Homework week 1

3. ***REASONING*** The law of conservation of electric charges states that the net electric charge of an isolated system remains constant. Initially the plate-rod system has a net charge of –3.0 μC + 2.0 μC = –1.0 μC. After the transfer this charge is shared equally by both objects, so that each carries a charge of –0.50 μC. Therefore, 2.5 μC of negative charge must be transferred from the plate to the rod. To determine how many electrons this is, we will divide this charge magnitude by the magnitude of the charge on a single electron.

   SOLUTION The magnitude of the charge on an electron is *e*, so that the number *N* of electrons transferred is

$$N = \frac{\text{Magnitude of transferred charge}}{e} = \frac{2.5\times10^{-6}\ \text{C}}{1.60\times10^{-19}\ \text{C}} = \boxed{1.6\times10^{13}}$$

5. **SSM** ***REASONING*** Identical conducting spheres equalize their charge upon touching. When spheres A and B touch, an amount of charge +*q*, flows from A and instantaneously neutralizes the –*q* charge on B leaving B momentarily neutral. Then, the remaining amount of charge, equal to +4*q*, is equally split between A and B, leaving A and B each with equal amounts of charge +2*q*. Sphere C is initially neutral, so when A and C touch, the +2*q* on A splits equally to give +*q* on A and +*q* on C. When B and C touch, the +2*q* on B and the +*q* on C combine to give a total charge of +3*q*, which is then equally divided between the spheres B and C; thus, B and C are each left with an amount of charge +1.5*q*.

SOLUTION Taking note of the initial values given in the problem statement, and summarizing the final results determined in the *Reasoning* above, we conclude the following:

a. Sphere C ends up with an amount of charge equal to $\boxed{+1.5q}$.

b. The charges on the three spheres before they were touched, are, according to the problem statement, +5*q* on sphere A, –*q* on sphere B, and zero charge on sphere C. Thus, the total charge on the spheres is $+5q - q + 0 = \boxed{+4q}$.

c. The charges on the spheres after they are touched are +*q* on sphere A, +1.5*q* on sphere B, and +1.5*q* on sphere C. Thus, the total charge on the spheres is $+q + 1.5q + 1.5q = \boxed{+4q}$.

10. ***REASONING*** The magnitude of the electrostatic force that acts on particle 1 is given by Coulomb's law as $F = k|q_1||q_2|/r^2$. This equation can be used to find the magnitude $|q_2|$ of the charge.

SOLUTION Solving Coulomb's law for the magnitude $|q_2|$ of the charge gives

$$|q_2| = \frac{F\,r^2}{k|q_1|} = \frac{(3.4\text{ N})(0.26\text{ m})^2}{\left(9.0\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(3.5\times10^{-6}\text{ C}\right)} = \boxed{7.3\times10^{-6}\text{ C}} \tag{18.1}$$

Since q_1 is positive and experiences an attractive force, the charge q_2 must be $\boxed{\text{negative}}$.

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11. **SSM** ***REASONING AND SOLUTION***

a. Since the gravitational force between the spheres is one of attraction and the electrostatic force must balance it, the electric force must be one of repulsion. Therefore, the charges must have

$\boxed{\text{the same algebraic signs, both positive or both negative}}$.

b. There are two forces that act on each sphere; they are the gravitational attraction F_G of one sphere for the other, and the repulsive electric force F_E of one sphere on the other. From the problem statement, we know that these two forces balance each other, so that $F_G = F_E$. The magnitude of F_G is given by Newton's law of gravitation (Equation 4.3: $F_G = Gm_1m_2/r^2$), while the magnitude of F_E is given by Coulomb's law (Equation 18.1: $F_E = k|q_1||q_2|/r^2$). Therefore, we have

$$\frac{Gm_1m_2}{r^2} = \frac{k|q_1||q_2|}{r^2} \quad \text{or} \quad Gm^2 = k|q|^2$$

since the spheres have the same mass m and carry charges of the same magnitude $|q|$. Solving for $|q|$, we find

$$|q| = m\sqrt{\frac{G}{k}} = (2.0\ \times10^{-6}\text{ kg})\sqrt{\frac{6.67\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2}{8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2}} = \boxed{1.7\times10^{-16}\text{ C}}$$

13. **SSM** **WWW** ***REASONING*** Each particle will experience an electrostatic force due to the presence of the other charge. According to Coulomb's law (Equation 18.1), the magnitude of the force felt by each particle can be calculated from

$F = k|q_1||q_2|/r^2$, where $|q_1|$ and $|q_2|$ are the respective charges on particles 1 and 2 and r is the distance between them. According to Newton's second law, the magnitude of the force experienced by each particle is given by $F = ma$, where a is the acceleration of the particle and we have assumed that the electrostatic force is the only force acting.

SOLUTION

a. Since the two particles have identical positive charges, $|q_1| = |q_2| = |q|$, and we have, using the data for particle 1,

$$\frac{k|q|^2}{r^2} = m_1 a_1$$

Solving for $|q|$, we find that

$$|q| = \sqrt{\frac{m_1 a_1 r^2}{k}} = \sqrt{\frac{(6.00\times10^{-6}\ \text{kg})\ (4.60\times10^{3}\ \text{m/s}^2)\ (2.60\times10^{-2}\ \text{m})^2}{8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2}} = \boxed{4.56\times10^{-8}\ \text{C}}$$

b. Since each particle experiences a force of the same magnitude (From Newton's third law), we can write $F_1 = F_2$, or $m_1a_1 = m_2a_2$. Solving this expression for the mass m_2 of particle 2, we have

$$m_2 = \frac{m_1 a_1}{a_2} = \frac{(6.00\times10^{-6}\ \text{kg})(4.60\times10^{3}\ \text{m/s}^2)}{8.50\times10^{3}\ \text{m/s}^2} = \boxed{3.25\times10^{-6}\ \text{kg}}$$