1. (a) A  
(b) A  
(c) B  
(d) tie  
2. D  
3. D  
4. C  
5. D  
6. B  
7. (a) Let $\theta$ the angle between the rope and the vertical direction, when the ball is at point P. From the geometry of the drawing, we have $\cos \theta = 4/5$.

If we take the origin to be at the center of the ball with the +y axis along the rope (i.e. in the radial direction) we can write a Newton’s 2nd law equation for the ball:

$$\sum F_y = m \frac{v^2}{r}$$

Here, $v = 0$, so

$$\sum F_y = 0$$

$$T - mg \cos \theta = 0$$

We can solve this for $T$, the rope tension:

$$T = mg \cos \theta = (50 \text{ kg})(9.8 \text{ N/kg})(4/5) = 392 \text{ N}$$

(b) At Q, take the +y direction to be vertically up. Here the ball is moving along a circular path, so the proper Newton’s 2nd law equation is:

$$\sum F_y = m \frac{v^2}{r}$$

$$T - mg = m \frac{v^2}{r}$$

We can solve for the rope tension, $T$,

$$T = mg + m \frac{v^2}{r}$$

but we need to know the value of $v$ to get a numerical solution.

We can find $v$ using the principle of conservation of energy:

$$mgh = \frac{1}{2}mv_{BOT}^2$$

$$v_{BOT} = \sqrt{2gh} = \sqrt{2(9.8 \text{ N/kg})(1.0 \text{ m})} = 4.43 \text{ m/s}$$

and so, the rope tension is:

$$T = mg + m \frac{v^2}{r} = m(g + \frac{v^2}{r}) = (50 \text{ kg})(9.8 \text{ N/kg} + \frac{(4.43 \text{ m/s})^2}{5.0 \text{ m}}) = 686 \text{ N}$$
8. (a) 10 N applied force accelerates the entire 7 kg at $a = (10 \, \text{N})/(7 \, \text{kg}) = 1.43 \, \text{N/kg}$. The only horizontal force that acts on the 2.0 kg block alone is static friction, $f_s = (2.0 \, \text{kg})(1.43 \, \text{N/kg}) = 2.86 \, \text{N}$.

The frictional force is 2.86 N.

(b) For the 2.0 kg block, $f_{s,\text{MAX}} = \mu_s mg = (0.040)(2.0 \, \text{kg})(9.8 \, \text{N/kg}) = 7.84 \, \text{N}$. This force would accelerate the 2.0 kg block at $a = (7.84 \, \text{N})/(2.0 \, \text{kg}) = 3.92 \, \text{N/kg}$. The applied force required to accelerate both blocks at this acceleration would be $F = (7.0 \, \text{kg})(3.92 \, \text{N/Kg}) = 27.4 \, \text{N}$.

The maximum applied force for no slipping is 27.4 N.

9. (a) Linear momentum is conserved as the bullet passes through the block.

$$m_{\text{bul}} v_{\text{bul},i} = m_{\text{bul}} v_{\text{bul},f} + M_{\text{block}} v_{\text{block},f}$$

$$v_{\text{block},f} = \frac{m_{\text{bul}} (v_{\text{bul},f} - v_{\text{bul},i})}{M_{\text{block}}} = \frac{(0.020 \, \text{kg})(250 \, \text{m/s})}{1.50 \, \text{kg}} = 3.33 \, \text{m/s}$$

The block leaves the surface with a speed of $v = 3.33 \, \text{m/s}$ straight up and rises to a maximum height $h_f$ given by:

$$M_{\text{block}} gh_f = \frac{1}{2} M_{\text{block}} v^2$$

$$h_f = \frac{v^2}{2g} = \frac{(3.3 \, \text{m/s})^2}{2(9.81 \, \text{m/s}^2)} = 0.566 \, \text{m}$$

(b) Compare the mechanical energy just before the collision to the energy just afterwards.

Before:

$$K_i = \frac{1}{2} m_{\text{bul}} v_{\text{bul},i}^2 = \frac{1}{2}(0.020 \, \text{kg})(300 \, \text{m/s})^2 = 900 \, \text{J}$$

After

$$K_f = K_{\text{block},f} + K_{\text{bullet},f}$$

$$= \frac{1}{2} M_{\text{block}} v_{\text{block},f}^2 + \frac{1}{2} m_{\text{bul}} v_{\text{bul},f}^2$$

$$= \frac{1}{2}(1.50 \, \text{kg})(3.33 \, \text{m/s})^2 + \frac{1}{2}(0.020 \, \text{kg})(50.0 \, \text{m/s})^2$$

$$= 25 \, \text{J} + 8.33 \, \text{J} = 33.3 \, \text{J}$$

Energy is not conserved (about 870 J lost) so this is an inelastic collision.