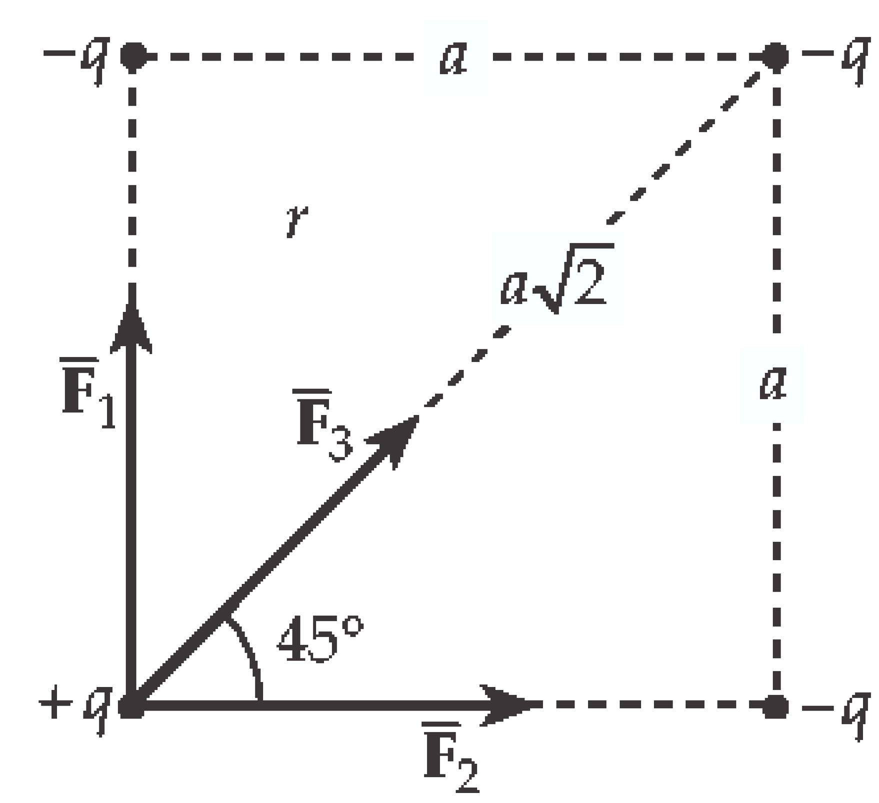
15.1 Since the charges have opposite signs, the force is one of $\boxed{\text{attraction}}$.

Its magnitude is

$$F = \frac{k_e |q_1 q_2|}{r^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{\left(4.5\times10^{-9}\ \text{C}\right)\left(2.8\times10^{-9}\ \text{C}\right)}{(3.2\ \text{m})^2} = \boxed{1.1\times10^{-8}\ \text{N}}$$

15.4 The attractive forces exerted on the positive charge by the negative charges are shown in the sketch and have magnitudes



$$F_1 = F_2 = \frac{k_e q^2}{a^2} \quad \text{and} \quad F_3 = \frac{k_e q^2}{\left(a\sqrt{2}\right)^2} = \frac{k_e q^2}{2a^2}$$

$$\Sigma F_x = F_2 + F_3 \cos 45° = \frac{k_e q^2}{a^2} + \frac{k_e q^2}{2a^2}(0.707) = 1.35\left(\frac{k_e q^2}{a^2}\right)$$

and $$\Sigma F_y = F_1 + F_3 \sin 45° = \frac{k_e q^2}{a^2} + \frac{k_e q^2}{2a^2}(0.707) = 1.35\left(\frac{k_e q^2}{a^2}\right)$$

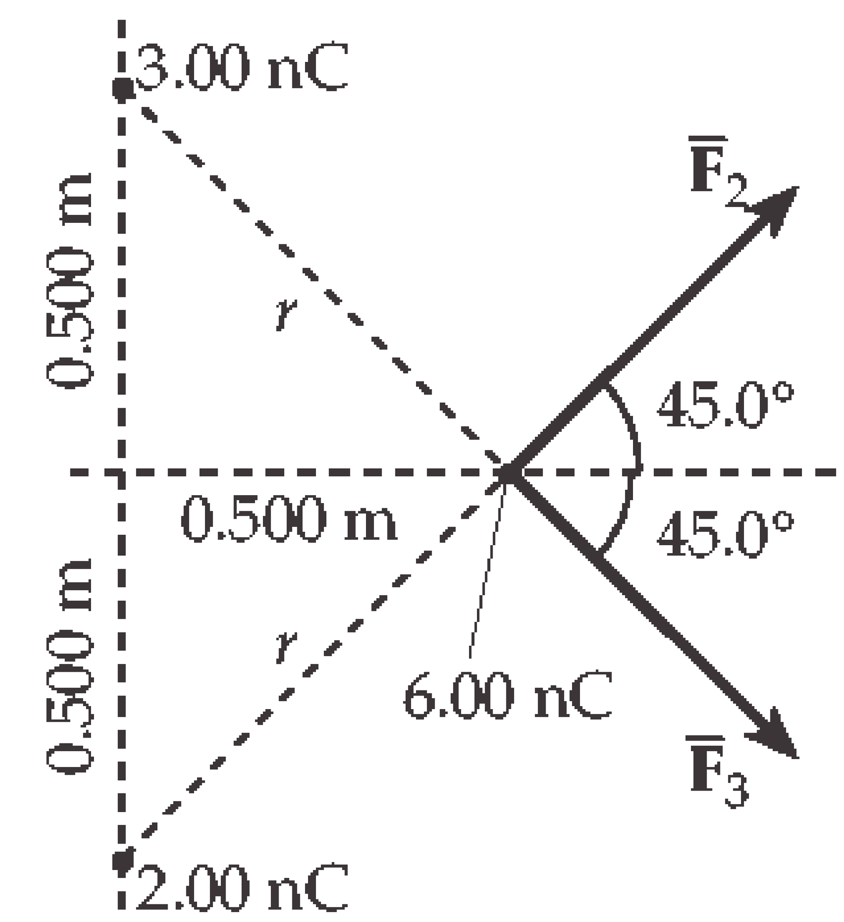
$$F_R = \sqrt{\left(\Sigma F_x\right)^2 + \left(\Sigma F_y\right)^2} = 1.91\frac{k_e q^2}{a^2} \quad \text{and} \quad \theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) = \tan^{-1}(1) = 45°$$

so $$\boxed{\vec{\mathbf{F}}_R = 1.91\left(\frac{k_e q^2}{a^2}\right) \text{ along the diagonal toward the negative charge}}$$

15.8 The magnitude of the repulsive force between electrons must equal the weight of an electron, Thus, $k_e e^2/r^2 = m_e g$

or $$r = \sqrt{\frac{k_e e^2}{m_e g}} = \sqrt{\frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.60\times10^{-19}\ \text{C}\right)^2}{\left(9.11\times10^{-31}\ \text{kg}\right)\left(9.80\ \text{m/s}^2\right)}} = \boxed{5.08\ \text{m}}$$

15.12 Consider the arrangement of charges shown in the sketch at the right. The distance r is



$$r = \sqrt{(0.500\ \text{m})^2 + (0.500\ \text{m})^2} = 0.707\ \text{m}$$

The forces exerted on the 6.00 nC charge are

$$F_2 = \left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(6.00\times10^{-9}\ \text{C})(2.00\times10^{-9}\ \text{C})}{(0.707\ \text{m})^2}$$

$$= 2.16 \times 10^{-7}\ \text{N}$$

and $$F_3 = \left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(6.00\times10^{-9}\ \text{C})(3.00\times10^{-9}\ \text{C})}{(0.707\ \text{m})^2} = 3.24 \times 10^{-7}\ \text{N}$$

15.14 Assume that the third bead has charge Q and is located at $0 < x < d$. Then the forces exerted on it by the $+3q$ charge and by the $+1q$ charge have magnitudes

$$F_3 = \frac{k_e Q(3q)}{x^2} \text{ and } F_1 = \frac{k_e Q(q)}{(d-x)^2} \text{ respectively}$$

These forces are in opposite directions, so charge Q is in equilibrium if $F_3 = F_1$. This gives $3(d-x)^2 = x^2$, and solving for x, the equilibrium position is seen to be

$$x = \frac{d}{1 + 1/\sqrt{3}} = \boxed{0.634d}$$

This is a position of $\boxed{\text{stable equilibrium if } Q > 0}$. In that case, a small displacement from the equilibrium position produces a net force directed so as to move Q back toward the equilibrium position.

15.17 For the object to "float" it is necessary that the electrical force support the weight, or

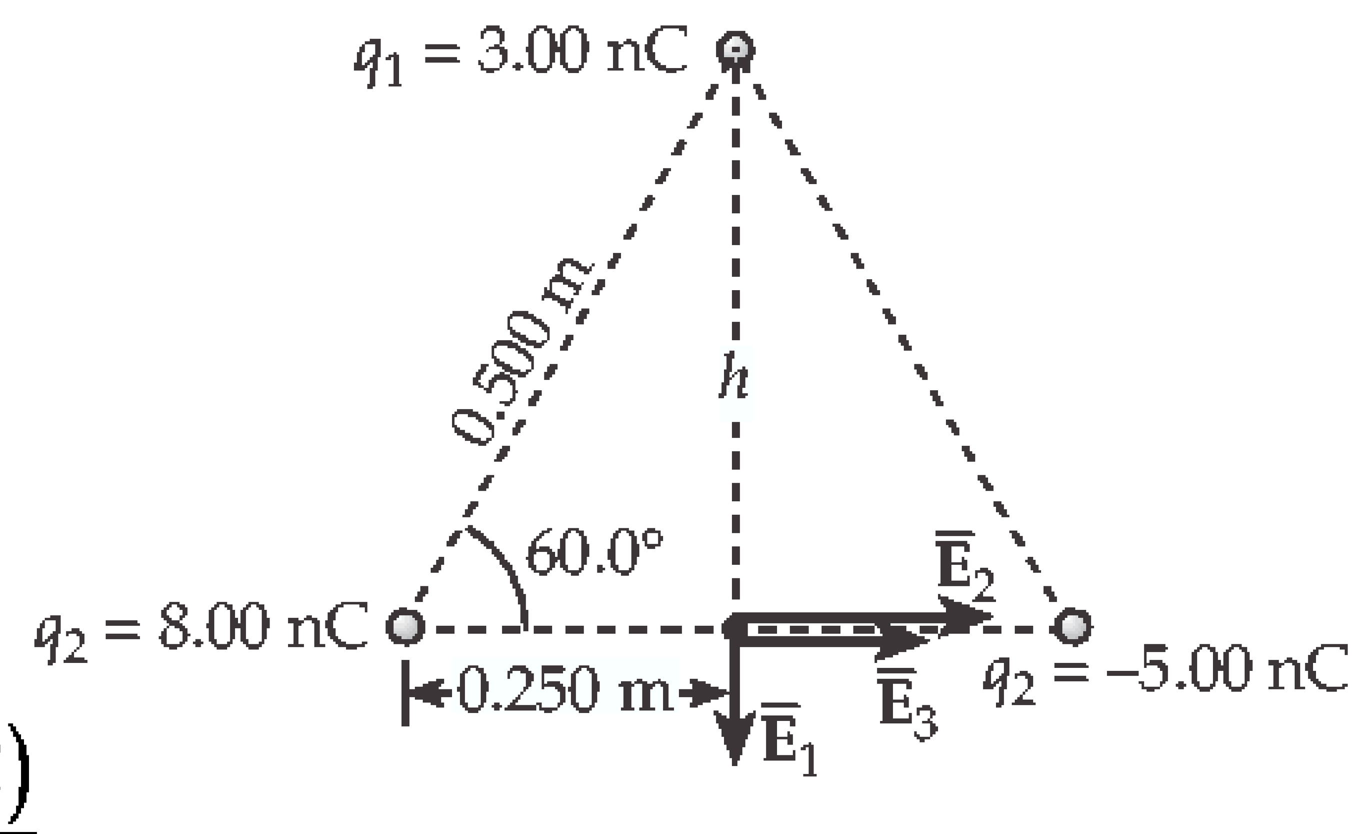
$$qE = mg \quad \text{or} \quad m = \frac{qE}{g} = \frac{(24\times10^{-6}\ \text{C})(610\ \text{N/C})}{9.8\ \text{m/s}^2} = \boxed{1.5\times10^{-3}\ \text{kg}}$$

15.22 The force an electric field exerts on a positive change is in the direction of the field. Since this force must serve as a retarding force and bring the proton to rest, the force and hence the field must be $\boxed{\text{in the direction opposite to the proton's velocity}}$.

The work-energy theorem, $W_{net} = KE_f - KE_i$, gives the magnitude of the field as

$$-(qE)\Delta x = 0 - KE_i \quad \text{or} \quad E = \frac{KE_i}{q(\Delta x)} = \frac{3.25\times10^{-15}\ \text{J}}{(1.60\times10^{-19}\ \text{C})(1.25\ \text{m})} = \boxed{1.63\times10^{4}\ \text{N/C}}$$

15.24 The altitude of the triangle is



$$h = (0.500\ \text{m})\sin 60.0° = 0.433\ \text{m}$$

and the magnitudes of the fields due to each of the charges are

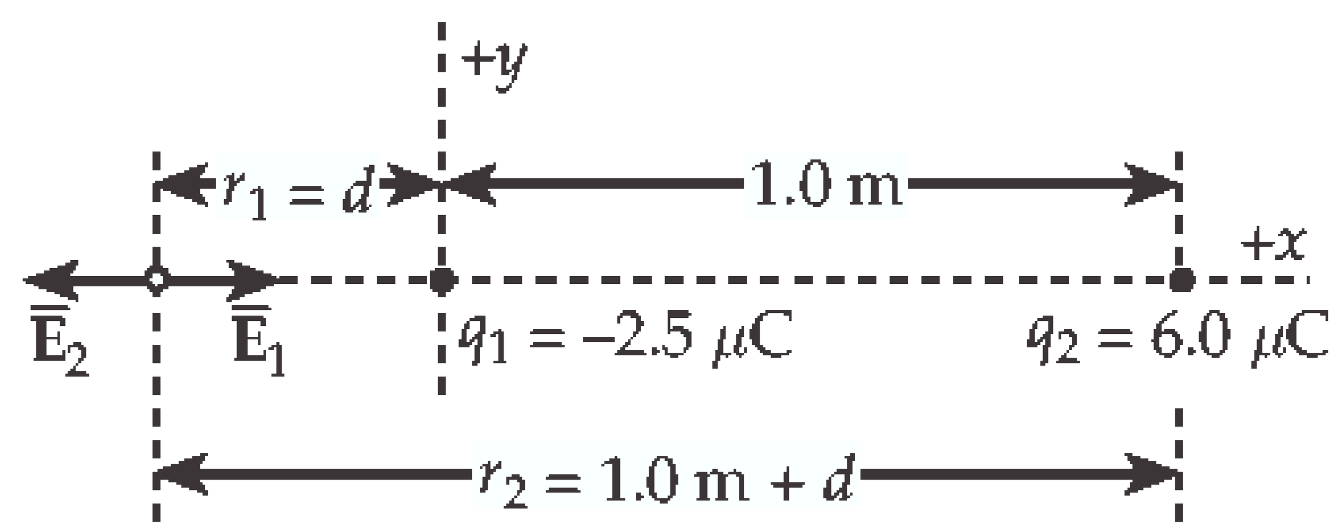
$$E_1 = \frac{k_e q_1}{h^2} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(3.00\times10^{-9}\ \text{C})}{(0.433\ \text{m})^2}$$

$$= 144\ \text{N/C}$$

$$E_2 = \frac{k_e q_2}{r_2^2} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(8.00\times10^{-9}\ \text{C})}{(0.250\ \text{m})^2} = 1.15\times10^3\ \text{N/C}$$

and $$E_3 = \frac{k_e |q_3|}{r_3^2} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(5.00\times10^{-9}\ \text{C})}{(0.250\ \text{m})^2} = 719\ \text{N/C}$$

15.27 If the resultant field is zero, the contributions from the two charges must be in opposite directions and also have equal magnitudes. Choose the line connecting the charges as the x-axis, with the origin at the $-2.5\ \mu$C charge. Then, the two contributions will have opposite directions only in the regions $x < 0$ and $x > 1.0\ \text{m}$. For the magnitudes to be equal, the point must be nearer the smaller charge. Thus, the point of zero resultant field is on the x-axis at $x < 0$.



Requiring equal magnitudes gives $\frac{k_e|q_1|}{r_1^2} = \frac{k_e|q_2|}{r_2^2}$ or $\frac{2.5\ \mu\text{C}}{d^2} = \frac{6.0\ \mu\text{C}}{(1.0\ \text{m} + d)^2}$

Thus, $(1.0\ \text{m} + d)\sqrt{\frac{2.5}{6.0}} = d$

Solving for d yields

$d = 1.8\ \text{m}$, or $\boxed{1.8\ \text{m to the left of the } -2.5\ \mu\text{C charge}}$

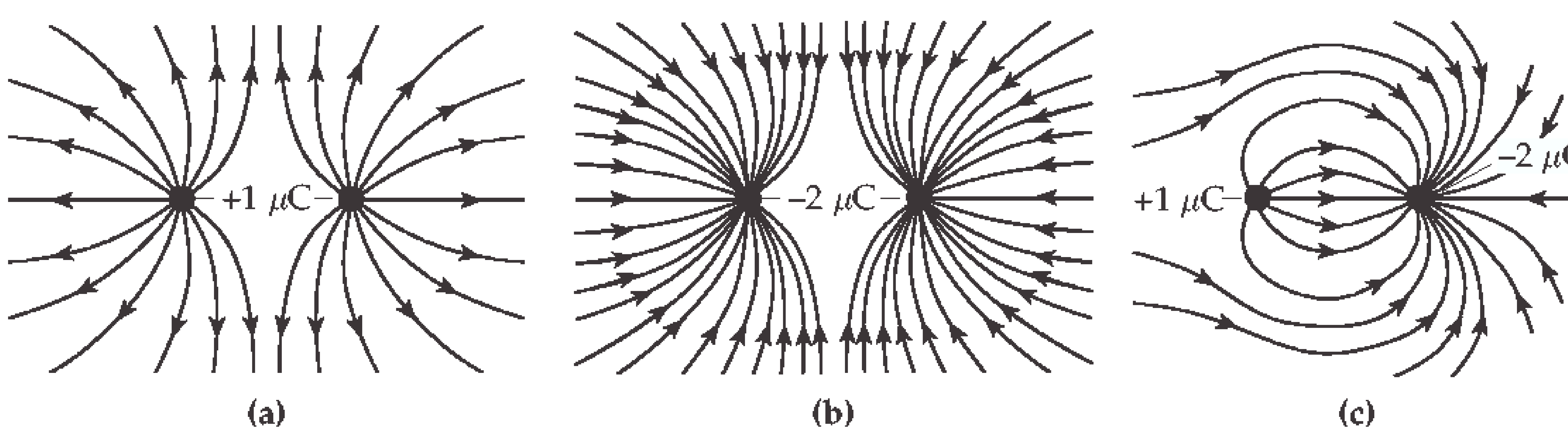
15.28 The magnitude of q_2 is three times the magnitude of q_1 because 3 times as many lines emerge from q_2 as enter q_1. $|q_2| = 3|q_1|$

(a) Then, $\boxed{q_1/q_2 = -1/3}$

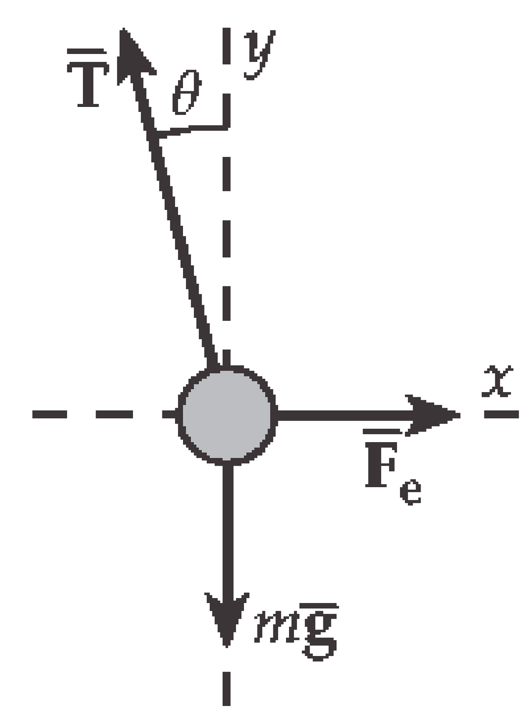
(b) $\boxed{q_2 > 0}$ because lines emerge from it,

and $\boxed{q_1 < 0}$ because lines terminate on it.

15.30 Rough sketches for these charge configurations are shown below.



15.50 Consider the free-body diagram shown at the right.



$$\Sigma F_y = 0 \Rightarrow T\cos\theta = mg \quad \text{or} \quad T = \frac{mg}{\cos\theta}$$

$$\Sigma F_x = 0 \Rightarrow F_e = T\sin\theta = mg\tan\theta$$

Since $F_e = qE$, we have

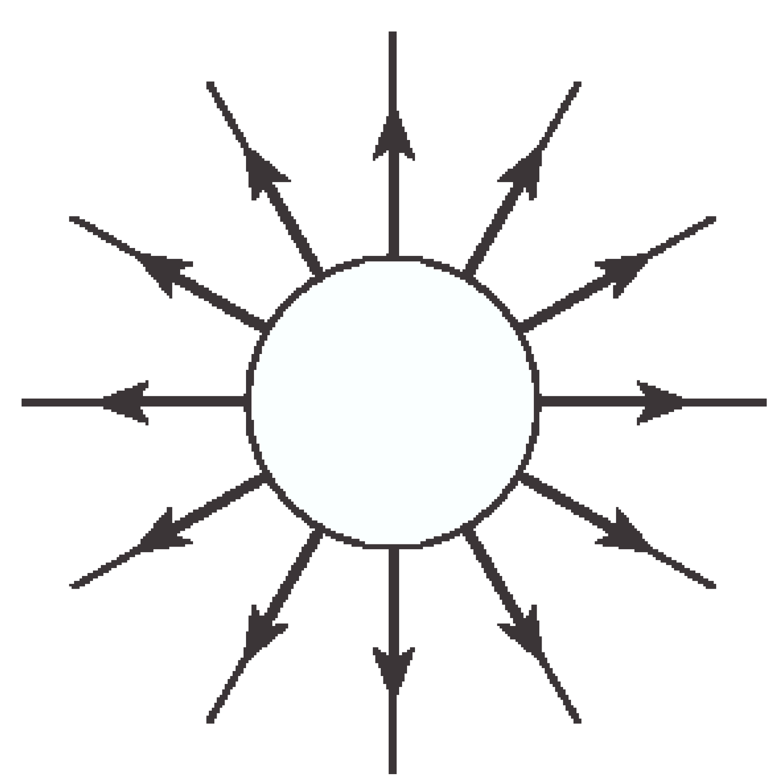
$$qE = mg\tan\theta, \text{ or } q = \frac{mg\tan\theta}{E}$$

$$q = \frac{\left(2.00\times10^{-3}\text{ kg}\right)\left(9.80\text{ m/s}^2\right)\tan 15.0^\circ}{1.00\times10^3\text{ N/C}} = 5.25\times10^{-6}\text{ C} = \boxed{5.25\ \mu\text{C}}$$

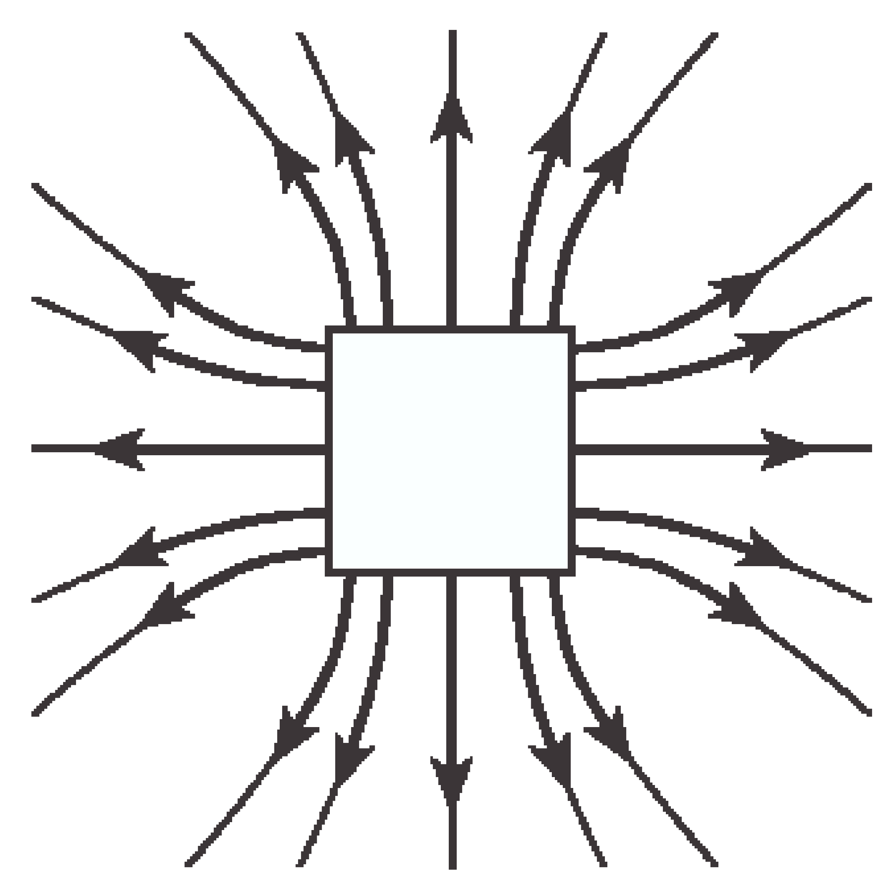
15.9 (a) The spherically symmetric charge distributions behave as if all charge was located at the centers of the spheres. Therefore, the magnitude of the $\boxed{\text{attractive}}$ force is

$$F = \frac{k_e q_1 |q_2|}{r^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{\left(12\times10^{-9}\text{ C}\right)\left(18\times10^{-9}\text{ C}\right)}{(0.30\text{ m})^2} = \boxed{2.2\times10^{-5}\text{ N}}$$

15.32 (a) In the sketch for (a) at the right, note that there are no lines inside the sphere. On the outside of the sphere, the field lines are uniformly spaced and radially outward.



(a)



(b)

(b) In the sketch for (b) above, note that the lines are perpendicular to the surface at the points where they emerge. They should also be symmetrical about the symmetry axes of the cube. The field is zero inside the cube.

15.33 (a) $\boxed{\text{Zero}}$ net charge on each surface of the sphere.

(b) The negative charge lowered into the sphere repels $\boxed{-5\ \mu\text{C to the outside}}$ surface, and leaves $\boxed{+5\ \mu\text{C on the inside}}$ surface of the sphere.

(c) The negative charge lowered inside the sphere neutralizes the inner surface, leaving $\boxed{\text{zero charge on the inside}}$. This leaves $\boxed{-5\mu\text{C on the outside}}$ surface of the sphere.

(d) When the object is removed, the sphere is left with $\boxed{-5.00\ \mu\text{C on the outside}}$ surface and $\boxed{\text{zero charge on the inside}}$.

15.54 The charges on the spheres will be equal in magnitude and opposite in sign. From $F = k_e q^2/r^2$, this charge must be

$$q = \sqrt{\frac{F \cdot r^2}{k_e}} = \sqrt{\frac{\left(1.00\times10^4\ \text{N}\right)\left(1.00\ \text{m}\right)^2}{8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2}} = 1.05\times10^{-3}\ \text{C}$$

The number of electrons transferred is

$$n = \frac{q}{e} = \frac{1.05\times10^{-3}\ \text{C}}{1.60\times10^{-19}\ \text{C}} = 6.59\times10^{15}$$

The total number of electrons in 100-g of silver is

$$N = \left(47\ \frac{\text{electrons}}{\text{atom}}\right)\left(6.02\times10^{23}\ \frac{\text{atoms}}{\text{mole}}\right)\left(\frac{1\ \text{mole}}{107.87\ \text{g}}\right)\left(100\ \text{g}\right) = 2.62\times10^{25}$$

Thus, the fraction transferred is

$$\frac{n}{N} = \frac{6.59\times10^{15}}{2.62\times10^{25}} = \boxed{2.51\times10^{-10}}\ \text{(that is, 2.51 out of every 10 billion).}$$