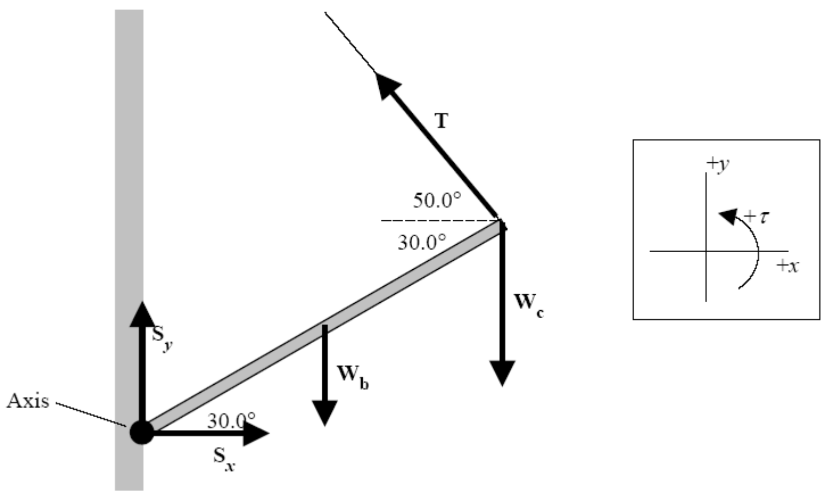
1

20. ***REASONING*** The drawing shows the beam and the five forces that act on it: the horizontal and vertical components $\mathbf{S}_x$ and $\mathbf{S}_y$ that the wall exerts on the left end of the beam, the weight $\mathbf{W}_b$ of the beam, the force due to the weight $\mathbf{W}_c$ of the crate, and the tension $\mathbf{T}$ in the cable. The beam is uniform, so its center of gravity is at the center of the beam, which is where its weight can be assumed to act. Since the beam is in equilibrium, the sum of the torques about any axis of rotation must be zero $(\Sigma\tau = 0)$, and the sum of the forces in the horizontal and vertical directions must be zero $\left(\Sigma F_x = 0,\ \Sigma F_y = 0\right)$. These three conditions will allow us to determine the magnitudes of $\mathbf{S}_x$, $\mathbf{S}_y$, and $\mathbf{T}$.



SOLUTION

a. We will begin by taking the axis of rotation to be at the left end of the beam. Then the torques produced by $\mathbf{S}_x$ and $\mathbf{S}_y$ are zero, since their lever arms are zero. When we set the sum of the torques equal to zero, the resulting equation will have only one unknown, T, in it. Setting the sum of the torques produced by the three forces equal to zero gives (with L equal to the length of the beam)

$$\Sigma\tau = -W_b\left(\tfrac{1}{2}L\cos 30.0°\right) - W_c\left(L\cos 30.0°\right) + T\left(L\sin 80.0°\right) = 0$$

Algebraically eliminating L from this equation and solving for T gives

$$T = \frac{W_b\left(\frac{1}{2}\cos 30.0°\right) + W_c\left(\cos 30.0°\right)}{\sin 80.0°}$$

$$= \frac{(1220\ \text{N})\left(\frac{1}{2}\cos 30.0°\right) + (1960\ \text{N})\left(\cos 30.0°\right)}{\sin 80.0°} = \boxed{2260\ \text{N}}$$

b. Since the beam is in equilibrium, the sum of the forces in the vertical direction must be zero:

$$\Sigma F_y = +S_y - W_b - W_c + T\sin 50.0° = 0$$

Solving for S_y gives

$$S_y = W_b + W_c - T\sin 50.0° = 1220\ \text{N} + 1960\ \text{N} - (2260\ \text{N})\sin 50.0° = \boxed{1450\ \text{N}}$$

The sum of the forces in the horizontal direction must also be zero:

$$\Sigma F_x = +S_x - T\cos 50.0° = 0$$

so that

$$S_x = T\cos 50.0° = (2260\ \text{N})\cos 50.0° = \boxed{1450\ \text{N}}$$

2

109. $\boxed{\text{SSM}}$ ***REASONING AND SOLUTION***

a. The left mass (mass 1) has a tension T_1 pulling it up. Newton's second law gives

$$T_1 - m_1 g = m_1 a \qquad (1)$$

The right mass (mass 3) has a different tension, T_3, trying to pull it up. Newton's second for it is

$$T_3 - m_3 g = -m_3 a \qquad (2)$$

The middle mass (mass 2) has both tensions acting on it along with friction. Newton's second law for its horizontal motion is

$$T_3 - T_1 - \mu_k m_2 g = m_2 a \qquad (3)$$

Solving Equation (1) and Equation (2) for T_1 and T_3, respectively, and substituting into Equation (3) gives

$$a = \frac{\left(m_3 - m_1 - \mu_k m_2\right) g}{m_1 + m_2 + m_3}$$

Hence,

$$a = \frac{\left[25.0\text{ kg} - 10.0\text{ kg} - (0.100)(80.0\text{ kg})\right]\left(9.80\text{ m/s}^2\right)}{10.0\text{ kg} + 80.0\text{ kg} + 25.0\text{ kg}} = \boxed{0.60\text{ m/s}^2}$$

b. From part a:

$$T_1 = m_1(g + a) = (10.0\text{ kg})\left(9.80\text{ m/s}^2 + 0.60\text{ m/s}^2\right) = \boxed{104\text{ N}}$$

$$T_3 = m_3(g - a) = (25.0\text{ kg})\left(9.80\text{ m/s}^2 - 0.60\text{ m/s}^2\right) = \boxed{230\text{ N}}$$

#3

70. ***REASONING AND SOLUTION*** The conservation of energy gives

$$mgh + (1/2)\, mv^2 + (1/2)\, I\omega^2 = (1/2)\, mv_0{}^2 + (1/2)\, I\omega_0{}^2$$

If the ball rolls without slipping, $\omega = v/R$ and $\omega_0 = v_0/R$. We also know $I = (2/5)\, mR^2$. Substitution of the last two equations into the first and rearrangement gives

$$v = \sqrt{v_0^2 - \tfrac{10}{7}gh} = \sqrt{(3.50\text{ m/s})^2 - \tfrac{10}{7}\left(9.80\text{ m/s}^2\right)(0.760\text{ m})} = \boxed{1.3\text{ m/s}}$$

#4

23. $\boxed{\text{SSM}}$ ***REASONING*** The charged insulator experiences an electric force due to the presence of the charged sphere shown in the drawing in the text. The forces acting on the insulator are the downward force of gravity (i.e., its weight, $W = mg$), the electrostatic force $F = k|q_1||q_2|/r^2$ (see Coulomb's law, Equation 18.1) pulling to the right, and the tension T in the wire pulling up and to the left at an angle θ with respect to the vertical as shown in the drawing in the problem statement. We can analyze the forces to determine the desired quantities θ and T.

SOLUTION.

a. We can see from the diagram given with the problem statement that

$$T_x = F \qquad \text{which gives} \qquad T\sin\theta = k|q_1||q_2|/r^2$$

and

$$T_y = W \qquad \text{which gives} \qquad T\cos\theta = mg$$

Dividing the first equation by the second yields

$$\frac{T\sin\theta}{T\cos\theta} = \tan\theta = \frac{k|q_1||q_2|/r^2}{mg}$$

Solving for θ, we find that

$$\theta = \tan^{-1}\left(\frac{k|q_1||q_2|}{mgr^2}\right)$$

$$= \tan^{-1}\left[\frac{(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(0.600\times10^{-6}\text{ C})(0.900\times10^{-6}\text{ C})}{(8.00\times10^{-2}\text{ kg})(9.80\text{ m/s}^2)(0.150\text{ m})^2}\right] = \boxed{15.4^\circ}$$

b. Since $T\cos\theta = mg$, the tension can be obtained as follows:

$$T = \frac{mg}{\cos\theta} = \frac{(8.00\times10^{-2}\text{ kg})\,(9.80\text{ m/s}^2)}{\cos 15.4^\circ} = \boxed{0.813\text{ N}}$$

#5

29. ***REASONING AND SOLUTION***
a. In order for the field to be zero, the point cannot be between the two charges. Instead, it must be located on the line between the two charges on the side of the positive charge and away from the negative charge. If x is the distance from the positive charge to the point in question, then the negative charge is at a distance (3.0 m + x) meters from this point. For the field to be zero here we have

$$\frac{k|q_-|}{(3.0\text{ m}+x)^2} = \frac{k|q_+|}{x^2} \quad \text{or} \quad \frac{|q_-|}{(3.0\text{ m}+x)^2} = \frac{|q_+|}{x^2}$$

Solving for the ratio of the charge magnitudes gives

$$\frac{|q_-|}{|q_+|} = \frac{16.0\ \mu\text{C}}{4.0\ \mu\text{C}} = \frac{(3.0\text{ m}+x)^2}{x^2} \quad \text{or} \quad 4.0 = \frac{(3.0\text{ m}+x)^2}{x^2}$$

Suppressing the units for convenience and rearranging this result gives

$$4.0x^2 = (3.0+x)^2 \quad \text{or} \quad 4.0x^2 = 9.0+6.0x+x^2 \quad \text{or} \quad 3x^2 - 6.0x - 9.0 = 0$$

Solving this quadratic equation for x with the aid of the quadratic formula (see Appendix C.4) shows that

$$x = 3.0\text{ m} \quad \text{or} \quad x = -1.0\text{ m}$$

We choose the positive value for x, since the negative value would locate the zero-field spot between the two charges, where it can not be (see above). Thus, we have $\boxed{x = 3.0\text{ m}}$.

b. Since the field is zero at this point, the force acting on a charge at that point is $\boxed{0\text{ N}}$.