SAMPLE PROBLEM A

Coulomb's Law

PROBLEM

The electron and proton of a hydrogen atom are separated, on average, by a distance of about 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force that each particle exerts on the other.

SOLUTION

1. DEFINE

Given: $r = 5.3 \times 10^{-11}$ m, $q_e = -1.60 \times 10^{-19}$ C, $k_C = 8.99 \times 10^{9}$ N•m^2/C^2, $q_p = +1.60 \times 10^{-19}$ C, $m_e = 9.109 \times 10^{-31}$ kg, $G = 6.673 \times 10^{-11}$ N•m^2/kg^2, $m_p = 1.673 \times 10^{-27}$ kg

Unknown: $F_{electric} = ?$ $F_g = ?$

2. PLAN

Choose an equation or situation:

Find the magnitude of the electric force using Coulomb's law and the magnitude of the gravitational force using Newton's law of gravitation (introduced in the chapter "Circular Motion and Gravitation" in this book).

$$F_{electric} = k_C \frac{q_1 q_2}{r^2} \qquad F_g = G \frac{m_e m_p}{r^2}$$

3. CALCULATE

Substitute the values into the equations and solve:

Because we are finding the magnitude of the electric force, which is a scalar, we can disregard the sign of each charge in our calculation.

$$F_{electric} = k_C \frac{q_e q_p}{r^2} = \left(8.99 \times 10^{9} \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)\left(\frac{(1.60 \times 10^{-19}\ \text{C})^2}{(5.3 \times 10^{-11}\ \text{m})^2}\right)$$

$$\boxed{F_{electric} = 8.2 \times 10^{-8}\ \text{N}}$$

$$F_g = G \frac{m_e m_p}{r^2} =$$

$$\left(6.673 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}\right)\left(\frac{(9.109 \times 10^{-31}\ \text{kg})(1.673 \times 10^{-27}\ \text{kg})}{(5.3 \times 10^{-11}\ \text{m})^2}\right)$$

$$\boxed{F_g = 3.6 \times 10^{-47}\ \text{N}}$$

4. EVALUATE

The electron and the proton have opposite signs, so the electric force between the two particles is attractive. The ratio $F_{electric}/F_g \approx 2 \times 10^{39}$; hence, the gravitational force between the particles is negligible compared with the electric force between them. Because each force is inversely proportional to distance squared, their ratio is independent of the distance between the two particles.