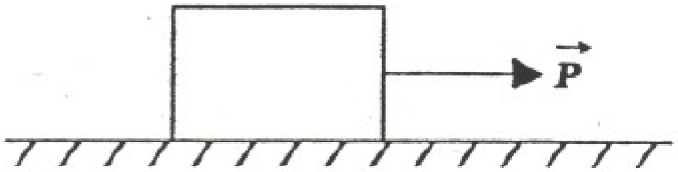
Name: _____ Assignment Due Date: December 20, 2011

AP Physics: Newton's Laws 3

Multiple Choice

Identify the choice that best completes the statement or answers the question.

____ 1. A 50-kg block rests on a horizontal surface. The coefficient of static friction $\mu_s = 0.50$. The coefficient of kinetic friction $\mu_k = 0.35$. A force $\vec{P}$ of 250N is applied as shown.



a. The block remains at rest

b. The block moves and continues to move at constant velocity.

c. The block accelerates to the right.

d. The block does not move until $\vec{P}$ is increased to greater than 490N.

e. No conclusions can be drawn conceming the movement of the block from the information given.

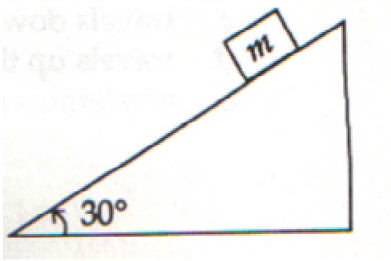
____ 2. A 5.0-kg stone is pushed out onto a level horizontal surface with a speed of 2.0 m/s. If it comes to rest after moving a distance of 20 m, the average frictional force acting on the block must have been

a. 1.0 N
b. 10 N
c. 15 N
d. 0.5 N
e. 50 N

____ 3. A tired worker pushes a heavy (100-kg)crate that is resting on a thick pile carpet. The coefficients of static and kinetic friction are 0.6 and 0.4, respectively. The worker pushes with a force of 500 N. The frictional force exerted by the surface is

a. 1000 N
b. 600 N
c. 500 N
d. 400 N
e. 100 N

____ 4. A block of mass m is at rest on an inclined plane that makes an angle of 30° with the horizontal, as shown in the figure. Which of the following statements about the force of static friction is true?



a. $f_s > mg$
b. $f_s > mg\cos 30°$
c. $f_s = mg\cos 30°$
d. $f_s = mg\sin 30°$
e. None of these statements is true.

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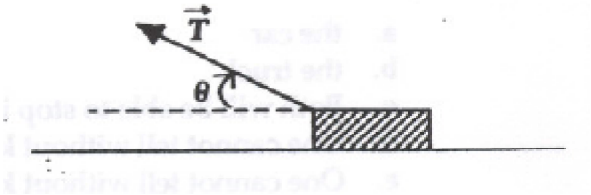
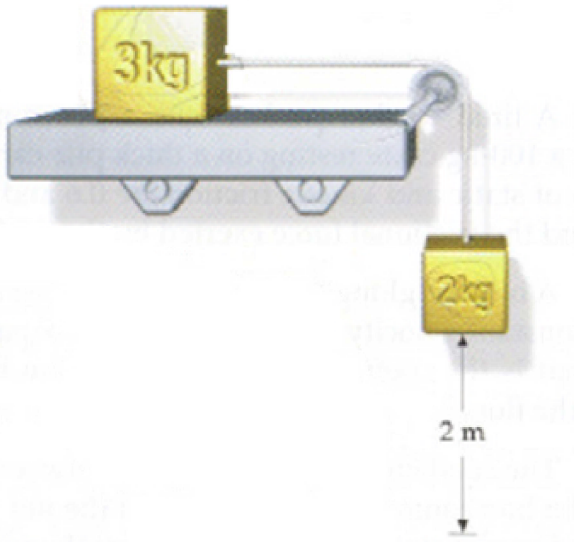
____ 5. A block of mass *m* is pulled in the direction shown in the figure across a rough surface at a constant velocity. The magnitude of the frictional force is



a. $\mu_k mg$
b. $\mu_k T\cos\theta$
c. $\mu_k(T - mg)$
d. $\mu_k T\sin\theta$
e. $\mu_k(mg - T\sin\theta)$

Problem

6. A 3-kg box resting on a horizontal shelf is attached to a 2-kg box by a light string as in the figure below. *(a)*What is the minimum coefficient of static friction such that the objects remain at rest? *(b)* If the coefficient of static friction is less than that found in part *(a)*, and the coefficient of kinetic friction between the box and the shelf is 0.3, find the time for the 2-kg mass to fall 2 m to the floor if the system starts from rest.



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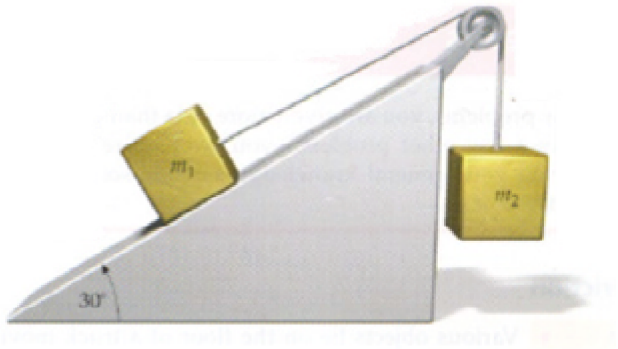
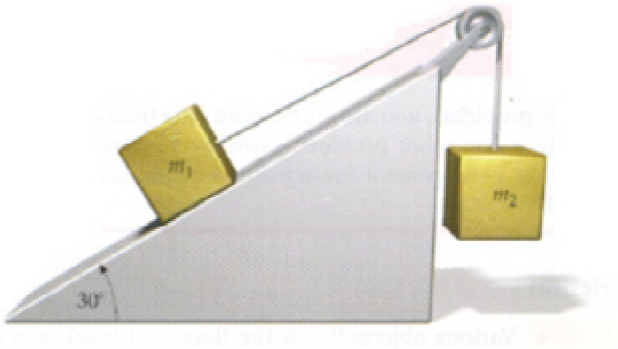
7. In the figure below, m_1 = 4 kg. The coefficient of static friction between the block and the incline is 0.4. *(a)* Find the range of possible values for m_2 for which the system will be in static equilibrium. *(b)* What is the frictional force on the 4-kg block if m_2 = 1 kg?



8. Referring to the figure below, time m_1 = 4 kg, m_2 = 5 kg, and the coefficient of kinetic friction between the inclined plane and the 4-kg block is μ_k = 0.24. Find the acceleration of the masses and the tension in the cord.



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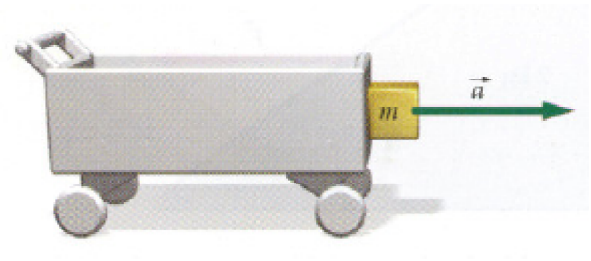
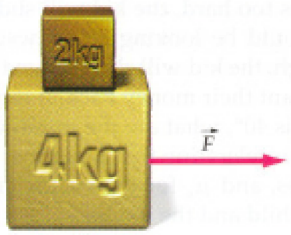
9. Lou bets an innocent stranger that he can place a 2-kg block against the side of a cart, as in the figure below, and that the block will not fall to the ground, even though Lou will use no hooks, ropes, fasteners, magnets, glue, or adhesives of any kind. When the stranger accepts the bet, Lou begins to push the cart in the direction shown. The coefficient of static friction between the block and the cart is 0.6. *(a)* Find the minimum acceleration for which Lou will win the bet. *(b)* What is the magnitude of the frictional force in this case? *(c)* Find the force of friction on the block if a is twice the minimum needed for the block not to fall. *(d)* Show that, for a block of any mass, the block will not fall if the acceleration is $a \geq g/\mu_s$ where μ_s is the coefficient of static friction.



10. A 2-kg block sits on a 4-kg block that is on a frictionless table (see figure below). The coefficients of friction between the blocks are $\mu_s = 0.3$ and $\mu_k = 0.2$. *(a)* What is the maximum force F that can be applied to the 4-kg block if the 2-kg block is not to slide? *(b)* If F is half this value, find the acceleration of each block and the force of friction acting on each block. *(c)* If F is twice the value found in *(a)*, find the acceleration of each block.



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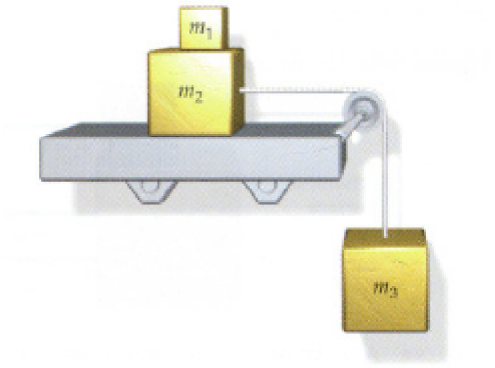
11. In the figure below, the mass m_2 = 10 kg slides on a frictionless shelf. The coefficients of static and kinetic friction between m_2 and m_1 = 5 kg are μ_s= 0.6and μ_k = 0.4.*(a)*What is the maximum acceleration of m_1? *(b)* What is the maximum value of m_3 if m_1 moves with m_2 without slipping? (c) If m_3 = 30 kg, find the acceleration of each body and the tension in the string.



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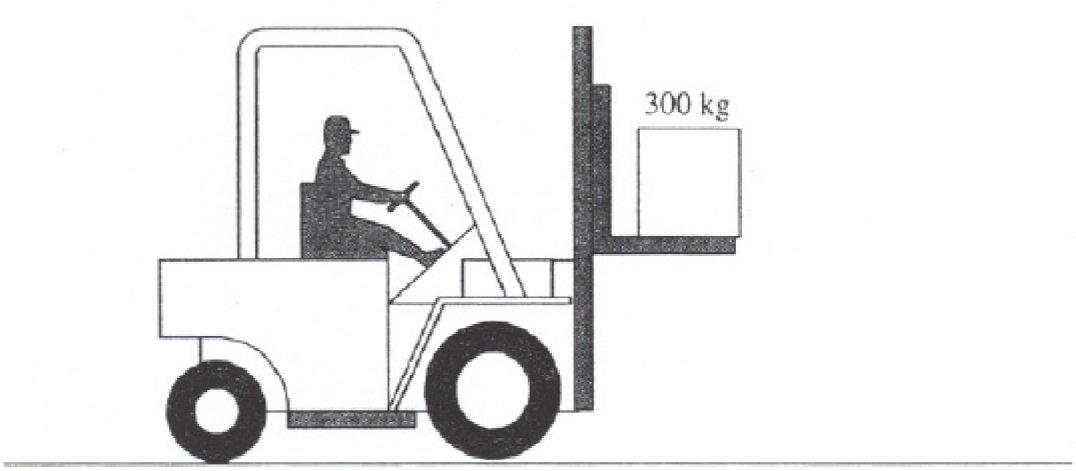

A 300-kg box rests on a platform attached to a forklift, as shown above. Starting from rest at time $T = 0$, the box is lowered with a downward acceleration of 1.5 m/s^2.

12. Determine the upward force exerted by the horizontal platform on the box as it is lowered.

13. At time $t = 0$, the forklift also begins to move forward with an acceleration of 2 m/s^2 while lowering the box as described above. The box does not slip or tip over.

    Determine the frictional force on the box.

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14. Given that the box does not slip, determine the minimum possible coefficient of friction between the box and the platform.

15. Determine an equation for the path of the box that expresses y as a function of x (and not of t), assuming that, at time $T = 0$, the box has a horizontal position $x = 0$ and a vertical position $y = 2$ m above the ground, with zero velocity.

16. On the axes below, sketch the path taken by the box.

AP Physics: Newton's Laws 3
Answer Section

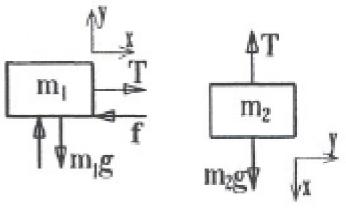
MULTIPLE CHOICE

1. ANS: C REF: Tipler 4th ed Mult Choice Question Bank p.75 #2
2. ANS: D REF: Tipler 4th ed Mult Choice Question Bank p.76 #4
3. ANS: C REF: Tipler 4th ed Mult Choice Question Bank p.76 #6
4. ANS: D REF: Tipler 4th ed Mult Choice Question Bank p.76 #7
5. ANS: E REF: Tipler 4th ed Mult Choice Question Bank p.78 #15

PROBLEM

6. ANS:

1. Draw a free-body diagram for each object. In the absence of friction, m_1 will move to the right, m_2 will move down. The friction force is indicated by f without subscript; it is f_s for (*a*), f_k for (*b*).



(*a*) 1. Apply $\Sigma F = ma$ for each mass. Note that $a = 0$
2. $f_s = f_{s,max} = \mu_s F_n$; solve for μ_s

$F_n - m_1g = 0;\ T - f = 0;\ \ m_2g - T = 0;\ f = f_s = T = m_2g$
$F_n = m_1g$
$m_2g = \mu_s m_1g;\ \mu_s = m_2/m_1 = 2/3 = 0.667$

(*b*) If $\mu_s < 0.667$, the system will accelerate.
1. Apply $\Sigma F = ma$; $a_y = 0$; $a = a_x$
2. Solve for a
3. Find a for $m_1 = 3$ kg, $m_2 = 2$ kg, $\mu_k = 0.3$
4. Use $s = \frac{1}{2}at^2$; solve for and find t

$F_n = m_1g;\ T - f_k = m_1a;\ m_2g - T = m_2a;\ \ f_k = \mu_k m_1g$
$a = (m_2 - \mu_k m_1)g/(m_1 + m_2)$
$a = 2.16\ \text{m/s}^2$
$t = (2s/a)^{1/2} = (2 \times 2/2.16)^{1/2}\ \text{s} = 1.36\ \text{s}$

REF: Tipler4thed.p.140#18

7. ANS:

(*a*) 1. Use the result of Problem 5-20; set $a = 0$. Note that f_s may point up or down the plane.
2. Solve for m_2 with $m_1 = 4$ kg, $\mu_s = 0.4$

$0 = m_2 - m_1(\sin\theta \pm \mu_s \cos\theta)$

$m_2 = 3.39$ kg, 0.614 kg.
$m_{2,max} = 3.39$ kg, $m_{2,min} = 0.614$ kg

(*b*) 1. Apply $\Sigma F = ma$; set $a = 0$
2. Solve for and find f_s

$m_2g + f_s - m_1g\sin\theta = 0$
$f_s = [(4.0 \times 0.5 - 1.0) \times 9.81]\ \text{N} = 9.81\ \text{N}$

REF: Tipler4thed.p.140#21

8. ANS:

1. Use the result of Problem 5-20; substitute numerical values. $a = 2.36 \text{ m/s}^2$

2. Use $T = m_2g - m_2a$ and Problem 5-20 to obtain an expression for T and substitute numerical values. $T = \dfrac{m_1 m_2 g(1 + \sin\theta + \mu_s \cos\theta)}{m_1 + m_2}$; $T = 37.2 \text{ N}$

REF: Tipler4thed.p.140#22

9. ANS:

(*a*) 1. The normal force acting on the block is the force exerted by the cart.

2. Apply $\Sigma F = ma$ $F_n = F = ma$

(*b*) $f_s = f_{s,max}$ $f_{s,max} = \mu_s ma = mg$; $a_{min} = g/\mu_s = 16.4 \text{ m/s}^2$

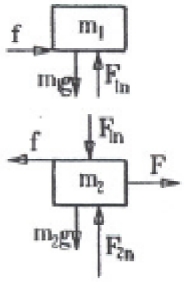
(*c*) f_s is again mg $f_s = mg = 19.6 \text{ N}$

(*d*) Since g/μ_s is a_{min}, block will not fall if $a \geq g/\mu_s$ $f_s = 19.6 \text{ N}$

REF: Tipler4thed.p.140#28

10. ANS:

(*a*) 1. Draw the free-body diagram



2. Apply $\Sigma F = ma$ $f_{s,max} = m_1 a_{max}$; $F_{n1} = m_1 g$; $F_{max} - f_{s,max} = m_2 a_{max}$

3. Use $f_{s,max} = \mu_s F_{n1}$ and solve for a_{max} and F_{max} $a_{max} = \mu_s g$; $F_{max} = (m_1 + m_2)g\mu_s$;

4. Evaluate a_{max} and F_{max} $a_{max} = 2.94 \text{ m/s}^2$, $F_{max} = 17.7 \text{ N}$

(*b*) 1. The blocks move as a unit. The force on m_1 is $m_1 a = f_s$. $a = F/(m_1 + m_2)$; $a = 2.95 \text{ m/s}^2$ 1.47 m/s²

$f_s = (2.95 \times 2) \text{ N} = 5.9 \text{ N}$

(*c*) 1. If $F = 2F_{max}$ then m_1 slips on m_2. $f = f_k = \mu_k m_1 g$

2. Apply $\Sigma F = ma$ $m_1 a_1 = f_k = \mu_k m_1 g$; $m_2 a_2 = F - \mu_k m_1 g$

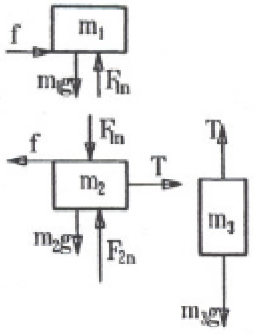
3. Solve for and evaluate a_1 and a_2 for $F = 35.4 \text{ N}$ $a_1 = \mu_k g$; $a_2 = (F - \mu_k g m_1)/m_2$;

$a_1 = 1.96 \text{ m/s}^2$, $a_2 = 7.87 \text{ m/s}^2$

REF: Tipler4thed.p.141#37

11. ANS:

The free-body diagrams for m_1 and m_2 are identical to those of the previous problem. Now the force F arises from the tension T in the string supporting m_3, as shown.



(*a*)	See Problem 5-37	$a_{max} = \mu_s g$; $a_{max} = 5.89$ m/s^2
(*b*)	1. Apply $\Sigma F = ma$	$T = (m_1 + m_2)a_{max}$; $m_3 g - T = m_3 a_{max}$
	2. Solve for and evaluate m_3	$m_3 = \mu_s(m_1 + m_2)/(1 - \mu_s)$; $m_3 = 22.5$ kg
(*c*)	1. For $m_3 = 30$ kg, m_1 will slide on m_2. Follow the procedure of Problem 5-37(*c*). Note that $a_3 = a_2$	$m_1 a_1 = f_k = \mu_k m_1 g$; $m_2 a_2 = T - \mu_k m_1 g$; (1) $m_3 a_3 = m_3 g - T = m_3 a_2$ (2)
	2. Add the equations involving T to find a_2	$a_2 = (m_3 - m_1\mu_k)g/(m_2 + m_3)$; $a_2 = a_3 = 6.87$ m/s^2
	3. Evaluate a_1 and T using equation (1)	$a_1 = (0.4 \times 9.81)$ m/s^2 $= 3.92$ m/s^2; $T = 88.3$ N

REF: Tipler4thed.p.142#38

12. ANS:

3 points

For indicating, via an equation or a free-body diagram, that the net force is the sum of gravity and the normal force exerted by the platform — 1 point

Using Newton's second law:

$mg - N = ma_y$

Solving for the force exerted by the platform:

$N = m(g - a_y)$

For correctly substituting both accelerations — 1 point

$N = (300\text{ kg})(10\text{ m/s}^2 - 1.5\text{ m/s}^2)$

For the correct answer — 1 point

$N = 2550$ N (or 2490 N if using 9.8 m/s^2)

REF: AP Physics Final 1996 Free Resp (Mech) #2a

13. ANS:

2 points

For indicating that the frictional force is the only horizontal force exerted — 1 point

$f = ma_h$

$f = (300\ \text{kg})(2\ \text{m/s}^2)$

For the correct answer — 1 point

$f = 600\ \text{N}$

REF: AP Physics Final 1996 Free Resp (Mech) #2b

14. ANS:

3 points

Expressing the frictional force in terms of the normal force:

$f = \mu N$

$\mu = f/N$

For correctly substituting the frictional force from part (b) — 1 point

For correctly substituting the normal force from part (a) — 1 point

$\mu = (600\ \text{N})/(2550\ \text{N})$

For the correct answer, with no units — 1 point

$\mu = 0.24$

REF: AP Physics Final 1996 Free Resp (Mech) #2c

15. ANS:

4 points

For writing the equation for the vertical motion, and indicating that $a_v = -1.5\ \text{m/s}^2$ — 1 point

$$y = y_0 + \frac{1}{2}(-1.5)t^2$$

For indicating that $y_0 = 2$ — 1 point

For writing the equation for the horizontal motion, and indicating that $a_h = 2\ \text{m/s}^2$ — 1 point

$$x = \frac{1}{2}(2)t^2$$

The relationship between x and y can be obtained by combining the equations for the horizontal and vertical motions, eliminating t^2.

For a correct equation relating y and x — 1 point

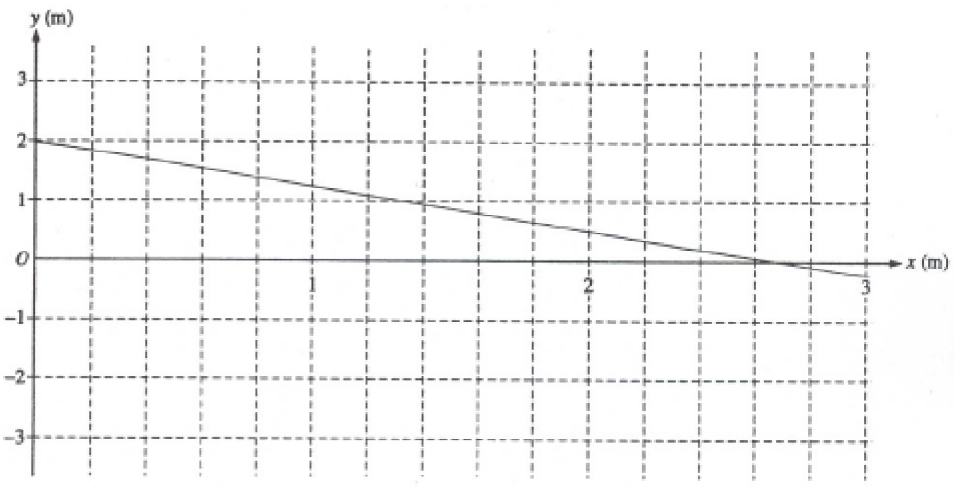
$$y = 2 - 0.75x$$

Note: Alternate methods that derive this equation from a relationship between the components of acceleration or velocity could also receive full credit.

REF: AP Physics Final 1996 Free Resp (Mech) #2d

16. ANS:

(c) 3 points



For a straight line with a negative slope, extending at least to $x = -1$ m	1 point
For a y-intercept at 2 m	1 point
For an x-intercept at $2\frac{2}{3}$ m or a slope of $-\frac{3}{4}$	1 point

Note: Credit was only awarded for showing the items above on the graph. Students were expected to show an understanding of the physics of the situation, and thus were not awarded full credit for graphing an incorrect equation from part (d).

REF: AP Physics Final 1996 Free Resp (Mech) #2e