Homework#1

3. ***REASONING***

a. Since the objects are metallic and identical, the charges on each combine and produce a net charge that is shared equally by each object. Thus, each object ends up with one-fourth of the net charge.

b. The number of electrons (or protons) that make up the final charge on each object is equal to the final charge divided by the charge of an electron (or proton).

SOLUTION

a. The net charge is the algebraic sum of the individual charges. The charge *q* on each object after contact and separation is one-fourth the net charge, or

$$q = \tfrac{1}{4}\left(1.6\ \mu\text{C} + 6.2\ \mu\text{C} - 4.8\ \mu\text{C} - 9.4\ \mu\text{C}\right) = \boxed{-1.6\ \mu\text{C}}$$

b. Since the charge on each object is negative, the charge is comprised of electrons. The number of electrons on each object is the charge *q* divided by the charge –*e* of a single electron:

$$\text{Number of electrons} = \frac{q}{-e} = \frac{-1.6\times10^{-6}\ \text{C}}{-1.60\ \times\ 10^{-19}\ \text{C}} = \boxed{1.0\times10^{13}}$$

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8. ***REASONING*** The magnitude *F* of the forces that point charges q_1 and q_2 exert on each other varies with the distance *r* separating them according to $F = k\frac{|q_1||q_2|}{r^2}$ (Equation 18.1), where $k = 8.99\times10^9\ \text{N·m}^2/\text{C}^2$. We note that both charges are given in units of microcoulombs (μC), rather than the base SI units of coulombs (C). We will replace the prefix μ with 10^{-6} when calculating the distance *r* from Equation 18.1.

SOLUTION Solving $F = k\frac{|q_1||q_2|}{r^2}$ (Equation 18.1) for the distance *r*, we obtain

$$r^2 = k\frac{|q_1||q_2|}{F} \qquad \text{or} \qquad r = \sqrt{k\frac{|q_1||q_2|}{F}}$$

Therefore, when the force magnitude *F* is 0.66 N, the distance between the charges must be

$$r = \sqrt{k\frac{|q_1||q_2|}{F}} = \sqrt{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(8.4\times10^{-6}\ \text{C}\right)\left(5.6\times10^{-6}\ \text{C}\right)}{0.66\ \text{N}}} = \boxed{0.80\ \text{m}}$$

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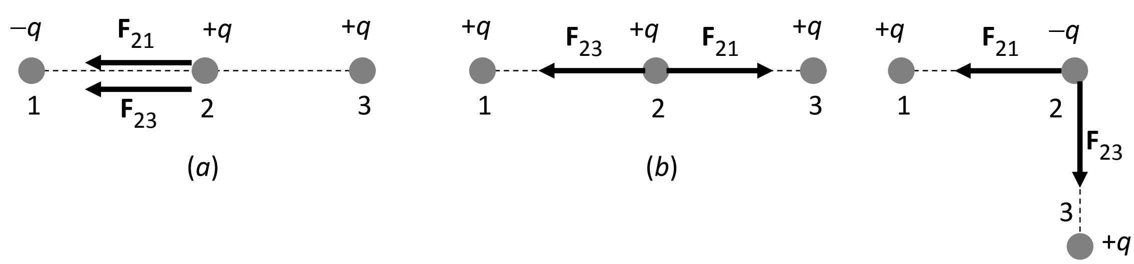
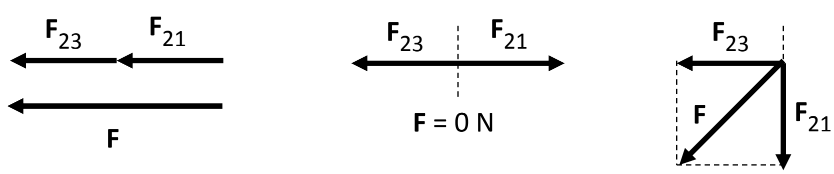
14. ***REASONING*** The electrical force that each charge exerts on charge 2 is shown in the following drawings. $\mathbf{F}_{21}$ is the force exerted on 2 by 1, and $\mathbf{F}_{23}$ is the force exerted on 2 by 3. Each force has the same magnitude, because the charges have the same magnitude and the distances are equal.



(*a*) (*b*) (*c*)

The net electric force **F** that acts on charge 2 is shown in the following diagrams.



(*a*) (*b*) (*c*)

It can be seen from the diagrams that the largest electric force occurs in (a), followed by (c), and then by (b).

SOLUTION The magnitude F_{21} of the force exerted on 2 by 1 is the same as the magnitude F_{23} of the force exerted on 2 by 3, since the magnitudes of the charges are the same and the distances are the same. Coulomb's law gives the magnitudes as

$$F_{21} = F_{23} = \frac{k|q||q|}{r^2}$$

$$= \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(8.6\times10^{-6}\ \text{C}\right)\left(8.6\times10^{-6}\ \text{C}\right)}{\left(3.8\times10^{-3}\ \text{m}\right)^2} = 4.6\times10^{4}\ \text{N}$$

In part (a) of the drawing showing the net electric force acting on charge 2, both $\mathbf{F}_{21}$ and $\mathbf{F}_{23}$ point to the left, so the net force has a magnitude of

$$F = 2F_{12} = 2\left(4.6\times10^{4}\ \text{N}\right) = \boxed{9.2\times10^{4}\ \text{N}}$$

In part (b) of the drawing showing the net electric force acting on charge 2, $\mathbf{F}_{21}$ and $\mathbf{F}_{23}$ point in opposite directions, so the net force has a magnitude of $\boxed{0\ \text{N}}$.

In part (c) showing the net electric force acting on charge 2, the magnitude of the net force can be obtained from the Pythagorean theorem:

$$F = \sqrt{F_{21}^2 + F_{23}^2} = \sqrt{\left(4.6\times10^{4}\ \text{N}\right)^2 + \left(4.6\times10^{4}\ \text{N}\right)^2} = \boxed{6.5\times10^{4}\ \text{N}}$$

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16. REASONING AND SOLUTION The electrostatic forces decreases with the square of the distance separating the charges. If this distance is increased by a factor of 5 then the force will decrease by a factor of 25. The new force is, then,

$$F = \frac{3.5\ \text{N}}{25} = \boxed{0.14\ \text{N}}$$

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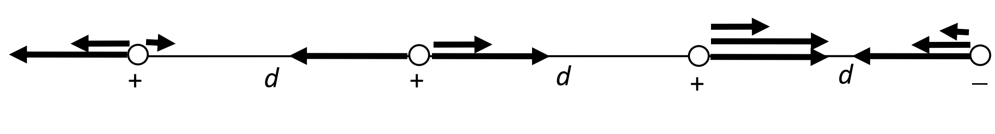
22. ***REASONING*** We will use Coulomb's law to calculate the force that any one charge exerts on another charge. Note that in such calculations there are three separations to consider. Some of the charges are a distance *d* apart, some a distance 2*d*, and some a distance 3*d*. The greater the distance, the smaller the force. The net force acting on any one charge is the vector sum of three forces. In the following drawing we represent each of those forces by an arrow. These arrows are not drawn to scale and are meant only to "symbolize" the three different force magnitudes that result from the three different distances used in Coulomb's law. In the drawing the directions are determined by the facts that like charges repel and unlike charges attract. By examining the drawing we will be able to identify the greatest and the smallest net force.



The greatest net force occurs for charge C, because all three force contributions point in the same direction and two of the three have the greatest magnitude, while the third has the next greatest magnitude. The smallest net force occurs for charge B, because two of the three force contributions cancel.

SOLUTION Using Coulomb's law for each contribution to the net force, we calculate the ratio of the greatest to the smallest net force as follows:

$$\frac{(\Sigma F)_{\rm C}}{(\Sigma F)_{\rm B}}=\frac{k\dfrac{|q|^2}{d^2}+k\dfrac{|q|^2}{d^2}+k\dfrac{|q|^2}{(2d)^2}}{k\dfrac{|q|^2}{d^2}-k\dfrac{|q|^2}{d^2}+k\dfrac{|q|^2}{(2d)^2}}=\frac{1+1+\frac{1}{4}}{\frac{1}{4}}=\boxed{9.0}$$

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30. ***REASONING***

a. The magnitude of the electric field is obtained by dividing the magnitude of the force (obtained from the meter) by the magnitude of the charge. Since the charge is positive, the direction of the electric field is the same as the direction of the force.

b. As in part (a), the magnitude of the electric field is obtained by dividing the magnitude of the force by the magnitude of the charge. Since the charge is negative, however, the direction of the force (as indicated by the meter) is opposite to the direction of the electric field. Thus, the direction of the electric field is opposite to that of the force.

SOLUTION

a. According to Equation 18.2, the magnitude of the electric field is

$$E=\frac{F}{|q|}=\frac{40.0\ \mu\text{N}}{20.0\ \mu\text{C}}=\boxed{2.0\ \text{N/C}}$$

As mentioned in the ***REASONING***, the direction of the electric field is the same as the direction of the force, or $\boxed{\text{due east}}$.

b. The magnitude of the electric field is

$$E = \frac{F}{|q|} = \frac{20.0\ \mu\text{N}}{10.0\ \mu\text{C}} = \boxed{2.0\ \text{N/C}}$$

Since the charge is negative, the direction of the electric field is opposite to the direction of the force, or $\boxed{\text{due east}}$. Thus, the electric fields in parts (a) and (b) are the same.

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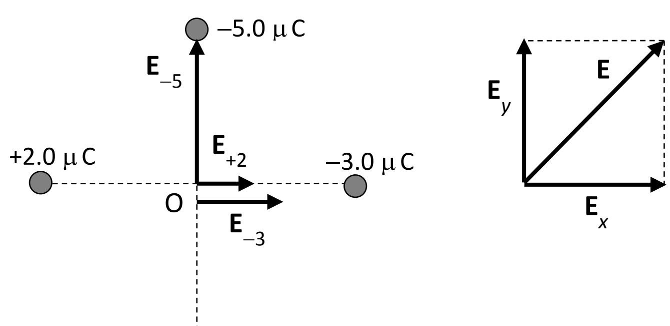
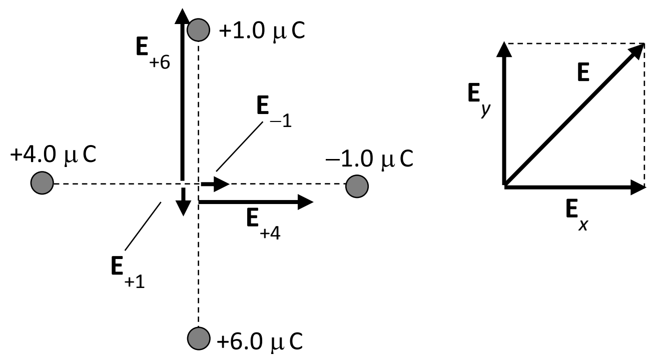
34. ***REASONING***

Part (*a*) of the drawing given in the text. The electric field produced by a charge points away from a positive charge and toward a negative charge. Therefore, the electric field $\mathbf{E}_{+2}$ produced by the +2.0 μC charge points away from it, and the electric fields $\mathbf{E}_{-3}$ and $\mathbf{E}_{-5}$ produced by the –3.0 μC and –5.0 μC charges point toward them (see the left-hand side of the following drawing). The magnitude of the electric field produced by a point charge is given by Equation 18.3 as $E = k|q|/r^2$. Since the distance from each charge to the origin is the same, the magnitude of the electric field is proportional only to the magnitude $|q|$ of the charge. Thus, the *x* component $\mathbf{E}_x$ of the net electric field is proportional to 5.0 μC (2.0 μC + 3.0 μC). Since only one of the charges produces an electric field in the *y* direction, the *y* component $\mathbf{E}_y$ of the net electric field is proportional to the magnitude of this charge, or 5.0 μC. Thus, the *x* and *y* components are equal, as indicated at the right-hand side of the following drawing, where the net electric field **E** is also shown.



Part (*b*) of the drawing given in the text. Using the same arguments as earlier, we find that the electric fields produced by the four charges are shown at the left-hand side of the following drawing.

These fields also produce the same net electric field **E** as before, as indicated at the right-hand side of the following drawing.



SOLUTION

Part (*a*) of the drawing given in the text. The net electric field in the *x* direction is

$$E_x = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(2.0\times10^{-6}\ \text{C}\right)}{\left(0.061\,\text{m}\right)^2} + \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(3.0\times10^{-6}\ \text{C}\right)}{\left(0.061\,\text{m}\right)^2}$$

$$= 1.2\times10^{7}\ \text{N/C}$$

The net electric field in the *y* direction is

$$E_y = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(5.0\times10^{-6}\ \text{C}\right)}{\left(0.061\,\text{m}\right)^2} = 1.2\times10^{7}\ \text{N/C}$$

The magnitude of the net electric field is

$$E = \sqrt{E_x^2 + E_y^2} = \sqrt{\left(1.2\times10^{7}\ \text{N/C}\right)^2 + \left(1.2\times10^{7}\ \text{N/C}\right)^2} = \boxed{1.7\times10^{7}\ \text{N/C}}$$

Part (*b*) of the drawing given in the text. The magnitude of the net electric field is the same as determined for part (a); *E* = $\boxed{1.7\times10^{7}\ \text{N/C}}$.
