Chapter 15

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. To balance the weight of the ball, the magnitude of the upward electric force must equal the magnitude of the downward gravitation force, or $qE = mg$, which gives

$$E = \frac{mg}{q} = \frac{(5.0\times 10^{-3}\ \text{kg})(9.80\ \text{m/s}^2)}{4.0\times 10^{-6}\ \text{C}} = 1.2\times 10^4\ \text{N/C}$$

and the correct choice is (b).

2. The magnitude of the electric field at distance r from a point charge q is $E = k_e q/r^2$, so

$$E = \frac{(8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.60\times 10^{-19}\ \text{C})}{(5.29\times 10^{-11}\ \text{m})^2} = 5.14\times 10^{11}\ \text{N/C} \sim 10^{12}\ \text{N/C}$$

making (e) the best choice for this question.

3. The magnitude of the electric force between two protons separated by distance r is $F = k_e e^2/r^2$, so the distance of separation must be

$$r = \sqrt{\frac{k_e e^2}{F}} = \sqrt{\frac{(8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.60\times 10^{-19}\ \text{C})^2}{2.3\times 10^{-26}\ \text{N}}} = 0.10\ \text{m}$$

and (a) is the correct choice.

7. The displacement from the -4.00 nC charge at point $(0,\ 1.00)$ m to the point $(4.00,\ -2.00)$ m has components $r_x = (x_f - x_i) = +4.00$ m and $r_y = (y_f - y_i) = -3.00$ m, so the magnitude of this displacement is $r = \sqrt{r_x^2 + r_y^2} = 5.00$ m and its direction is $\theta = \tan^{-1}(r_y/r_x) = -36.9°$. The x-component of the electric field at point $(4.00,\ -2.00)$ m is then

$$E_x = E\cos\theta = \frac{k_e q}{r^2}\cos\theta = \frac{(8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-4.00\times 10^{-9}\ \text{C})}{(5.00\ \text{m})^2}\cos(-36.9°) = -1.15\ \text{N/C}$$

and the correct response is (d).

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2. Electrons are more mobile than protons and are more easily freed from atoms than the protons which are tightly bound within the nuclei of the atoms.

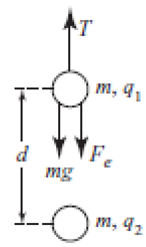
8. (a) Yes. The positive charges create electric fields that extend in all directions from those charges. The total field at point A is the vector sum of the individual fields produced by the charges at that point.

(b) No, because there are no field lines emanating from or converging on point A.

(c) No. There must be a charged object present to experience a force.

PROBLEM SOLUTIONS

15.4 (a) The gravitational force exerted on the upper sphere by the lower one is negligible in comparison to the gravitational force exerted by the Earth and the downward electrical force exerted by the lower sphere. Therefore,



$$\Sigma F_y = 0 \Rightarrow T - mg - F_e = 0$$

or $T = mg + \dfrac{k_e|q_1||q_2|}{d^2}$

$$T = \left(7.50\times10^{-3}\ \text{kg}\right)\left(9.80\ \frac{\text{m}}{\text{s}^2}\right) + \frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(32.0\times10^{-9}\ \text{C}\right)\left(58.0\times10^{-9}\ \text{C}\right)}{\left(2.00\times10^{-2}\ \text{m}\right)^2}$$

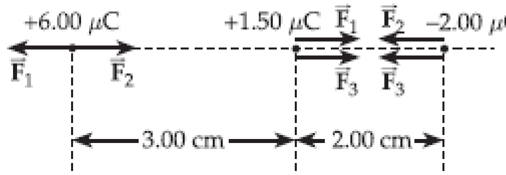
giving $T = \boxed{0.115\ \text{N}}$

15.5 (a) $F = \frac{k_e(2e)^2}{r^2} = \frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left[4\left(1.60\times10^{-19}\ \text{C}\right)^2\right]}{\left(5.00\times10^{-15}\ \text{m}\right)^2} = \boxed{36.8\ \text{N}}$

(b) The mass of an alpha particle is $m = 4.002\,6$ u, where 1 u $= 1.66\times10^{-27}$ kg is the unified mass unit. The acceleration of either alpha particle is then

$$a = \frac{F}{m} = \frac{36.8\ \text{N}}{4.002\,6\left(1.66\times10^{-27}\ \text{kg}\right)} = \boxed{5.54\times10^{27}\ \text{m/s}^2}$$

15.10 The forces are as shown in the sketch below.



$$F_1 = \frac{k_e q_1 q_2}{r_{12}^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{\left(6.00\times10^{-6}\ \text{C}\right)\left(1.50\times10^{-6}\ \text{C}\right)}{\left(3.00\times10^{-2}\ \text{m}\right)^2} = 89.9\ \text{N}$$

$$F_2 = \frac{k_e q_1 |q_3|}{r_{13}^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{\left(6.00\times10^{-6}\ \text{C}\right)\left(2.00\times10^{-6}\ \text{C}\right)}{\left(5.00\times10^{-2}\ \text{m}\right)^2} = 43.2\ \text{N}$$

$$F_3 = \frac{k_e q_2 |q_3|}{r_{23}^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{\left(1.50\times10^{-6}\ \text{C}\right)\left(2.00\times10^{-6}\ \text{C}\right)}{\left(2.00\times10^{-2}\ \text{m}\right)^2} = 67.4\ \text{N}$$

The net force on the 6 μC charge is $F_{6\mu C} = F_1 - F_2 = \boxed{46.7\ \text{N to the left}}$.

The net force on the 1.5 μC charge is $F_{1.5\mu C} = F_1 + F_3 = \boxed{157\ \text{N to the right}}$.

The net force on the -2 μC charge is $F_{-2\mu C} = F_2 + F_3 = \boxed{111\ \text{N to the left}}$.

15.19 The force on a negative charge is opposite to the direction of the electric field and has magnitude $F = |q|E$. Thus,

$$F = \left|-6.00\times10^{-6}\ \text{C}\right|\left(5.25\times10^{5}\ \text{N/C}\right) = 3.15\ \text{N}$$

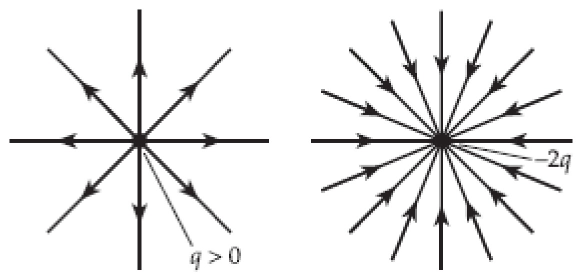
and $\vec{\mathbf{F}} = \boxed{3.15\ \text{N due north}}$

15.30 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.

15.31 Note in the sketches at the right that electric field lines originate on positive charges and terminate on negative charges. The density of lines is twice as great for the $-2q$ charge in (b) as it is for the $1q$ charge in (a).



(a) (b)