Chapter 5 Homework

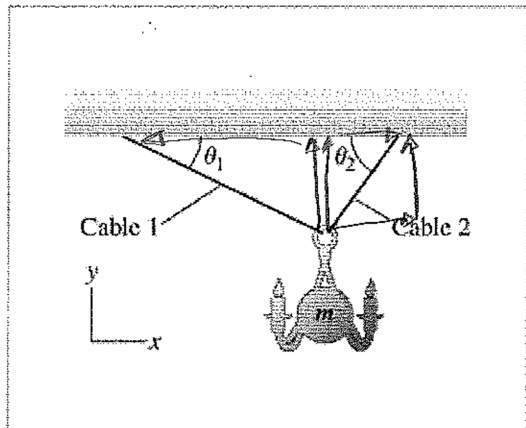
Due: 8:00am on Monday, October 28, 2013

You will receive no credit for items you complete after the assignment is due. Grading Policy

Hanging Chandelier

Description: Given a chandelier hanging from two nonsymmetric cables, find the tension in one cable.

A chandelier with mass m is attached to the ceiling of a large concert hall by two cables. Because the ceiling is covered with intricate architectural decorations (not indicated in the figure, which uses a humbler depiction), the workers who hung the chandelier couldn't attach the cables to the ceiling directly above the chandelier. Instead, they attached the cables to the ceiling near the walls. Cable 1 has tension T_1 and makes an angle of θ_1 with the ceiling. Cable 2 has tension T_2 and makes an angle of θ_2 with the ceiling.



Part A Dont worry bout trig. See answers included

Find an expression for T_1, the tension in cable 1, that does not depend on T_2.

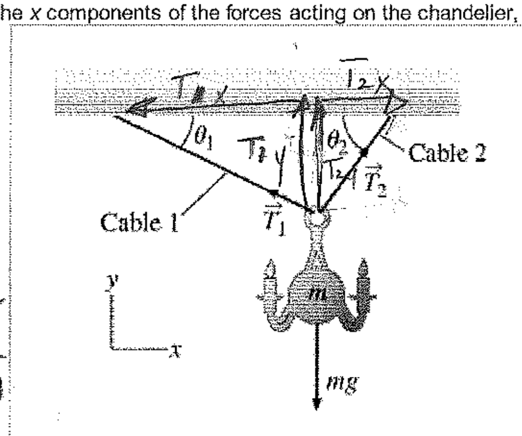
Express your answer in terms of some or all of the variables m, θ_1, and θ_2, as well as the magnitude of the acceleration due to gravity g.

Hint 1. Find the sum of forces in the x direction

The chandelier is static; hence the vector forces on it sum to zero. Type in the sum of the x components of the forces acting on the chandelier, using the coordinate system shown.

Typesetting math: 64%

Express your answer in terms of some or all of the variables m, T_1, T_2, θ_1, and θ_2.



Find T_1

$\Sigma F_x = 0$

$T_{2x} - T_{1x} = 0$

$\cos\theta_2 T_2 = \cos\theta_1 T_1$

$T_2 = \frac{T_1 \cos\theta_1}{\cos\theta_2}$

$\Sigma F_y = 0$

$T_{1y} + T_{2y} - mg = 0$

$\sin\theta_1 T_1 + \sin\theta_2 T_2 = mg$

$\sin\theta_2 T_2 = mg - \sin\theta_1 T_1$

$\sin\theta_2\left(\frac{T_1\cos\theta_1}{\cos\theta_2}\right) = mg - \sin\theta_1 T_1$

ANSWER:

$\sum F_x = 0 = T_2\cos(\theta_2) - T_1\cos(\theta_1)$

Hint 2. Find the sum of forces in the *y* direction

Now type the corresponding equation relating the *y* components of the forces acting on the chandelier, again using the coordinate system shown.

Express your answer in terms of some or all of the variables m, T_1, T_2, θ_1, and θ_2, as well as the magnitude of the acceleration due to gravity g.

ANSWER:

$\sum F_y = 0 =$ $T_1 \sin(\theta_1) + T_2 \sin(\theta_2) - mg$

or//

$T_2 = T_2$

$$\frac{T_1 \cos\theta_1}{\cos\theta_2} = \frac{mg - \sin\theta_1 T_1}{\sin\theta_2}$$

$$T_1 \cos\theta_1 \sin\theta_2 = \cos\theta_2 mg - \cos\theta_2 \sin\theta_1 T_1$$

Hint 3. Putting it all together

There are two unknowns in this problem, T_1 and T_2. Each of the previous two hints leads you to an equation involving these two unknowns. Eliminate T_2 from this pair of equations and solve for T_1.

$$T_1(\cos\theta_1 \sin\theta_2 + \cos\theta_2 \sin\theta_1) = \cos\theta_2 mg$$

ANSWER:

$T_1 = \dfrac{mg\cos(\theta_2)}{\sin(\theta_1 + \theta_2)}$

or// See Mr Lock's Solution

I don't care about final form + trig identities (next page) →

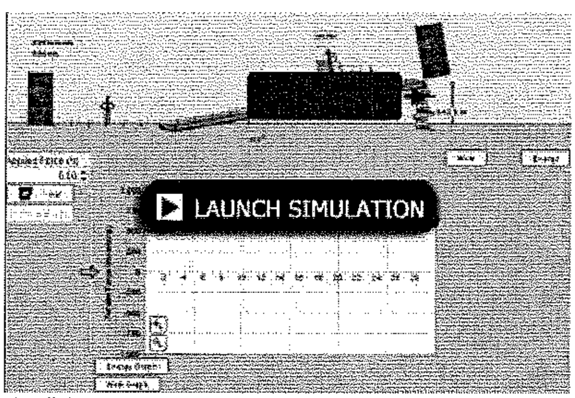
PhET Tutorial: The Ramp

Description: Students use the PhET simulation "The Ramp" to understand how the forces exerted on an object on an inclined plane affect the object's motion.

Learning Goal:

To understand how the forces exerted on an object on an inclined plane affect the object's motion.

For this tutorial, use the PhET simulation *The Ramp*. This simulation allows you to place a variety of objects on an inclined ramp and look at the resulting forces and motion.



Start the simulation. When you click the simulation link, you may be asked whether to run, open, or save the file. Choose to run or open it.
Select an object to place on the ramp by clicking on any object under the **Choose Object** section of the right panel. To change the ramp angle, you can adjust the **Ramp Angle** slider bar in the right panel or you can click on the ramp and drag it up or down. To turn off friction, you can click on the **Frictionless** option that is above the **Position** setting. You can have the person pushing on the object by setting an **Applied Force** that is nonzero (you can type in a value in the **Applied Force** box on the left, drag the big vertical slider bar to the left of the parallel-force graph, or you can click and drag on the object). While the simulation is running, a graph shows the parallel forces (i.e., the components of the forces along the ramp) as a function of time.

Feel free to play around with the simulation. When you are done, click **Reset** before beginning Part A.

Part A

The first thing you will investigate is static friction. The force of static friction is the parallel force exerted on a stationary object by the ramp. This force is always directed opposite the direction the object would slide if there were no friction.
Select the crate as the object for the ramp. Then, slowly increase the ramp angle. The individual forces acting on the crate are shown. They'll look something like this:

Find T_1 (elim T_2)

$$T_2 \cos\theta_2 = T_1 \cos\theta_1 \qquad T_2 \sin\theta_2 + T_1 \sin\theta_1 = mg$$

① Solve for T_2: $T_2 = \dfrac{T_1 \cos\theta_1}{\cos\theta_2}$

② Substitute T_2 in second formula:

$$T_1 = \frac{mg\cos(\theta_2)}{\sin(\theta_1+\theta_2)}$$

$$\left(\frac{T_1 \cos\theta_1}{\cos\theta_2}\right)\sin\theta_2 + T_1 \sin\theta_1 = mg$$

③ Common Denominator of $\cos\theta_2$:

$$\frac{T_1 \cos\theta_1 \sin\theta_2}{\cos\theta_2} + \frac{T_1 \sin\theta_1}{1} = mg$$

$$\frac{T_1 \cos\theta_1 \sin\theta_2}{\cos\theta_2} + \frac{T_1 \sin\theta_1 \cos\theta_2}{\cos\theta_2} = mg$$

④ Add:

$$\frac{T_1 \cos\theta_1 \sin\theta_2 + T_1 \sin\theta_1 \cos\theta_2}{\cos\theta_2} = mg$$

⑤ Multiply $\cos\theta_2$:

$$T_1 \cos\theta_1 \sin\theta_2 + T_1 \sin\theta_1 \cos\theta_2 = mg\cos\theta_2$$

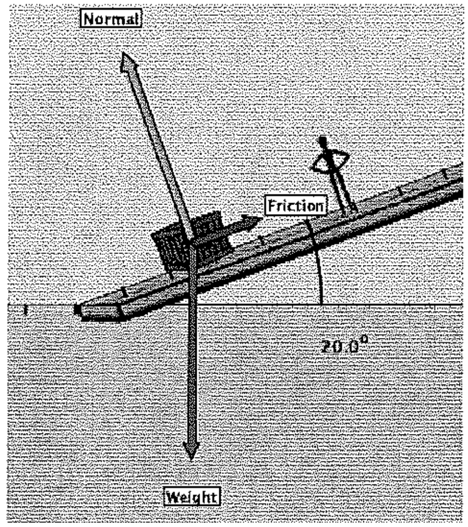
⑥ Factor T_1:

$$T_1 (\cos\theta_1 \sin\theta_2 + \sin\theta_1 \cos\theta_2) = mg\cos\theta_2$$

⑦ Divide: $T_1 = \dfrac{mg\cos\theta_2}{\sin\theta_1 \cos\theta_2 + \cos\theta_1 \sin\theta_2}$

⑧ Use Identity $\sin(A+B) = \sin A \cos B + \cos A \sin B$

$$T_1 = \frac{mg\cos\theta_2}{\sin(\theta_1+\theta_2)}$$



Watch what happens to the force of friction (the red vector in the picture or the red plot in the graph) before the crate starts to slide down the ramp.

As the ramp angle increases, the force of static friction

ANSWER:

- increases.
- decreases.
- remains the same.

In order for the crate to remain at rest, the force of static friction must be equal in magnitude to the component of the force of gravity parallel to the ramp. As the ramp angle increases, this component of the force of gravity increases.

Part B

With the crate stationary on a *horizontal* ramp, the force of static friction is

ANSWER:

- directed to the left.
- zero.
- directed to the right.

Since the force of gravity is vertical, it has no component parallel to the horizontal ramp. This means that there is no force along the ramp that friction has to oppose.

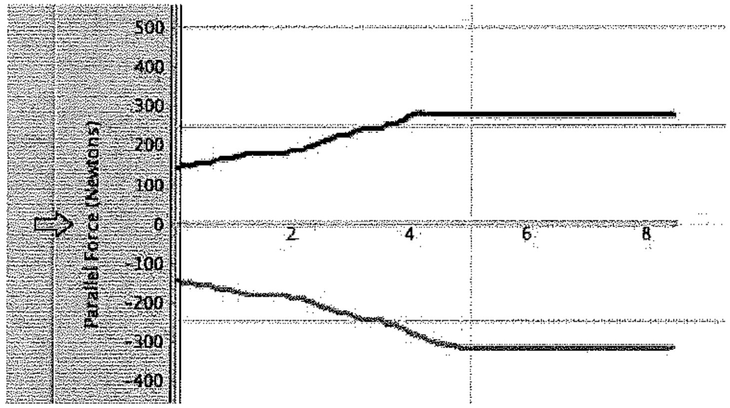
Part C

What is the maximum ramp angle that still allows the crate to remain at rest? (Make sure the coefficient of friction is 0.7.)

Express your answer to the nearest degree.

Hint 1. How to approach the problem

Slowly increase the ramp angle, and look at the value of the angle once the crate begins to slide. Your graph will look something like this, and the slipping occurs when the red curve flattens out:



ANSWER:

θ = 35 °

The crate accelerates when the component of the force of gravity along the ramp is greater than the maximum force of static friction. The component of the force of gravity along the ramp is $mg \sin(\theta)$, where mg is the weight of the object and θ is the ramp angle. The maximum force of static friction is $\mu n = \mu mg \cos(\theta)$, where n is the normal force and μ is the coefficient of static friction. The maximum angle can be determined by equating these two forces, which gives $\sin(\theta) = \mu \cos(\theta)$, or $\theta = \mathrm{atan}(\mu) = 35°$.

Part D

In the previous part, you determined the maximum angle that still allows the crate to remain at rest. If the coefficient of friction is less than 0.7, what happens to this angle? (Note that you can adjust the coefficient of friction by clicking on the **More Features** tab near the top of the window and then using the slider bar in the right panel.)

Hint 1. How to approach the problem

The maximum force of static friction is given by $f_{\mathrm{s,\,max}} = \mu n$, where n is the normal force acting on the crate and μ is the coefficient of static friction. Think about what happens to this maximum force when the coefficient of friction decreases.

ANSWER:

- ◉ The maximum angle decreases.
- ○ The maximum angle remains the same.
- ○ The maximum angle increases.

Since the maximum force of static friction decreases due to the smaller coefficient of friction, a smaller component of the force of gravity along the ramp is required to make the crate accelerate.

Part E

The mass of the crate can also be adjusted by clicking on the **More Features** tab and then using the slider bar in the right panel.

How does the maximum angle for which the crate can remain at rest on the ramp depend on the mass of the crate?

Hint 1. How to approach this part

Think about how the maximum force of static friction depends on the mass of the object, and compare that to how the force of gravity depends on the mass. Keep in mind that the file cabinet will begin slipping when the maximum force of static friction is equal to the component of the force of gravity along the ramp.

ANSWER:

- The maximum angle decreases as the mass increases.
- ● The maximum angle does not depend on the mass.
- The maximum angle increases as the mass increases.

Although the normal force and thus the maximum force of static friction increases with increasing mass, the component of the force of gravity parallel to the ramp increases at the same rate. The maximum angle is therefore independent of the mass.

Part F

Click **Reset**, and then adjust the ramp angle to 15°. Compare the force of static friction when there is no applied force to when there is an applied force of 100 N (pushing up the ramp).

How do the two forces of static friction compare?

ANSWER:

- The force of static friction when there is no applied force is less than the case when there is an applied force.
- The force of static friction when there is no applied force is equal to the case when there is an applied force.
- ● The force of static friction when there is no applied force is greater than the case when there is an applied force.

In order for the crate to be stationary, the sum of the applied force and the force of static friction must have the same magnitude as the component of gravity parallel to the ramp (so that the net force is zero). Thus, the force of friction decreases by 100 N when the applied force goes from zero to 100 N.

Part G

For a stationary crate (with a coefficient of friction of 0.7) on the 15° ramp, can the force of static friction ever be zero?

Hint 1. How to approach the problem using the simulation

Adjust the applied force while watching the force of static friction in the parallel-force graph. Determine if you can make the force of static friction go to zero.

Hint 2. How to approach the problem using physics reasoning

Think about what would be required for the cabinet to be at rest on a frictionless surface. In which direction is the force of gravity? In which direction would the applied force have to be exerted to balance the force of gravity along the ramp?

ANSWER:

- No
- Yes, but only for a specific applied force directed down the ramp.
- ● Yes, but only for a specific applied force directed up the ramp.

When the applied force has the same strength as the component of the force of gravity parallel to the ramp, then the net force on the crate would be zero if the surface were frictionless. This means friction doesn't have to help, and so the force of friction is zero (this is similar to Part B, where the crate is sitting on a horizontal surface with no applied forces). Notice that if the applied force is greater than this value, the force of static friction is directed *down* the ramp.

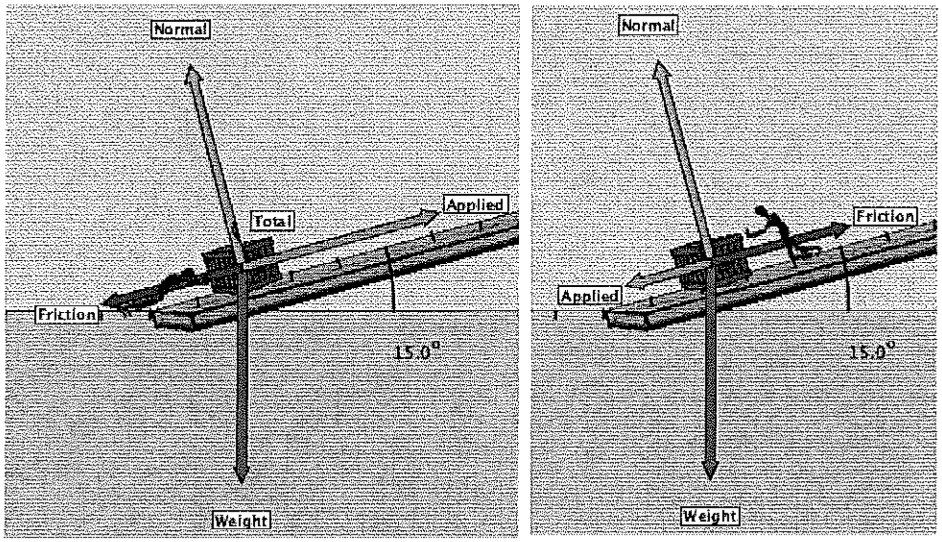
Part H

Slowly adjust the applied force (pushing both up and down the ramp) until the crate begins to move. Determine the minimum strength of the pushing force needed to accelerate the crate up the ramp and the minimum strength of the pushing force needed to accelerate the crate down the ramp. How do these two minimum strengths compare to each other?

ANSWER:

- ◯ The minimum push needed to get the crate to slide up the ramp is less than that to get the crate to slide down the ramp.
- ◯ The minimum push needed to get the crate to slide up the ramp is the same as that to get the crate to slide down the ramp.
- ● The minimum push needed to get the crate to slide up the ramp is greater than that to get the crate to slide down the ramp.

When pushing up the ramp, the applied force is opposing not only the static friction force (which is directed down the ramp) but also the component of the force of gravity along the ramp. When pushing down the ramp, the applied force is being helped by the component of the force of gravity down the ramp in opposing the friction force (directed up the ramp), and so doesn't need to be as strong.



This should be consistent with your own experiences trying to move things up and down slopes.

PhET Interactive Simulations
University of Colorado
http://phet.colorado.edu

Problem 5.17: Air-Bag Safety.

Description: According to safety standard for air bags, the maximum acceleration during a car crash should not exceed 60 g and should last for no more than 36 ms. (a) In such a case, what force does the air bag exert on a ## kg person? Start with a free-body...

$60(9.8\,m/s^2) = 588\,m/s^2$

According to safety standard for air bags, the maximum acceleration during a car crash should not exceed 60 g and should last for no more than 36 ms.

Part A

In such a case, what force does the air bag exert on a 85.0kg person? Start with a free-body diagram.

F_{airbag}

ANSWER:

$F = m \cdot 60g = 5.00\times10^4$ N

$$\Sigma F = ma$$
$$F_{ab} = 85\,kg(588\,m/s^2)$$
$$= 49980\,N$$
$$= 5\times10^4\,N$$

Part B

Express the force in part (A) in terms of the person's weight. $= mg = 85(9.8)$

ANSWER:

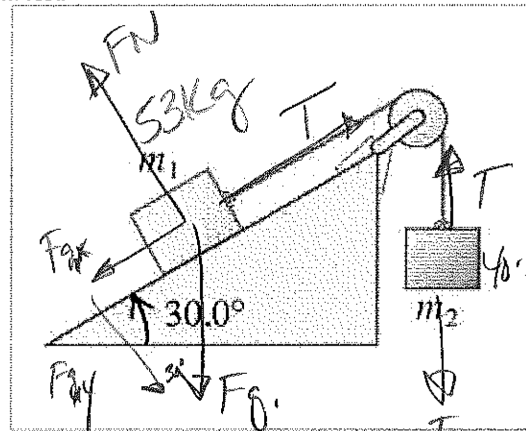
$F = 60.0\ w_{person}$

$$\frac{5\times10^4\,N}{(85)(9.8)} = 60W$$

Problem 5.29

Description: Two boxes (m1=## kg and m2=## kg) are connected by a light string that passes over a light, frictionless pulley. One box rests on a frictionless ramp that rises at 30.0 degree(s) above the horizontal (see the figure below), and the system is released...

Two boxes ($m1$ = 53.0kg and $m2$ = 40.5kg) are connected by a light string that passes over a light, frictionless pulley. One box rests on a frictionless ramp that rises at 30.0° above the horizontal (see the figure below), and the system is released from rest.



frictionless!

$T = T$

$m_1 a + \sin\theta\, m_1 g = m_2 g - m_2 a$

$m_1 a + m_2 a = m_2 g - \sin\theta\, m_1 g$

$\frac{a(m_1 + m_2)}{(m_1 + m_2)} = \frac{m_2 g - \sin\theta\, m_1 g}{(m_1 + m_2)}$

$a = 1.46\ m/s^2$

Part A

Which way will the 53.0kg box move, up the plane or down the plane? Or will it even move at all?

Select the correct answer.

ANSWER:

- (●) up
- ( ) down
- ( ) rest

b/c frictionless!

Object #1		Object #2
$\Sigma F_x = ma$	$\Sigma F_y = 0$	$\Sigma F_y = -ma$
$T - F_{gx} = m_1 a$	$F_N - F_{gy} = 0$	$T - F_{g2} = -m_2 a$
$T = m_1 a + F_{gx}$	$F_N = F_{gy}$	$T = m_2 g - m_2 a$
$T = m_1 a + \sin\theta\, F_g$	$F_N = \cos\theta\, F_g$	
$T = m_1 a + \sin\theta\, m_1 g$	$F_N = \cos\theta\, mg$	
	constant unless have friction	

Part B

Find the acceleration of each box.

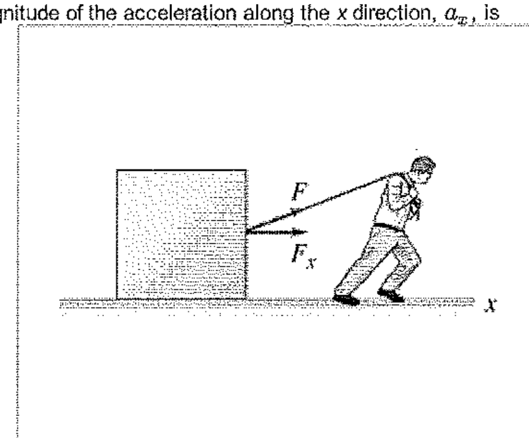
ANSWER:

$a = \frac{9.8\left(m2 - \frac{m1}{2}\right)}{m1 + m2} = 1.47\ \mathrm{m/s^2}$

A Friction Experiment

Description: Short quantitative problem relating a pulling force to a frictional force and acceleration. Requires that students interpret graphical data. This problem is based on Young/Geller Quantitative Analysis 5.2

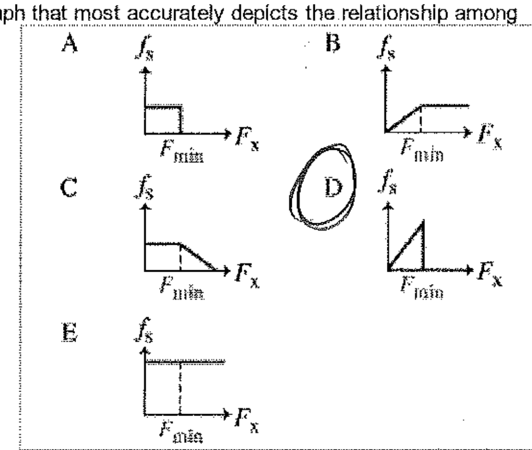
During an experiment, a crate is pulled along a rough horizontal surface by a force $\vec{F}$ and the magnitude of the acceleration along the *x* direction, a_x, is measured. The vector $\vec{F}$ has a component along the *x* direction of magnitude F_x. The experiment is repeated several times, with different values of F_x each time, while maintaining a constant value for, F_y, the vertical component of $\vec{F}$.



Part A

Create a plot of the force of static friction, f_s, versus the x component of the pulling force, F_x, for the experiment. Let the point $F_{\min}$, along the horizontal axis, represent the minimum force required to accelerate the crate. Choose the graph that most accurately depicts the relationship among f_s, F_x, and $F_{\min}$.

as F_x ↑, f_s will ↑ untill it reaches the max value, then the crate wil accelerate + friction will stay same.



Hint 1. Characteristics of static friction

There are two important characteristics to keep in mind about the the force of static friction:

- Only a stationary object can be acted upon by the force of static friction.
- $f_s \le \mu_s n$, where μ_s is the coefficient of static friction and n is the magnitude of the normal force. This inequality means that the actual force of static friction can have any magnitude between zero and a maximum value of $\mu_s n$.

Hint 2. Find the force of static friction

f_s max = 15N!

A horizontal force of magnitude $F_{\rm H}$ is exerted on a stationary crate. The maximum force of static friction, $f_{\rm s,\ max}$, between the crate and the floor is 15 $\rm N$. Assume that $F_{\rm H}$ is the only force, besides that of static friction, f_s, acting horizontally on the crate.

(F_x)

What is f_s when no horizontal force is applied to the crate, that is, when $F_{\rm H} = 0\ {\rm N}$? What is f_s when $F_{\rm H} = 10\ {\rm N}$? What is f_s the instant the crate starts to move?

$F_x = 0$, $f = 0$!

Enter your answers numerically in newtons. Separate each answer with a comma. For example if the answers are 100, 200, and −50 $\rm N$ enter `100,200,-50`.

Hint 1. Applying Newton's 2nd law

A horizontal force F is applied to the crate. However, the force of static friction, f_s, opposes this force and causes the crate to remain stationary, meaning that $a_x = 0$. From Newton's 2nd law we know that

$$\sum F_x = ma_x.$$

This yields

$$\sum F_x = F_{\rm H} - f_s = ma_x = 0$$

when applied to this specific problem.

ANSWER:

f_s = 0, 10, 15 $\rm N$

Now use what you have learned about the fore of static friction in the previous hint to determine the correct graph.

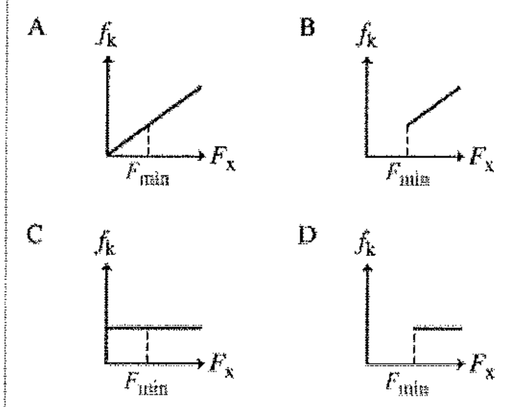
ANSWER:

- A
- B
- C
- D (selected)
- E

Notice that until the pulling force F_x exceeds $f_{\text{s, max}}$, the force of static friction is exactly equal in magnitude to the pulling force.

Part B

Create a plot of the force of kinetic friction, f_{k}, versus the *x* component of the pulling force, F_x, for the experiment. Let the point F_{min}, along the horizontal axis, represent the minimum force required to accelerate the crate. Choose the graph that most accurately depicts the relationship among f_{k}, F_x, and F_{min}.



Hint 1. Characteristics of kinetic friction

There are three important characteristics to keep in mind about the force of kinetic friction:

- Only an object that is sliding with respect to a surface can be acted upon by the force of kinetic friction.
- $\vec{f}_{\text{k}}$ points in a direction that is parallel to the surface of contact and opposes the motion of the object.
- $f_{\text{k}} = \mu_{\text{k}} n$, where μ_{k} is the coefficient of kinetic friction and N is the magnitude of the normal force.

ANSWER:

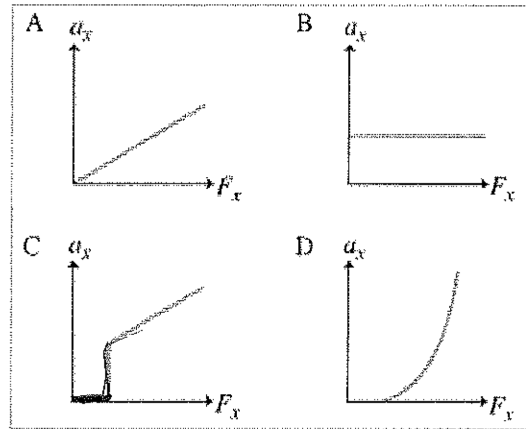
- ○ A
- ○ B
- ○ C
- ● D

The most important things to keep in mind when dealing with kinetic friction are the following:

- Only an object that is sliding with respect to a surface can be acted upon by the force of kinetic friction.
- $\vec{f}_{\text{k}}$ points in a direction that is parallel to the surface of contact and opposes the motion of the object.
- $f_{\text{k}} = \mu_{\text{k}} n$, where μ_{k} is the coefficient of kinetic friction and N is the magnitude of the normal force.

Part C

After all the trials are completed, a graph of acceleration a_x as a function of force F_x is plotted. Assuming the presence of both static and kinetic friction, which of the following graphs is most nearly correct?



ANSWER:

- ○ A
- ○ B
- ● C
- ○ D

Contact Forces Introduced

Description: Conceptual problem explaining contact forces, particularly the difference between static and kinetic friction. (multiple choice) (version for algebra-based courses)

Learning Goal:

To introduce contact forces: the normal force and the force due to friction..

Two types of contact forces operate in typical mechanics problems: the normal force (usually designated by $\vec{n}$) and frictional forces (designated by $\vec{f}$). The normal force is always perpendicular to the plane of contact, whereas the force due to friction is parallel to the plane of contact.

When two surfaces slide against each other, experiments show three things about the resulting *kinetic* frictional force $\vec{f}_{\rm k}$:

1. The frictional force opposes the relative motion of the two surfaces at their point of contact.
2. The magnitude of the kinetic frictional force, $f_{\rm k}$, is proportional to the magnitude of the normal force, n.
3. The ratio of $f_{\rm k}$ to n is fairly constant over a wide range of speeds.

The constant of proportionality is called the coefficient of kinetic friction and is often designated $\mu_{\rm k}$. As long as the sliding continues, the frictional force is f_{\rm k} = \mu_{\rm k} n.

When there is no relative motion of the two surfaces, the magnitude of the static frictional force can assume any value from zero up to a maximum \mu_{\rm s}n, where \texttip{\mu _{\rm s}}{mu_s} is known as the coefficient of static friction; \texttip{\mu _{\rm s}}{mu_s} is, invariably, larger than \texttip{\mu _{\rm k}}{mu_k}. The frictional force for surfaces that do not move relative to each other is therefore f_{\rm s} \leq \mu_{\rm s}n. The equality f_{\rm s} = \mu_{\rm s} n holds *only* when the surfaces are on the verge of sliding.

The following questions will help reinforce the ideas of kinetic and static friction.

Part A

When two objects slide against one another, which of the following statements about the force of friction between them is true?

ANSWER:

- ● The magnitude of the frictional force is always equal to \mu_{\rm k}n.
- ○ The magnitude of the frictional force is always less than \mu_{\rm k}n.
- ○ The magnitude of the frictional force is determined by other forces on the objects so it can be either equal to or less than \mu_{\rm k}n.

Part B

When two objects are in contact with no relative motion, which of the following statements about the frictional force between them is true?

ANSWER:

- ◯ The magnitude of the frictional force is always equal to \mu_{\rm s}n.
- ◯ The magnitude of the frictional force is always less than \mu_{\rm s}n.
- ● The magnitude of the frictional force may be either equal to or less than \mu_{\rm s}n.

For static friction, the actual magnitude of the friction force is such that it, together with any other forces present, will cause the object to have zero acceleration. The magnitude of the force due to static friction cannot, however, exceed \mu_{\rm s} n. If the magnitude of static friction needed to keep the acceleration equal to zero exceeds \mu_{\rm s} n, then the object will slide and will be subject to the force of *kinetic* friction. Do not automatically assume that f_{\rm s} = \mu_{\rm s}n unless you are considering a situation in which an object is just on the verge of slipping.

Part C

When a board with a box on it is slowly tilted to a larger and larger angle, common experience shows that the box will at some point "break loose" and start to accelerate down the board. The box begins to slide once the component of its weight parallel to the board, \texttip{w_{\rm ||}}{w_||}, equals the maximum force of static friction. Which of the following is the most general explanation for why the box *accelerates* down the board after it begins to slide (rather than sliding with constant speed)?

ANSWER:

- ● The coefficient of kinetic friction is less than the coefficient of static friction.
- ◯ Once the box is moving, \texttip{w_{\rm ||}}{w_||} is less than the force of static friction but greater than the force of kinetic friction.
- ◯ Once the box is moving, \texttip{w_{\rm ||}}{w_||} is greater than the force of static friction but less than the force of kinetic friction.
- ◯ When the box is stationary, \texttip{w_{\rm ||}}{w_||} equals the force of static friction, but once the box starts moving, the sliding reduces the normal force, which in turn reduces the friction.

At the point when the box finally does "break loose," the component of the box's weight that is parallel to the board, \texttip{w_{\rm ||}}{w_||}, is equal to \mu_{\rm s}n (the maximum force of static friction). For the box to then accelerate, there must be a nonzero net force acting on the box parallel to the board. In other words, \texttip{w_{\rm ||}}{w_||} must be greater than the force of kinetic friction, f_k = \mu_{\rm k} n. Therefore the force of kinetic friction, \mu_{\rm k} n , must be less than the force of static friction, \mu_{\rm s} n, which implies \mu_{\rm k} < \mu_{\rm s}, as expected.

Problem 5.76

Description: Block A in the figure weighs ## N and block B weighs ## N. The coefficient of kinetic friction between all surfaces is ##. (a) Find the magnitude of the horizontal force F_vec_a necessary to drag block B to the left at a constant speed of ## cm/s...

Block A in the figure weighs 1.30{\rm N} and block B weighs 4.40{\rm N}. The coefficient of kinetic friction between all surfaces is 0.500.

$\Sigma F_x = ma^{\to 0}$

$\Sigma F_x = 0$

$-F + f = 0$

$F = f$

$F = \mu F_N$

$F = 0.5(5.7N) = 2.85N$

$\Sigma F_y = 0$

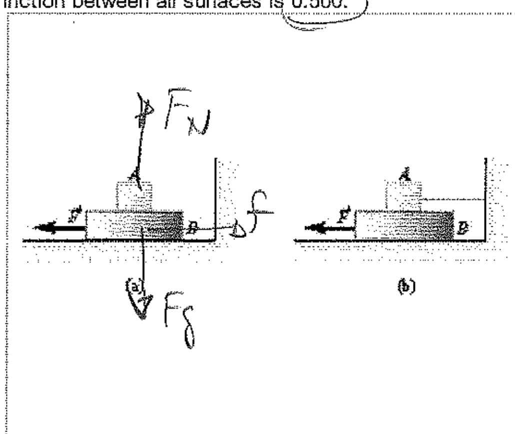
$F_N - F_g = 0$

$F_N = F_g$

$F_N = \cancel{mg}$

$F_N = 1.3\,N + 4.4\,N$

$F_N = 5.7N$



Part A

cm/s

Find the magnitude of the horizontal force \vec F_a necessary to drag block B to the left at a constant speed of 2.50{\rm cm/s} if A rests on B and moves with it (figure a).

ANSWER:

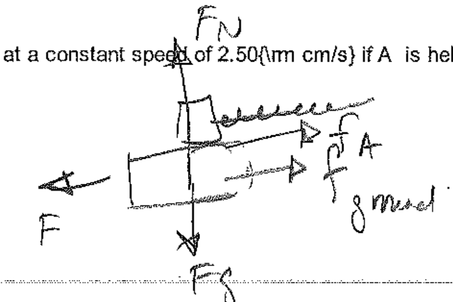
F_a = $f_k(w_A + w_B)$ = 2.85 {\rm N}

Part B

Find the magnitude of the horizontal force \vec F_b necessary to drag block B to the left at a constant speed of 2.50{\rm cm/s} if A is held at rest by a string (figure b).

ANSWER:

F_b = $f_k(2w_A + w_B)$ = 3.50 {\rm N}



Part C

In part (A), what is the friction force on block A?

ANSWER:

F_{\rm fric} = 0 {\rm N}

$\Sigma F_x = 0$

$-F + f_A + f_{ground} = 0$

$F = f_a + f_{ground}$

$F = \mu F_{N\,A} + \mu F_{N\,ground}$

$F = 0.5(1.3N) +$

$0.5(1.3N + 4.4N)$

$= \boxed{3.5N}$

Problem 5.82 A fractured tibia.

too hard! ~~Skip~~! removed

Description: While a fractured tibia (the larger of the two major lower leg bones in mammals) is healing, it must be held horizontal and kept under some tension so that the bones will heal properly to prevent a permanent limp. One way to do this is to support the...

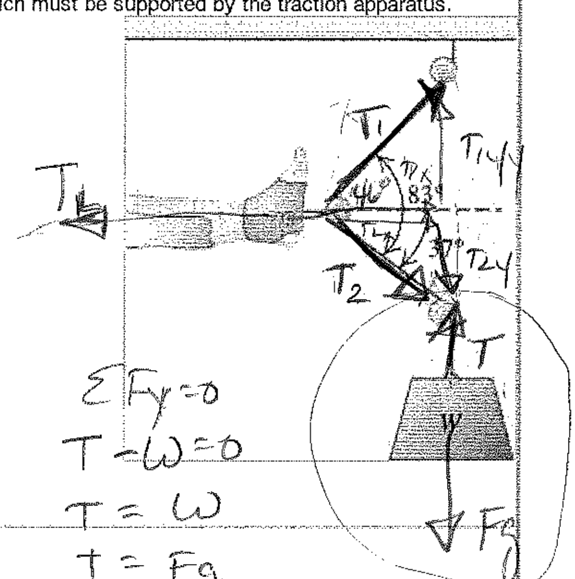
While a fractured tibia (the larger of the two major lower leg bones in mammals) is healing, it must be held horizontal and kept under some tension so that the bones will heal properly to prevent a permanent limp. One way to do this is to support the leg by using a variation of the Russell traction apparatus. (See the figure) The lower leg (including the foot) of a particular patient weighs 46.8{\rm N} , all of which must be supported by the traction apparatus.

$\Sigma F_y = 0$ $\Sigma F_x = 0$

$T_{1y} - T_{2y} - F_g = 0$

$\sin 46° T_1 = \sin 37° T_2 + F_g$ $T_1 = T_2$

answer on next page if interested



$\Sigma F_y = 0$

$T - W = 0$

$T = W$

$T = F_g$

Part A

What must be the mass of W, shown in the figure?

ANSWER:

m_W = $\frac{w_{leg} \cdot 8.5088}{g}$ = 40.6 {\rm kg}

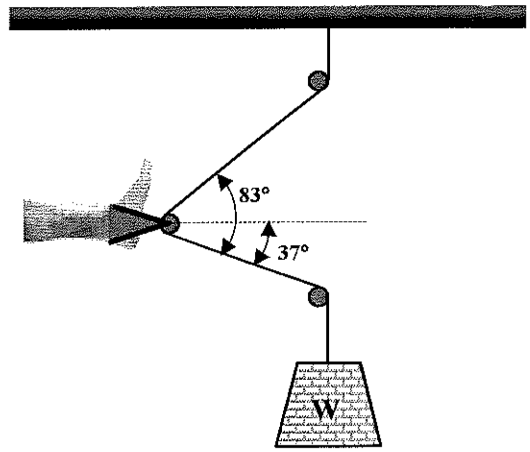
Part B

What traction force does the apparatus provide along the direction of the leg?

ANSWER:

F = $12.706 w_{leg}$ = 595 {\rm N}

Solution to Problem 82 in Chapter 5: Applications of Newton's 2nd Law



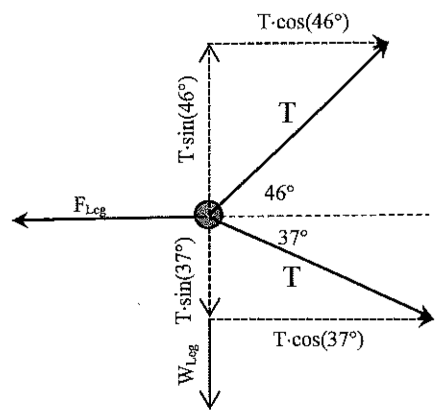
82. A fractured Tibia. While a fractured tibia (the larger of the two major lower leg bones in mammals) is healing, it must be held horizontal and kept under some tension so that the bones will heal properly to prevent a permanent limp. One way to do this is to support the leg by using a variation on the Russell traction apparatus. See figure. The lower leg (including the foot) of a particular patient weighs 51.5 N, all of which must be supported by the traction apparatus.

(a) What must be the mass of W, shown in the figure?

(b) What traction force does the apparatus provide along the direction of the leg?

Constraints:

1. The tension, T, in the line is constant from the ceiling to the hanging weight. If it was not constant, then the pulleys would turn until the tensions became constant on either side of the pulleys. Thus, the tension in the line is simply equal to the weight W hanging on the end of the line.
2. The net force on the foot must be totally horizontal.



Free Body Diagram centered on the pulley just off the foot.

Force Balance Equations

Horizontal: $F_{\text{Leg}} = T\cos(46^\circ) + T\cos(37^\circ)$

Vertical: $T\sin(46^\circ) = T\sin(37^\circ) + W_{\text{Leg}}$

The only unknowns in the two equations above are T and F_{Leg}. So a solution is possible for the two simultaneous equations. Substitute W for T and 51.5 N for W_{Leg}. Solve for W and F_{Leg}.

$W\sin(46^\circ) = W\sin(37^\circ) + 51.5\text{ N}$ and $F_{\text{Leg}} = W\cos(46^\circ) + W\cos(37^\circ)$

$W[\sin(46^\circ) - \sin(37^\circ)] = 51.5\text{ N}$
$\therefore \text{W} = 438.5\text{ N}$

and

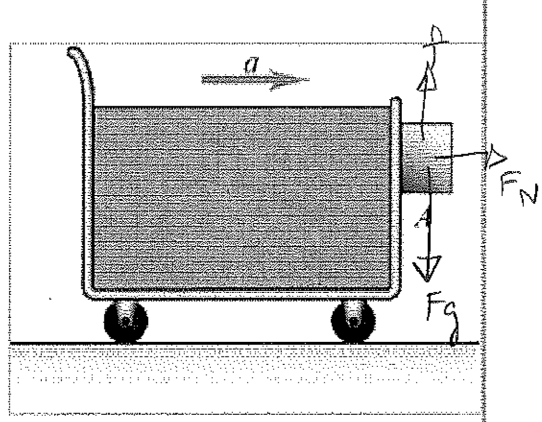
$F_{\text{Leg}} = W[\cos(46^\circ) + \cos(37^\circ)]$
$\therefore F_{\text{Leg}} = 654.4\text{ N}$

Note the weight of a 175 lb person is 778 N. So the force of extension on the leg is large but less than the weight of the person. So this answer is not alarmingly out of being reasonable.

Problem 5.87

Description: A block is placed against the vertical front of a cart as shown in the figure. (a) What acceleration must the cart have in order that block A does not fall? The coefficient of static friction between the block and the cart is mu_s. μ_s

A block is placed against the vertical front of a cart as shown in the figure.



$\Sigma F_y = 0$ $\qquad$ $\Sigma F_x = ma$

$f - F_g = 0$ $\qquad$ $F_N = ma$

$\mu F_N = mg$

$\mu (\cancel{m} a) = \cancel{m} g$

$\frac{\mu_s a}{\mu} = \frac{g}{\mu}$ $\qquad$ $a = \frac{g}{\mu}$

Part A

What acceleration must the cart have in order that block A does not fall? The coefficient of static friction between the block and the cart is \texttip{\mu _{\rm s}}{mu_s}.

ANSWER:

a = $\frac{g}{\mu_s}$

Problem 5.66: Atwood's machine.

Description: A load of bricks with mass m_1 hangs from one end of a rope that passes over a small, frictionless pulley. A counterweight of mass m_2 is suspended from the other end of the rope, as shown in the figure. The system is released from rest. (a) What is...

A load of bricks with mass \texttip{m_{\rm 1}}{m_1} = 15.6{\rm kg} hangs from one end of a rope that passes over a small, frictionless pulley. A counterweight of mass \texttip{m_{\rm 2}}{m_2} = 28.0{\rm kg} is suspended from the other end of the rope, as shown in the figure. The system is released from rest.

$m_1 = 15.6 kg$ $\qquad$ $m_2 = 28 kg$

Object #1 $\qquad$ Object #2

$\Sigma F_y = +ma$ $\qquad$ $\Sigma F_y = -ma$

$T - F_{g1} = m_1 a$ $\qquad$ $T - F_{g2} = -m_2 a$

$T = m_1 a + F_{g1}$ $\qquad$ $T = -m_2 a + F_{g2}$

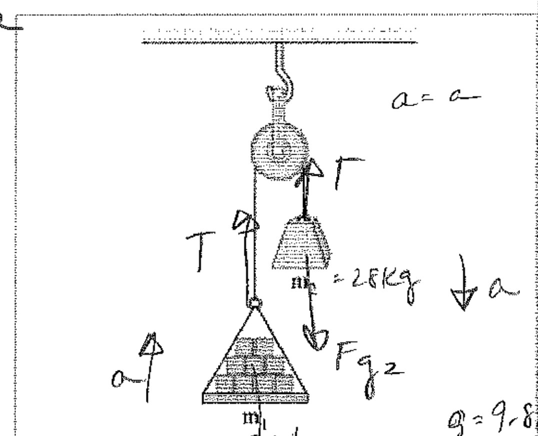
$T = m_1 a + m_1 g$ $\qquad$ $T = -m_2 a + m_2 g$

$T = T$

$m_1 a + m_1 g = -m_2 a + m_2 g$

$m_1 a + m_2 a = m_2 g - m_1 g$

$\frac{a(m_1 + m_2)}{(m_1 + m_2)} = \frac{m_2 g - m_1 g}{(m_1 + m_2)}$



Part A

What is the magnitude of the upward acceleration of the load of bricks?

$a = \frac{g(m_2 - m_1)}{(m_1 + m_2)}$

$a = \frac{9.8(28 - 15.6)}{(28 + 15.6)} = \boxed{2.79 m/s^2}$

ANSWER:

$\frac{m_2 - m_1}{m_2 + m_1} g$ = 2.79 \rm{m/s^{2}}

Part B

What is the tension in the rope while the load is moving?

ANSWER:

$\frac{2 m_1 m_2}{m_1 + m_2} g$ = 196 {\rm N}

$T = M_1 a + M_1 g$ (from other question)

$T = 15.6\ kg(2.79\ m/s^2) + 15.6\ kg(9.8\ m/s^2)$

$\boxed{T = 196.4\ N}$