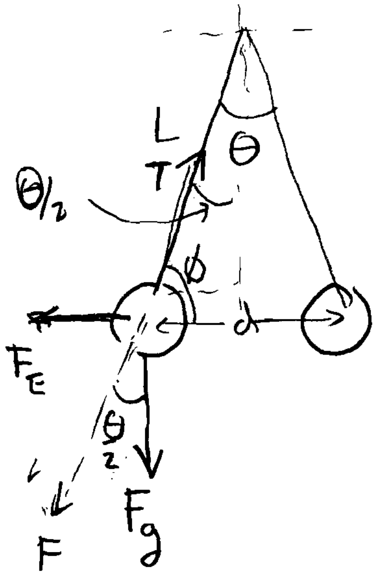
$$\theta = \tan^{-1}\left(\frac{F_{12}}{F_{23}}\right) = \tan^{-1}\left(\frac{0.67}{1.5}\right)$$

$= 24°$ above $+x$ direction



22. Two Styrofoam balls with the same mass $m = 9.0 \times 10^{-8}$ kg and the same positive charge Q are suspended from the same point by insulating threads of length $L = 0.98$ m. The separation of the balls is $d = 0.020$ m. What is the charge Q?



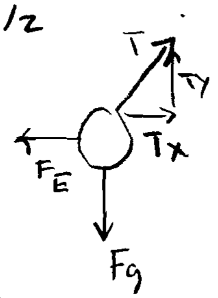


$$F_g = mg = (9.0 \times 10^{-8}\ kg)(9.8\ m/s^2)$$
$$= 8.82 \times 10^{-7}\ N = T_y = T\cos\theta/2$$

$$F_E = \frac{kQ^2}{d^2} = T_x = T\sin\frac{\theta}{2}$$

$$\sin\left(\frac{\theta}{2}\right) = \frac{d/2}{L} = \left(\frac{0.020}{2(0.98)}\right)$$
$$= 0.01$$

$$\frac{F_E}{F_g} = \frac{T\sin\theta/2}{T\cos\theta/2} = \tan\theta/2$$



$$\frac{\theta}{2} = \sin^{-1}(0.01)$$
$$= 0.58°$$
$$\tan(0.58°) = 0.01$$

$$\tan\left(\theta/2\right) = F_E / F_g$$

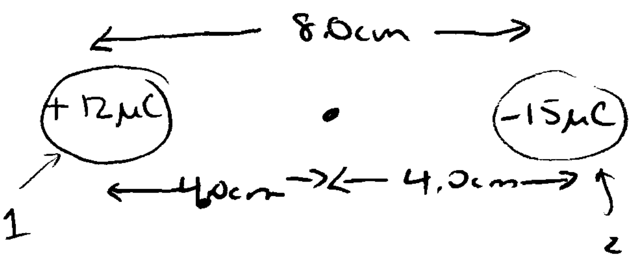
$$F_E = \frac{kQ^2}{d^2} = F_g \tan\theta/2$$

$$Q = \sqrt{\frac{d^2 F_g \tan\theta/2}{k}} = \sqrt{\frac{(0.020)^2\ m^2 (8.82 \times 10^{-7} N)\tan(0.58)}{8.99 \times 10^9\ \frac{Nm^2}{C^2}}}$$

$$= 2.0 \times 10^{-11}\ C$$

$$\boxed{Q = 0.02\ nC}$$

29. What are the magnitude and direction of the electric field midway between two point charges, −15 μC and +12 μC, that are 8.0 cm apart?



$$|E| = \frac{kq}{r^2} \qquad E_1 = \frac{8.99\times10^9\ Nm^2/C^2\ (12\times10^{-6}\ C)}{(0.04\ m)^2}$$

$$= 6.7\times10^7\ N/C$$ to the right (points in the direction a + test charge would move)

$$E_2 = \frac{(8.99\times10^9\ Nm^2/C^2)(15\times10^{-6}\ C)}{(0.04\ m)^2}$$

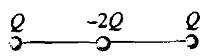
$$= 8.4\times10^7\ N/C$$ to the right

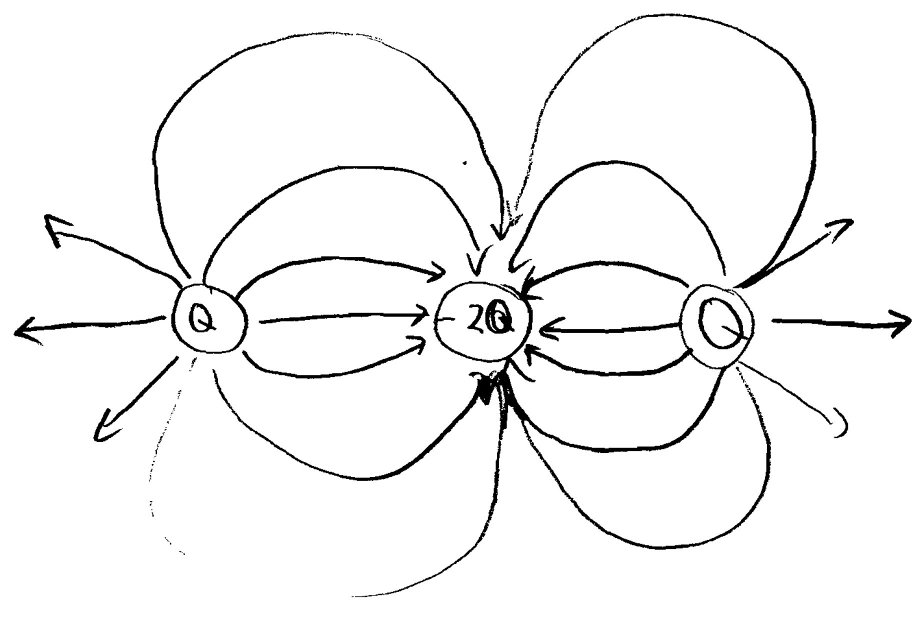
since both fields point in the same direction

$$E = E_1 + E_2 = 6.7\times10^7\ N/C + 8.4\times10^7\ N/C$$

$$= 1.5\times10^8\ N/C$$ to the right (or +x direction) or towards −15μC charge

37. Sketch the electric field lines in the plane of the page due to the charges shown in the diagram.





Lines point away from + and towards −

They are more dense close to the charges

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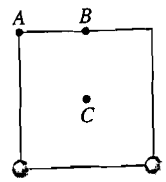
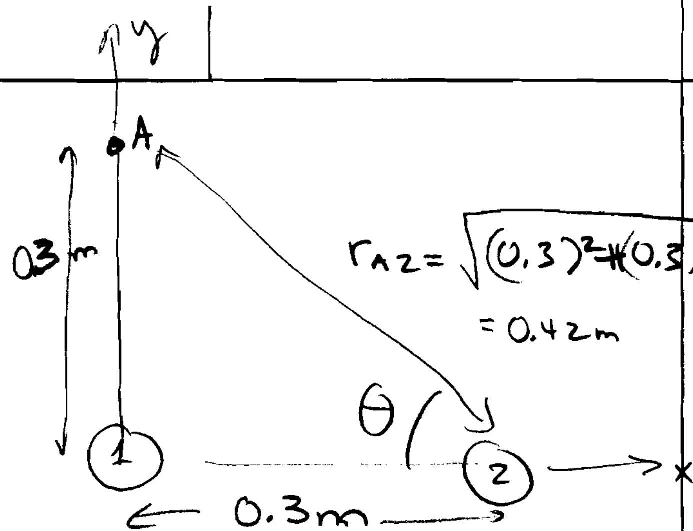
Problems 39–42. Two tiny objects with equal charges of 7.00 μC are placed at the two lower corners of a square with sides of 0.300 m, as shown.

39. Find the electric field at point *B*, midway between the upper left and right corners.
40. Find the electric field at point *C*, the center of the square.
41. Find the electric field at point *A*, the upper left corner.



Problems 39–42



$r_{A2} = \sqrt{(0.3)^2 + (0.3)^2}$
$= 0.42\,m$

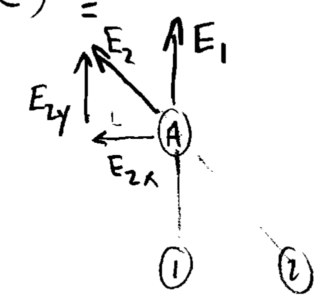
$Q_1 = Q_2 = +7.0\,\mu C$

$E_1 = \dfrac{kQ_1}{r_1^2} = \dfrac{(8.99\times10^9\,Nm^2/C^2)(7.0\times10^{-6}\,C)}{(0.3\,m)^2}$

$= 7.0\times10^5\,N/C$ upwards or $+y$

$E_2 = \dfrac{kQ_2}{r_{2A}^2} = \dfrac{(8.99\times10^9\,Nm^2/C^2)(7.0\times10^{-6}\,C)}{(0.42\,m)^2} =$

$= 3.6\times10^5\,N/C$



$\theta = \tan^{-1}\left(\dfrac{0.3m}{0.3m}\right) = 45°$

$E_{2x} = E_2 \cos 45 = 2.54\times10^5\,N/C$ in $-x$ direction

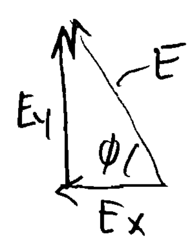
$E_{2y} = E_2 \sin 45 = 2.54\times10^5\,N/C$ in $+y$ direction

$E_x = \cancel{E_{1x}}^{\to 0} + E_{2x} = -2.54\times10^5\,N/C$

$E_y = E_{1y} + E_{2y} = (7\times10^5\,N/C) + 2.54\times10^5\,N/C$

$= 9.5\times10^5\,N/C$

$E = \sqrt{E_x^2 + E_y^2} = \boxed{E \quad 9.8\times10^5\,N/C}$



$\phi = \tan^{-1}\left(\dfrac{E_y}{E_x}\right) = \tan^{-1}\left(\dfrac{9.5\times10^5}{2.5\times10^5}\right)$

$\boxed{\phi = 75° \text{ above } -x \text{ direction}}$

50. A horizontal beam of electrons initially moving at 4.0×10^7 m/s is deflected vertically by the vertical electric field between oppositely charged parallel plates. The magnitude of the field is 2.00×10^4 N/C. (a) What is the direction of the field between the plates? (b) What is the charge per unit area on the plates? (c) What is the vertical deflection d of the electrons as they leave the plates?

$V_i = 4.0 \times 10^7$ m/s

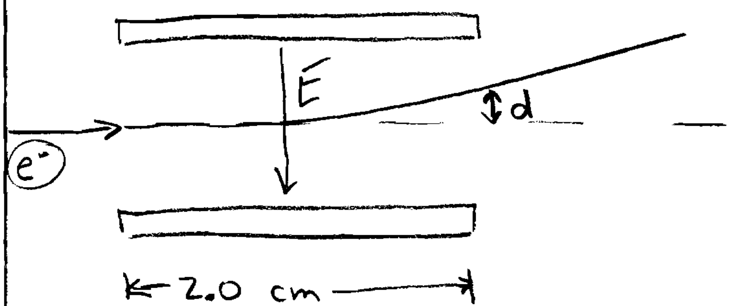
$E = 2.00 \times 10^4$ N/C

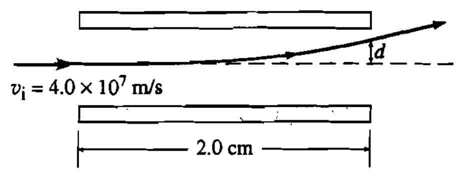
a) electron is deflected up, so Force is up

$F = qE$

since q is negative

E must point <u>down</u>





b) $E = \dfrac{Q}{\epsilon_0 A}$ $\qquad \dfrac{Q}{A} = E\epsilon_0 = (2.00 \times 10^4\ \mathrm{N/C})(8.85 \times 10^{-12}\ \tfrac{C^2}{Nm^2})$

$\dfrac{Q}{A} = 1.77 \times 10^{-7}\ \mathrm{C/m^2}$

c) Find acceleration

$F = qE = ma \qquad a = \dfrac{qE}{m} = \dfrac{(1.6 \times 10^{-19}\ \mathrm{C})(2.00 \times 10^4\ \mathrm{N/C})}{9.11 \times 10^{-31}\ \mathrm{kg}}$

$\underline{a_y = 3.5 \times 10^{15}\ \mathrm{m/s^2}}$

Find time between plates $\quad V_x = \dfrac{x}{t} \qquad t = \dfrac{x}{V_x} = \dfrac{2 \times 10^{-2}\ \mathrm{m}}{4.0 \times 10^7\ \mathrm{m/s}}$

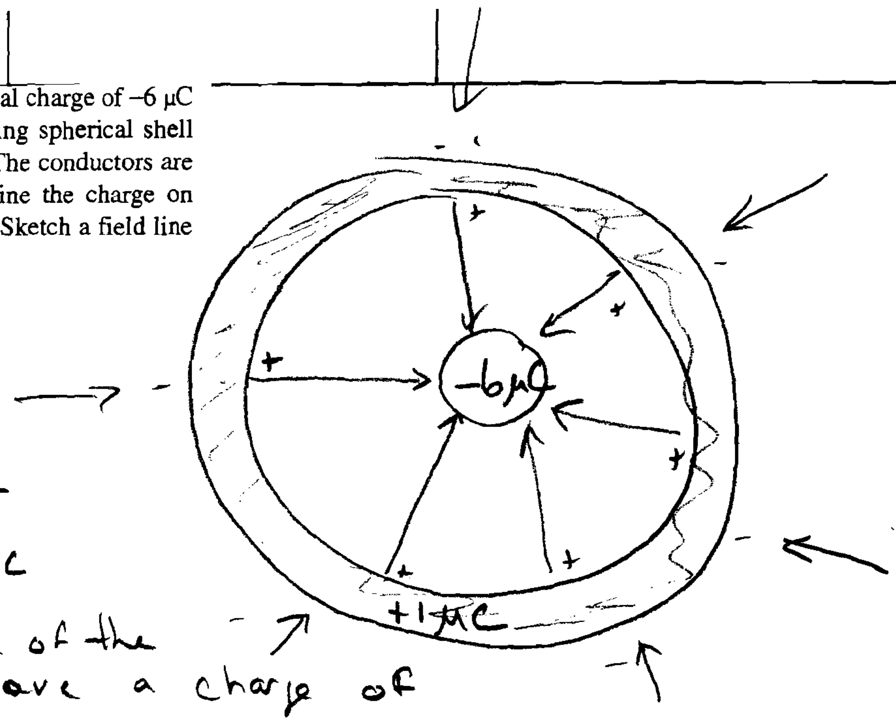
$\underline{t = 5 \times 10^{-10}\ \mathrm{s}}$

$d = y = \overset{0}{\cancel{V_{0y}}}t + \tfrac{1}{2}a_y t^2 \quad \leftarrow$ kinematics

$= \tfrac{1}{2}(3.5 \times 10^{15}\ \mathrm{m/s^2})(5 \times 10^{-10}\ \mathrm{s})^2$

$\boxed{d = 4.4 \times 10^{-4}\ \mathrm{m}}$

56. A conducting sphere that carries a total charge of $-6\ \mu C$ is placed at the center of a conducting spherical shell that carries a total charge of $+1\ \mu C$. The conductors are in electrostatic equilibrium. Determine the charge on the *outer surface* of the shell. [*Hint:* Sketch a field line diagram.]



The shell has a net charge of $+1\mu C$

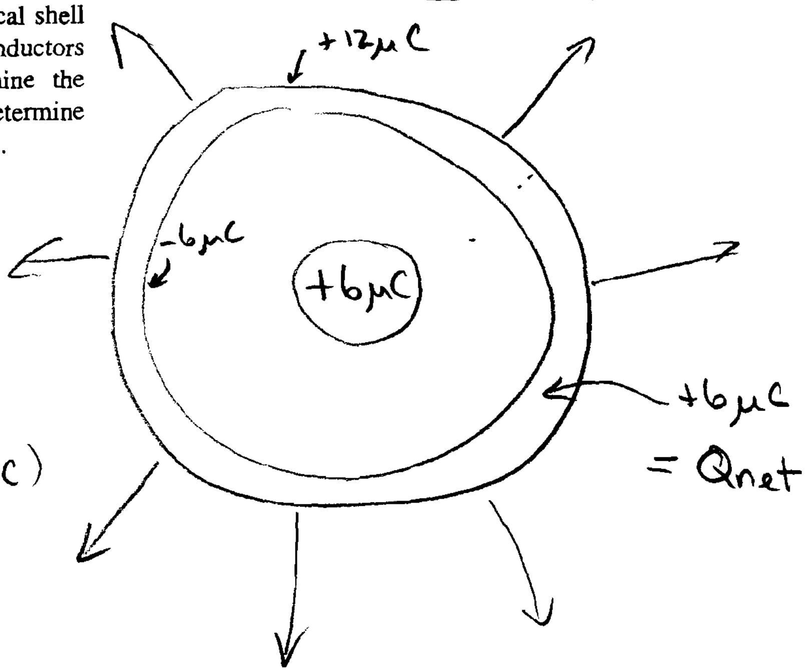
The inner surface of the shell must have a charge of $+6\ \mu C$ to balance the charged sphere inside

net Q = Q inner surface + Q outer surface

Q outer surface = net − inner

$= +1\mu C - 6\mu C = \boxed{-5\mu C}$

57. A conducting sphere that carries a total charge of $+6\ \mu C$ is placed at the center of a conducting spherical shell that also carries a total charge of $+6\ \mu C$. The conductors are in electrostatic equilibrium. (a) Determine the charge on the inner surface of the shell. (b) Determine the total charge on the outer surface of the shell.



a) $\boxed{Q_{inner} = -6\mu C}$

$Q_{outer} = Q_{net} - Q_{inner}$

$= 6\mu C - (-6\mu C)$

b) $\boxed{Q_{outer} = +12\mu C}$

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