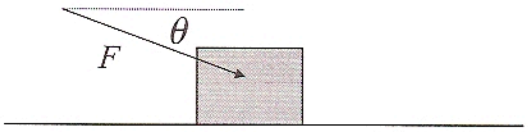

Figure 30

3. A force is applied at an angle θ below the horizontal to a mass m resting on a horizontal surface where the coefficients of friction are μ_s and μ_k. The magnitude of F is slowly increased until the mass just starts to move. At this point its acceleration is a_0. Calculate the following in terms of μ_s, μ_k, θ, m, and g.
   (a) Determine the value of F where movement just begins.
   (b) Determine a_0.

Answers and Explanations

MULTIPLE CHOICE

1. The answer is D. The vertical component of F is $F\sin\theta$. In the y-direction you then have $netF_y = 0 = N + Fsin\theta - W \Rightarrow N = W - Fsin\theta$.

2. The answer is D. $T = (3m)a \Rightarrow a = \frac{T}{3m}$. For the system you have: $F = (5m)a \Rightarrow F = \frac{5}{3}T$.

3. The answer is C. Applying the second law, you have: $netF = 8 - f = 4(1) \Rightarrow f = 4$ N. When F is doubled, the friction force doesn't change, so you have $netF = 16 - f = 12 = 4a \;\; a = 3\frac{\text{m}}{\text{s}^2}$.

4. The answer is D. At P the center is in the $-x$ direction and $a_{cp} = \frac{8^2}{4} = 16\,\frac{\text{m}}{\text{s}^2}$.

5. The answer is D. The tension force is the same for each team as a result of the third law, so only by pushing harder parallel to the ground can a team win. Strength and mass need not be a factor; imagine a football team on in-line skates.

6. The answer is D. Choose the center of the plank to calculate torques, because here the weight of the plank exerts no torque. Then $0 = net\tau = 40\frac{L}{2} - 60x \Rightarrow x = \frac{L}{3}$.

7. The answer is B. Find the acceleration: $a = \frac{\Delta v}{\Delta t} = \frac{0-6}{2} = -3\,\frac{\text{m}}{\text{s}}$. Applying the second law, you have $netF = ma = 3(-3) = -9$ N.

8. The answer is D. The component of weight down the incline is $mg\sin\theta = 120(0.5) =$ N. For equilibrium, the static friction must just supply this value.

9. The answer is D. At the lowest point you have $netF = T - mg = m\frac{v^2}{R}$

$$T = 4\frac{6^2}{2} + 40 = 112\text{N}$$

10. The answer is E. For the system as a whole, you have from the second law $netF = m_2 g = (m_1 + m_2)a \quad a = \frac{m_2 g}{(m_1 + m_2)}$. The answer follows from inspecting the formula.

Free Response

1. Apply the solution steps to each object (figure 31).

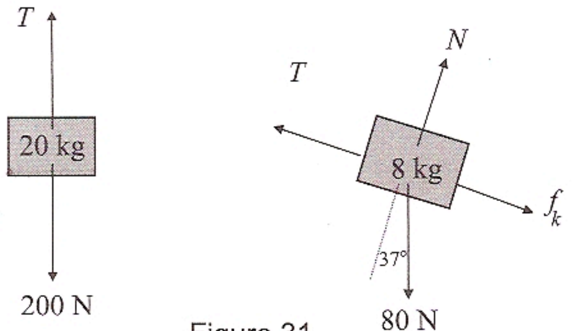

Figure 31

8 kg	20 kg
Step 1. See figure 31.	Step 1. See figure 31.
Step 2. $netF_y = \text{N} - 80\cos37$ $netF_x = T - 80\sin37 - 0.4\text{N}$	Step 2. $netF = 220 - T$
Step 3. $\text{N} - 64 = 0 \Rightarrow \text{N} = 64$ $T - 48 - 0.4(64) = 8a$	Step 3. $200 - T = 20a$

Note that the friction force is 25.6 N, the answer to part a.

Step 4. Add the equations: $-48 - 25.6 + 200 = 28a \Rightarrow a = 4.5 \text{ m/s}^2$.

Substitute to find T: $200 - T = 10(4.5) \Rightarrow \text{T} = 110\text{N}$.

2. (a) See figure 32.

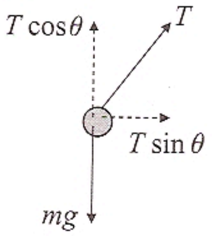

Figure 32

(b) Only the tension has a component toward the center, so

$netF_x = m\frac{v^2}{R}$ $\qquad$ $netF_y = T\cos\theta - mg = 0$

$T\sin\theta = m\frac{v^2}{L\sin\theta}$ $\qquad$ $T\cos\theta = mg$

Dividing the two equations eliminates T, and you have $v = \sqrt{g\tan\theta(L\sin\theta)}$

3. (a) Apply the basic steps to the object, remembering that when the object is just about to slide, the static friction force is at its maximum value.

Step 1. See figure 33.

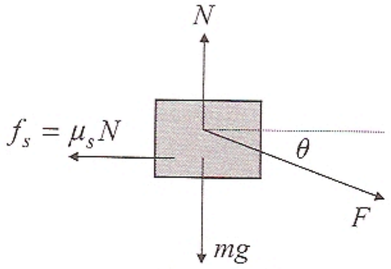

Figure 33

Step 2. $netF_x = F\cos\theta - \mu_s N$ $\qquad$ $netF_y = N - mg - F\sin\theta$

Step 3. $N - mg - F\sin\theta = 0$

$F\cos\theta - \mu_s N = 0$

Step 4. $N = mg + F\sin\theta$

$F\cos\theta - \mu_s(mg + F\sin\theta) = 0 \Rightarrow F = \frac{\mu_s mg}{\cos\theta - \mu_s\sin\theta}$

(b) As acceleration begins, this is the value of F, and now it is kinetic friction acting. Th analysis in steps 1, 2, and 3 is the same except for the friction name change and th fact that there is a nonzero horizontal acceleration. You can then move to Step to write

$$N = mg + F\sin\theta$$

$$F\cos\theta - \mu_k(mg + F\sin\theta) = ma \Rightarrow a = \frac{F}{m}\cos\theta - \mu_k\left(g - \frac{F}{m}\sin\theta\right)$$