Physics 2111
Unit 5

Today's Concepts:

1. Free Body Diagrams ***(very important!)***
2. Force due to gravity
3. Force due to strings
4. Force due to springs (just a little bit)

(We're going to save universal gravitation until the end of the term.)

Where are we?

Tuesday, September 4 | 9:15 AM

smartPhysics

Physics 2111

College of DuPage

[+] Go to current unit

− Linear Dynamics

1. 1-D Kinematics
2. Vectors and 2-D Kinematics
3. Relative and Circular Motion
4. Newton's Laws
5. Forces and Free-Body Diagrams ←
6. Friction

Just lots of examples of different specific forces

+ Conservation Laws

+ Rotational Dynamics

+ Applications

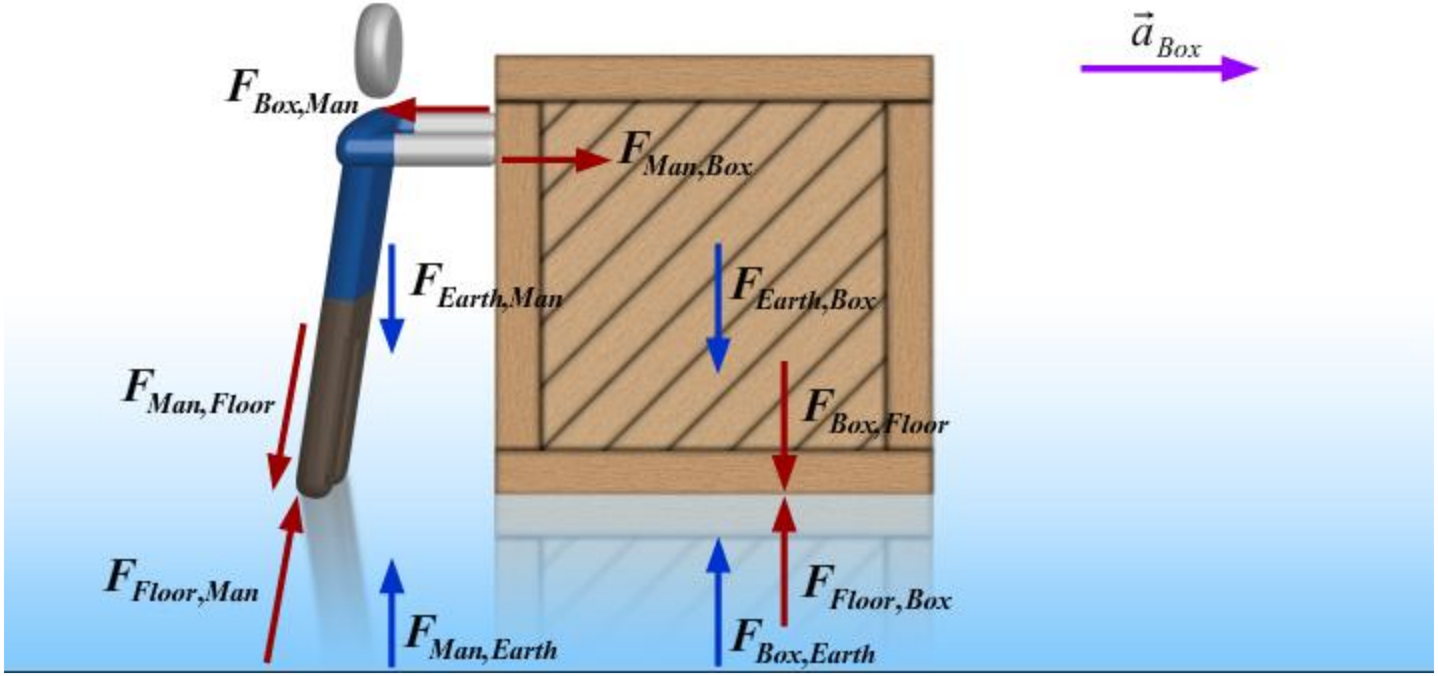
We will go over Newton's Universal Law of Gravitation much more during the last week of the term.

$$F_{GRAV\ 12} = -G\frac{m_1 m_2}{r^2}\hat{r}$$

Freebody Diagrams

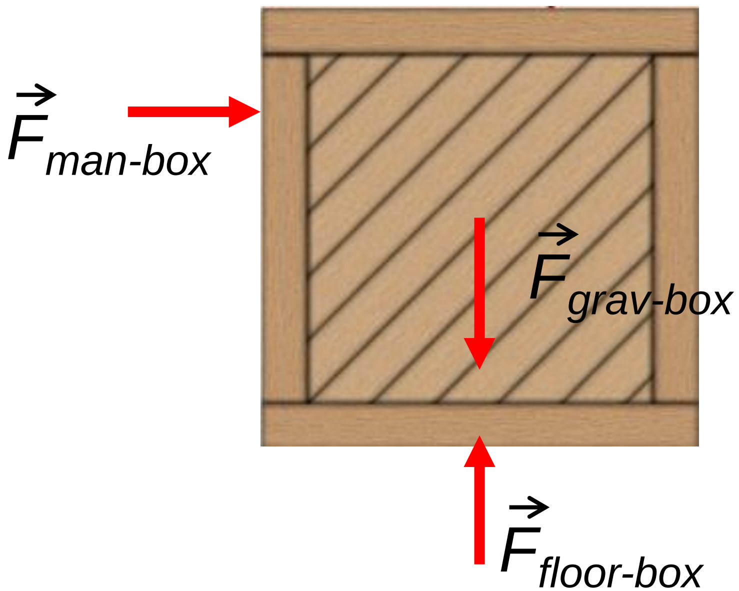
How to determine the box's acceleration...

draw a FBD *of the box*



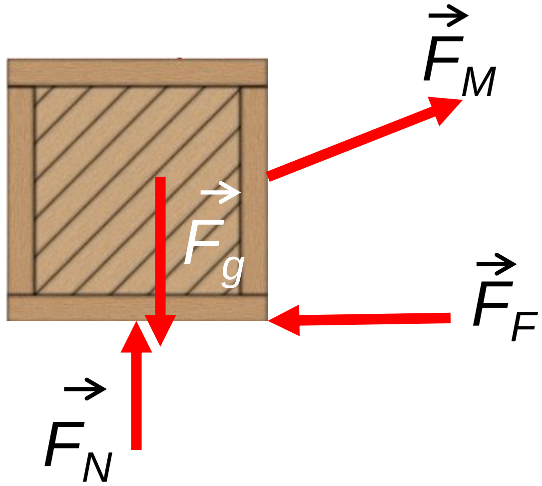
FBD of the box

1. Draw a rough diagram of the object in question
2. Only draw the forces *on the object*
3. Draw the forces roughly at the point applied
4. Apply Newton's 2nd Law to your diagram



In this diagram, where is the force of the box on the man?

Question



A chemistry student pulls a block across a rough horizontal surface at a constant speed by applying a force F_M. The arrows correctly indicate the directions, but not necessarily the magnitudes of the forces on the block.

Which of the following relations among the force magnitudes of F_M, F_F, F_N, and F_g must be true?

A) $|F_M| = |F_F|$ and $|F_N| = |F_g|$
B) $|F_M| > |F_F|$ and $|F_N| < |F_g|$
C) $|F_M| = |F_F|$ and $|F_N| > |F_g|$
D) $|F_M| > |F_F|$ and $|F_N| = |F_g|$
E) None of the above choices

Force of gravity

- $|\vec{F}_{grav}|$= mg = weight
- Units are Newtons or pounds (4.4N = 1lb)
- 1kg * 9.81m/sec^2 = 9.81N
- (1slug * 32.2ft/sec^2 = 32.2lb)
- (1lbm * 32.2ft/sec^2 = 1lbf)

Don't sweat this in 2111

A 1kg bowling ball is in free fall. (Ignore air resistance and take down as positive.) Which of the following is the correct application of Newton's second law to this situation?

A) $\sum \vec{F} = m\vec{a}$

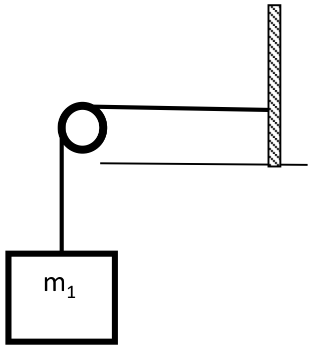
B) $\sum \vec{F} = m\vec{a} + m\vec{g}$

C) $\sum \vec{F} = m\vec{a} - m\vec{g}$

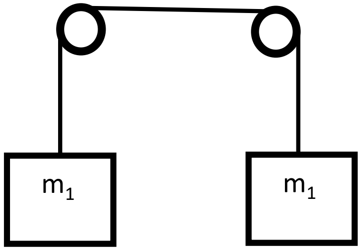
D) $\sum \vec{F} = 0$

Strings/Force from Tension

- Unless specifically stated, all strings have negligible mass. (Not a bad approximation.)
- Force from string is always parallel to string.
- Magnitude is always the same at both ends



In the top situation, the string is tied to a wall and the force due to tension in the string is m_1g. In the bottom situation, two masses are held by the string. What is the force due to tension in the bottom situation?

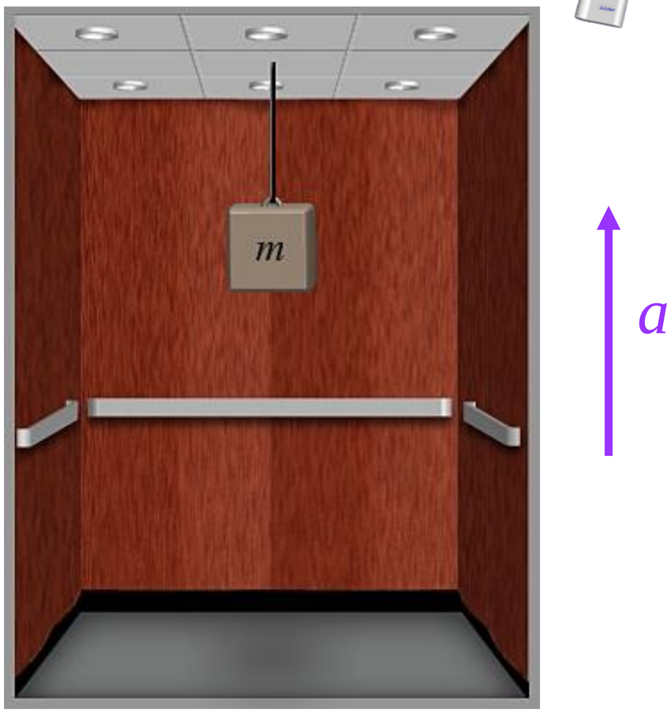


A) $2*m_1g$
B) m_1g
C) 0

Checkpoint

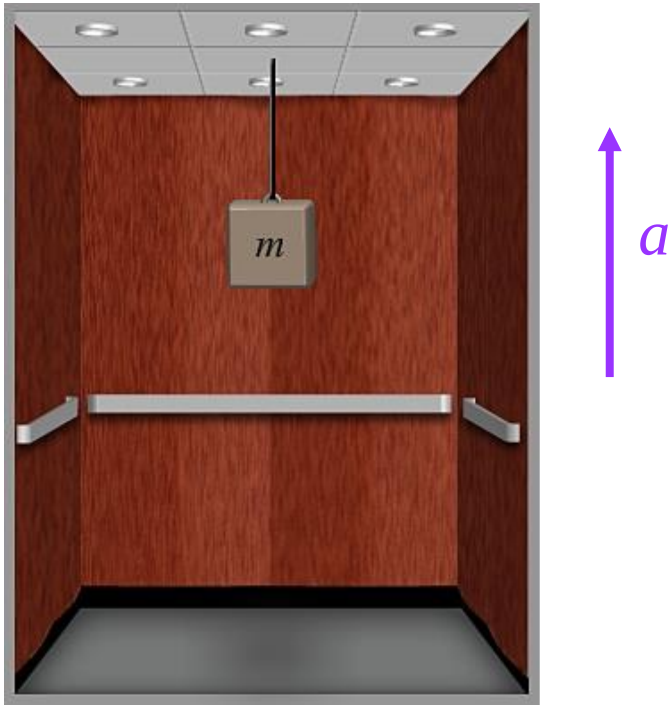
A box of mass m is hung with a string from the ceiling of an elevator that is accelerating upward. Which of the following best describes the tension T in the string:

A) T < mg
B) T = mg
C) T > mg



Example 5.1 (The elevator)

Let's say that m is 5kg and the elevator is accelerating upwards at $2m/sec^2$. What is the tension in the string?



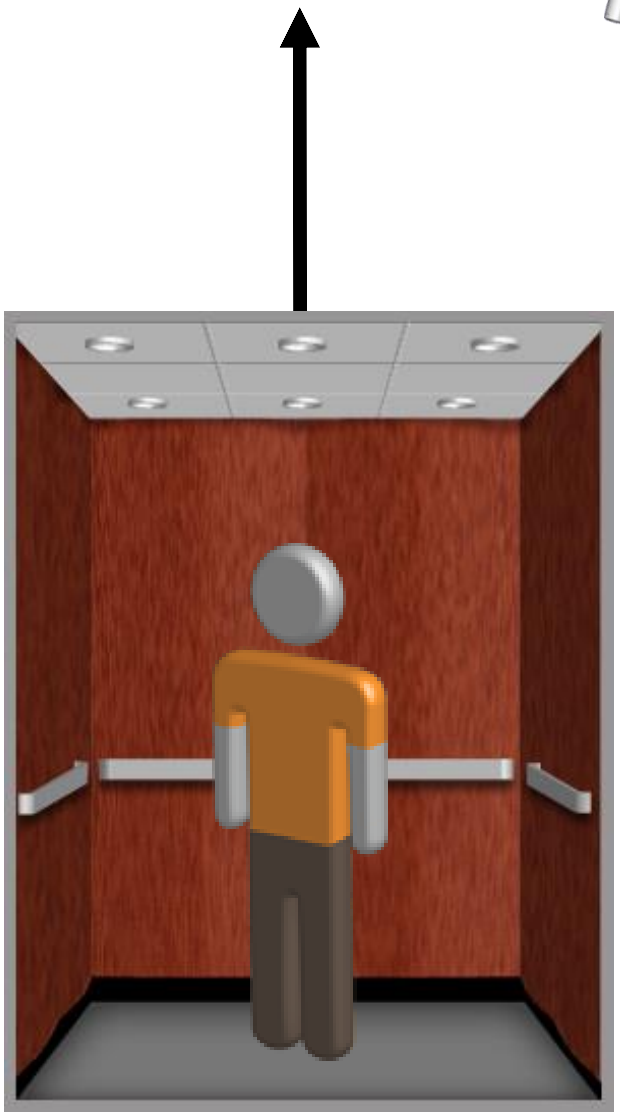
Question

You are traveling on an elevator up the Sears tower. As you near the top floor and are slowing down, your acceleration

A) is upward

B) is downward

C) is zero



Question

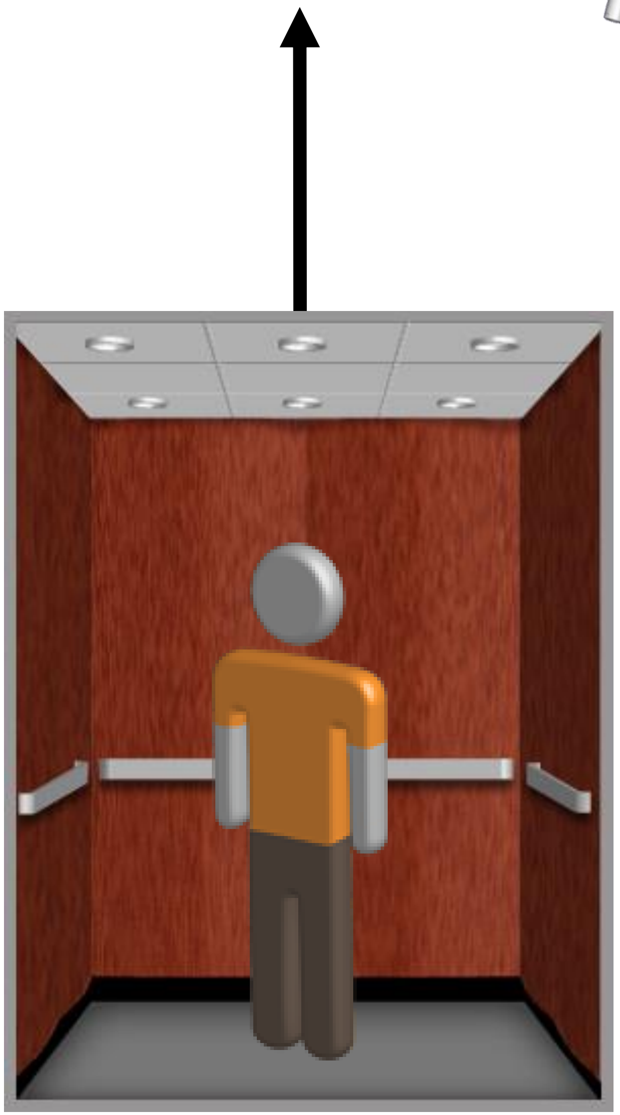
You are traveling on an elevator up the Sears tower, and you are standing on a bathroom scale.

As you near the top floor and are slowing down, the scale reads

A) More than your usual weight

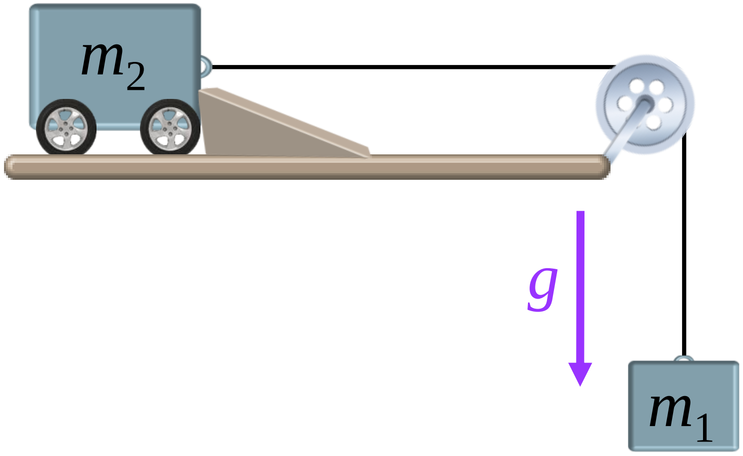
B) Less than your usual weight

C) Your usual weight



Question

A cart with mass m_2 is connected to a mass m_1 using a string that passes over a frictionless pulley, as shown below. The cart is held motionless.



The tension in the string is

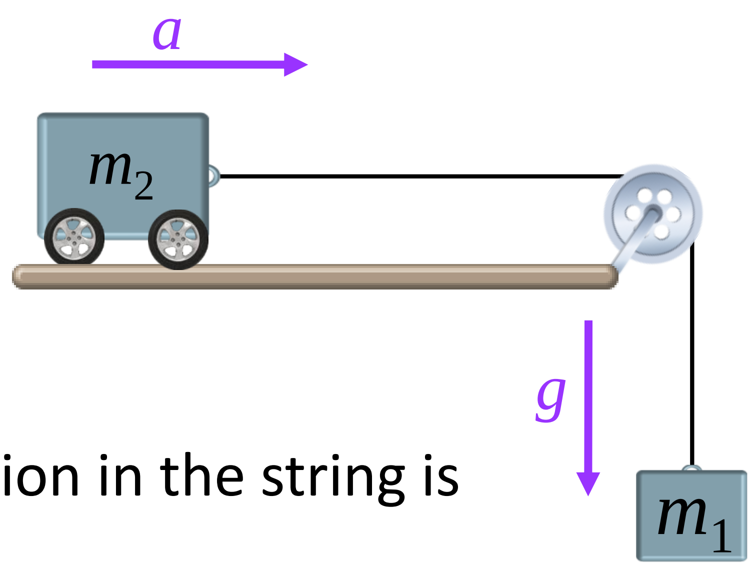
A) $m_1 g$

B) $m_2 g$

C) 0

Question

A cart with mass m_2 is connected to a mass m_1 using a string that passes over a frictionless pulley, as shown below. Initially, the cart is held motionless, but is then released and starts to accelerate.

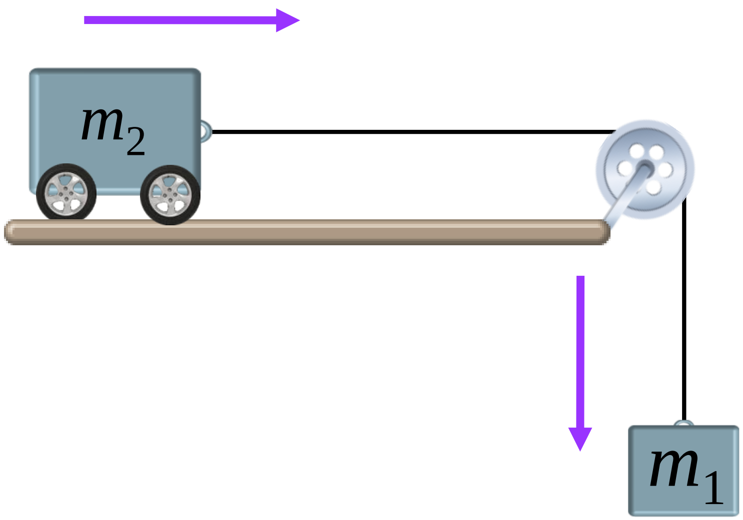


After the cart is released, the tension in the string is

A) $= m_1 g$
B) $> m_1 g$
C) $< m_1 g$

Example 5.2 (two carts)

A cart with mass m_2 = 10kg is connected to a mass m_1 = 5kg using a string that passes over a frictionless pulley, as shown below. Initially, the cart is held motionless, but is then released and starts to accelerate. What is the acceleration of m_1? What is the force due to tension in the string?



Question

Before we do any calculations, let's if we can come up with what is knows as a **limiting case check**.

What if $m_1 >>> m_2$? What will ***a*** approach?

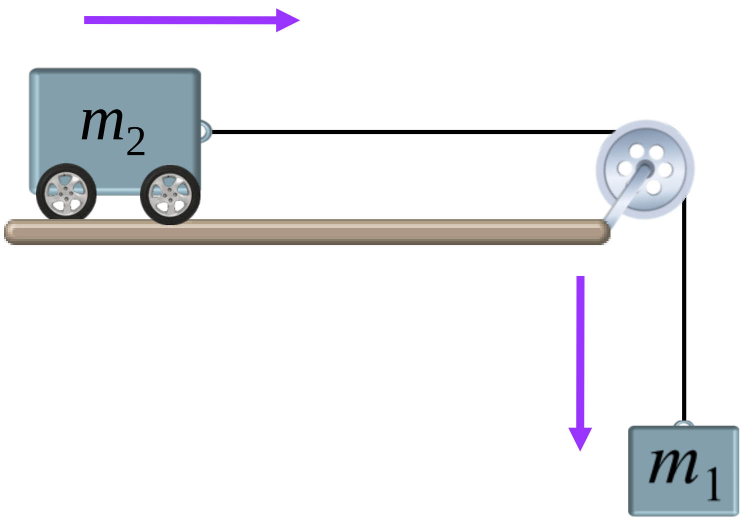
A) ***a*** ➞ g/2

B) ***a*** ➞ infinity

C) ***a*** ➞ zero

D) ***a*** ➞ g

E) ***a*** ➞ 2g



Lets find an additional **limiting case check**.

What if $m_2 >>> m_1$? What will $\boldsymbol{a}$ approach?

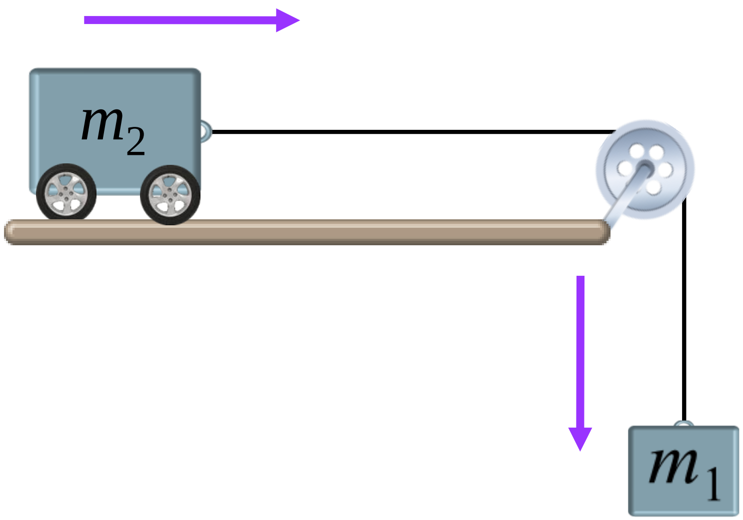
A) $\boldsymbol{a} \rightarrow g/2$

B) $\boldsymbol{a} \rightarrow$ infinity

C) $\boldsymbol{a} \rightarrow$ zero

D) $\boldsymbol{a} \rightarrow g$

E) $\boldsymbol{a} \rightarrow 2g$



Question

We has decided that if

- $m_1 >>> m_2$ then ***a*** would approach g
- $m_2 >>> m_1$ then ***a*** would approach 0

What if $m_1 = m_2$? What will ***a*** approach?

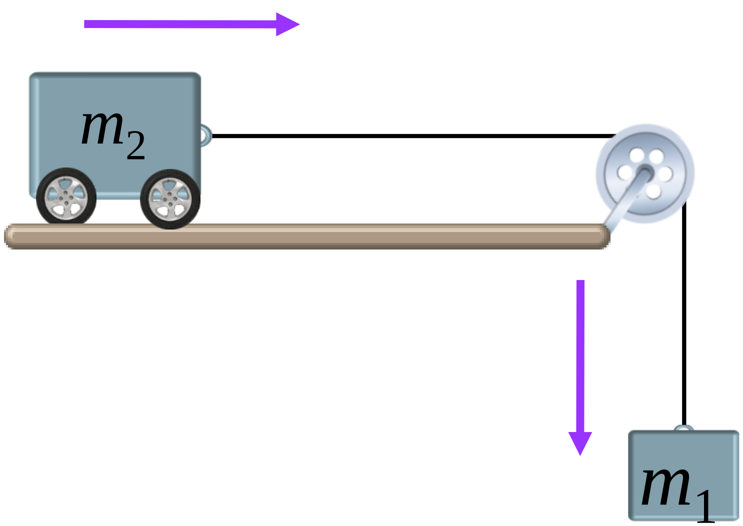
A) ***a*** → g/2

B) ***a*** → infinity

C) ***a*** → zero

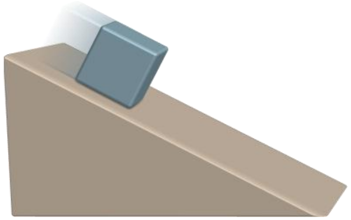
D) ***a*** → g

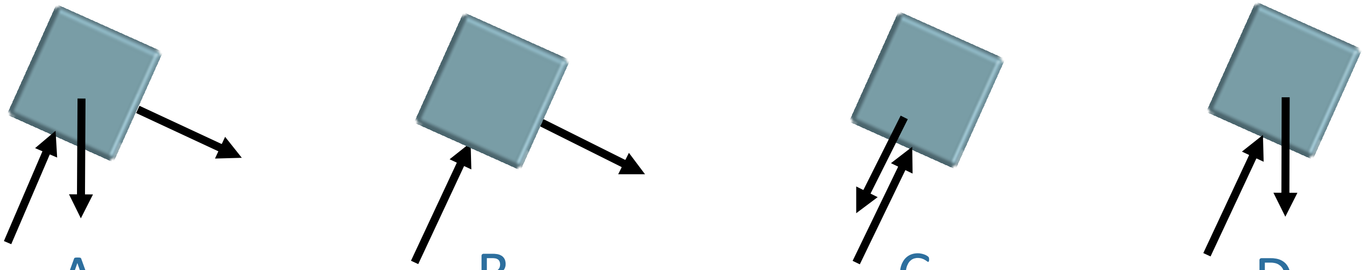
E) ***a*** → 2g



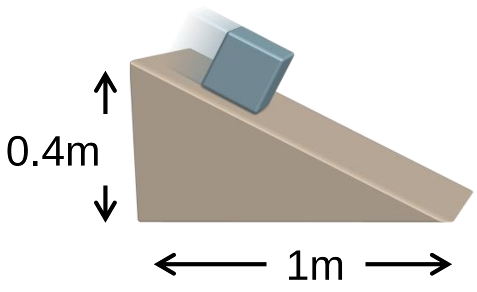
Question

A block slides down a frictionless inclined plane. Which of the following sketches most closely resembles the correct free body diagram for all forces acting on the block?

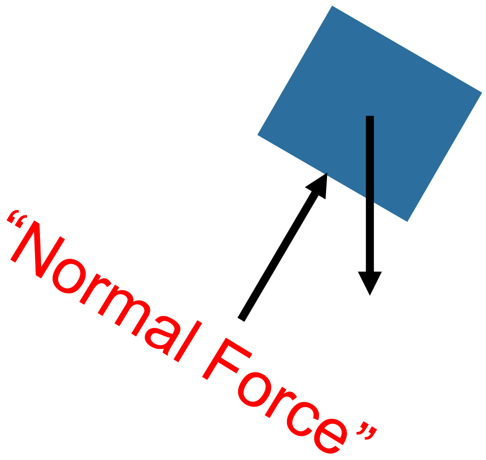




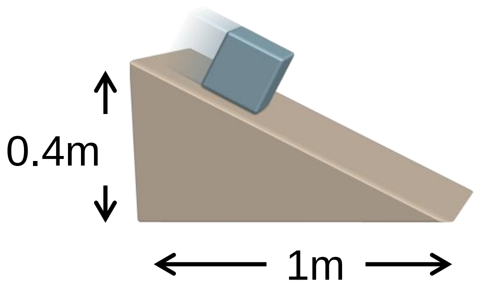
Example 5.3 (Block on Ramp)



A 1kg block slides down a frictionless ramp. The ramp has dimensions of 1m horizontally and 40cm vertically. What is the acceleration of the block?



Limiting Case Check



A 1kg block slides down a frictionless ramp. The ramp has dimensions of 1m horizontally and 40cm vertically.

What value of acceleration will be approached as the angle between the ramp and ground approaches zero?

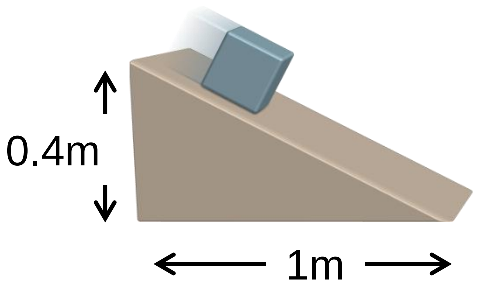
a) 0

b) g

c) g/2

d) infinitity

Limiting Case Check



A 1kg block slides down a frictionless ramp. The ramp has dimensions of 1m horizontally and 40cm vertically.

What value of acceleration will be approached as the angle between the ramp and ground approaches 90^o?

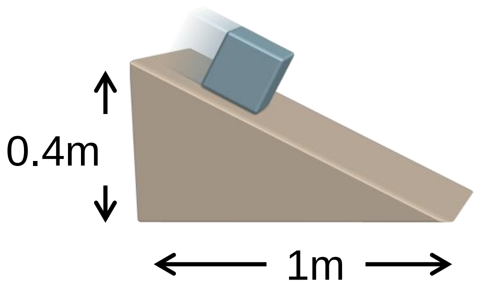
a) 0

b) g

c) g/2

d) infinitity

Limiting Case Check



A 1kg block slides down a frictionless ramp. The ramp has dimensions of 1m horizontally and 40cm vertically.

Based on our two limiting case checks, what might be a correct answer in this case?

a) $a = g*\sin\theta$

b) $a = g/\sin\theta$

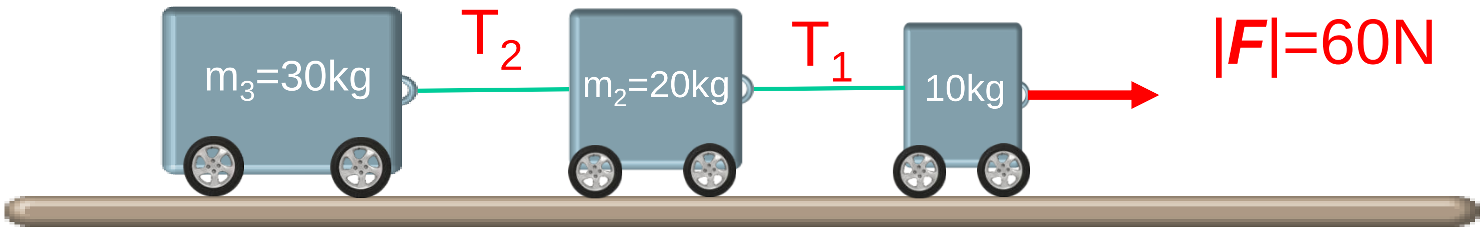
c) $a = g*\cos\theta$

d) $a = g/\cos\theta$

e) $a = g*\tan\theta$

Question

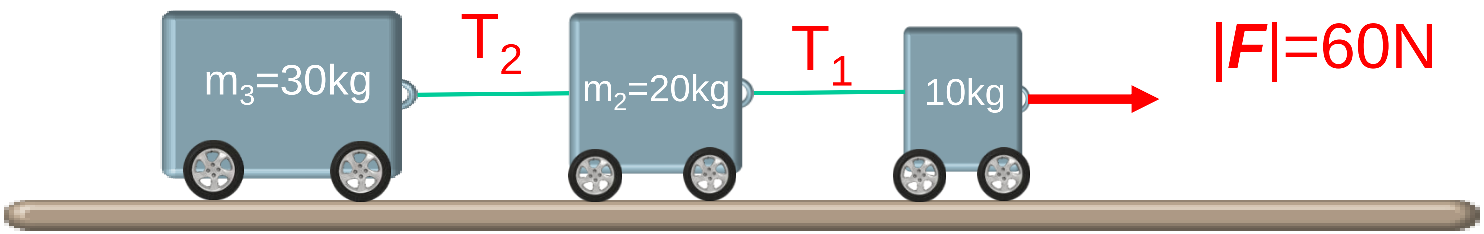
Three blocks of increasing mass are connected by string and are pulled across a frictionless surface by a 60N. What can we say about the acceleration of m_3, m_2 and m_1?



A. $|a_1| > |a_2| > |a_3|$
B. $|a_1| < |a_2| < |a_3|$
C. $|a_1| > |a_2| = |a_3|$
D. $|a_1| = |a_2| = |a_3|$

Question

Three blocks of increasing mass are connected by string and are pulled across a frictionless surface by a 60N. What can we say about the magnitude of ***|F|***, ***|T₂|*** and ***|T₁|***?



A. $|F| > |T_1| > |T_2|$

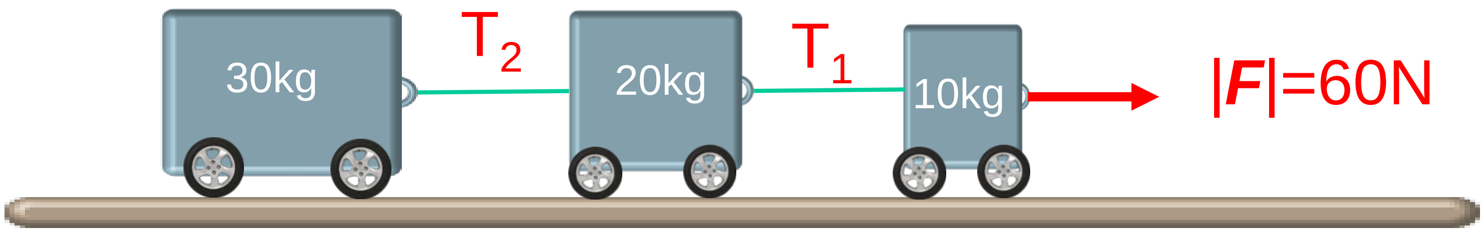
B. $|F| < |T_1| < |T_2|$

C. $|F| > |T_1| = |T_2|$

D. $|F| = |T_1| = |T_2|$

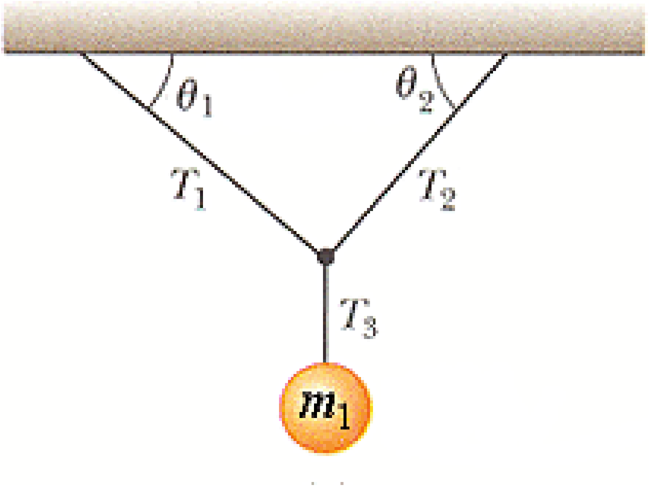
Example 5.5 (Three Blocks)

Three blocks of increasing mass are connected by string and are pulled across a frictionless surface by a 60N. What are ***|F|***, ***|T_2|*** and ***|T_1|***?



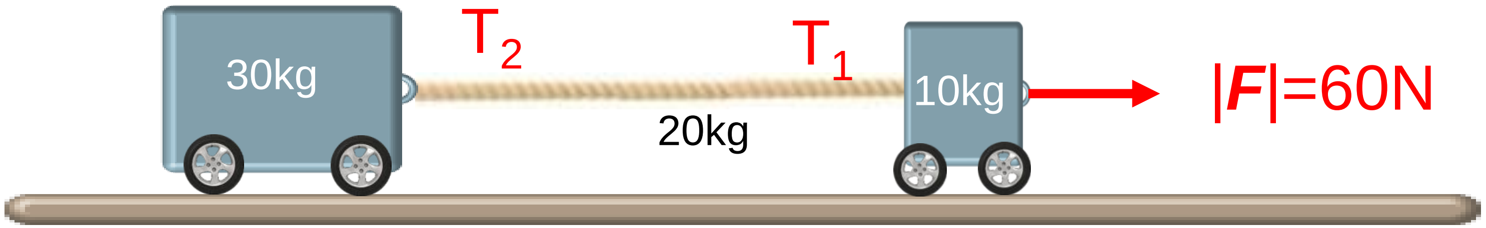
Example 5.4 (Cords Supporting a Mass)

Three cords support a m=15 kg mass as shown. Find the tensions in all three cords if $\theta_1 = 47°$ and $\theta_2 = 28°$

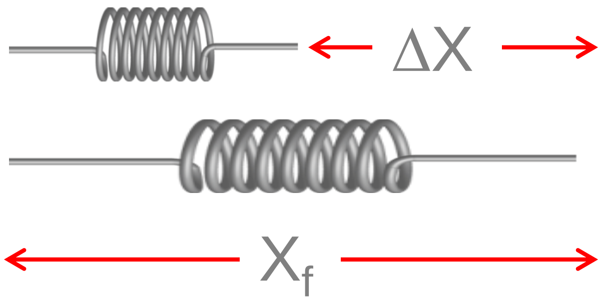


Example 5.5a (Massive Rope)

What if instead of a 20kg block, I had a massive 20kg rope there? What would be the force of tension at either end of the rope $|T_2|$ and $|T_1|$?



Springs



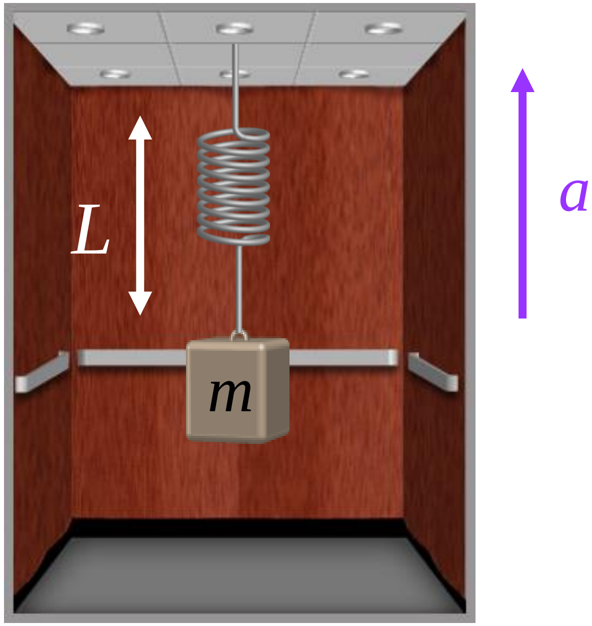
The harder you pull on them, the more they stretch.

Expressed as Hooke's Law:

$$\vec{F} = -k\Delta\vec{x}$$

Checkpoint

A box of mass m is hung by a spring from the ceiling of an elevator. When the elevator is at rest, the length of the spring is L = 1m.



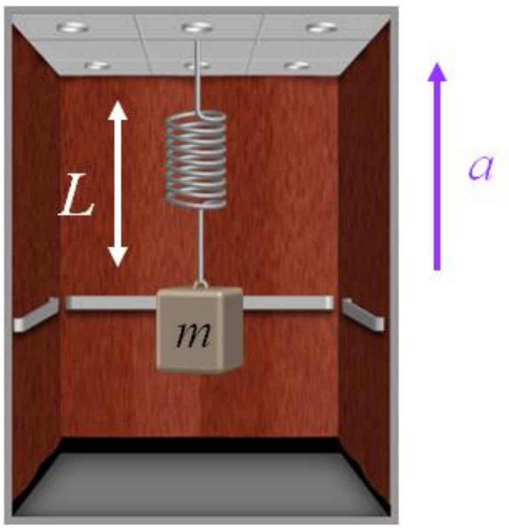
As the elevator accelerates upward, the length of the spring will be

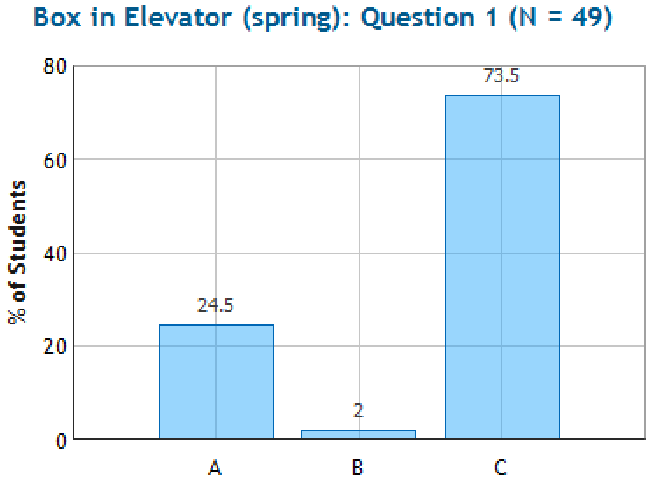
A. L < 1 m
B. L = 1 m
C. L > 1 m

What we thought……

As the elevator accelerates upward, the length of the spring will be

A. L < 1 m
B. L = 1 m
C. L > 1 m

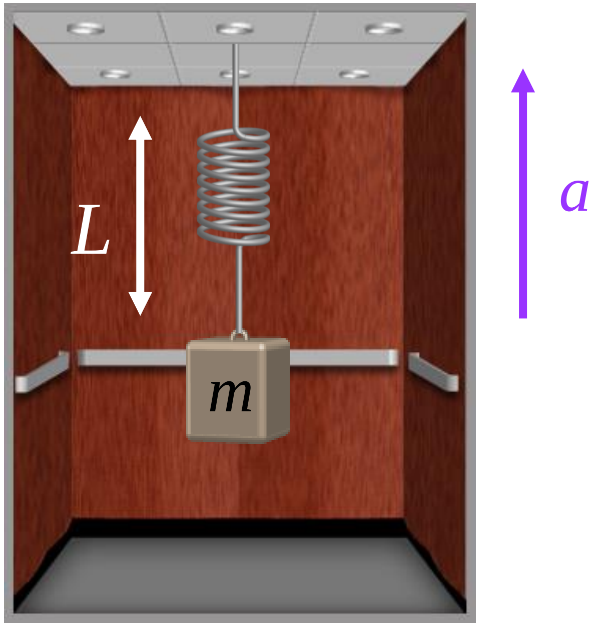




A. The two forces acting on the box are Fspring a accelerates upward, the spring will be compre smaller than 1 meter.

C. Since the force of gravity is pulling down and t pulling up, the tension on the spring is the sun greater than the force of gravity.

Example 5.6 (Spring in an elevator)

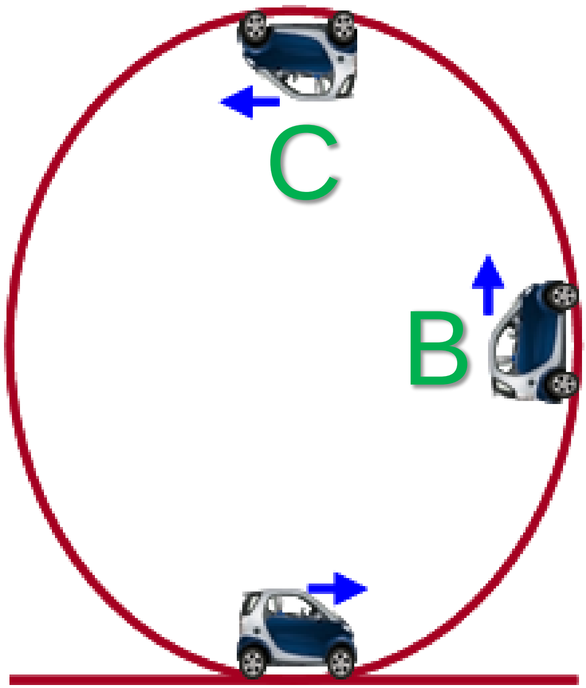


A mass of 5kg is hung vertically from a spring with a spring constant of k=100N/m. The spring has an unstretched length of 0.75m.

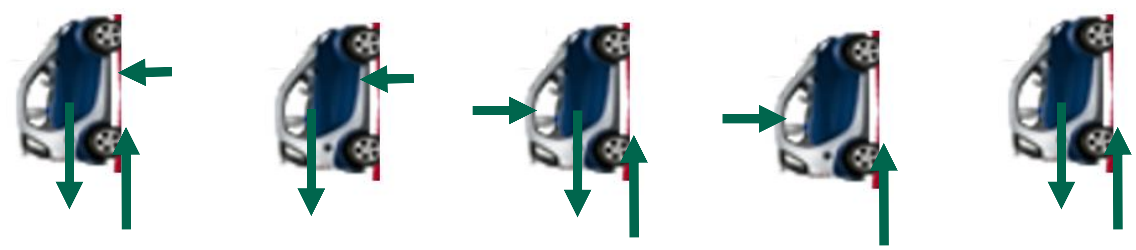
What is its length if the elevator is stationary?

What is its length if the elevator is accelerating upwards at 2m/sec^2?

What is the force of the spring on the top of the elevator?

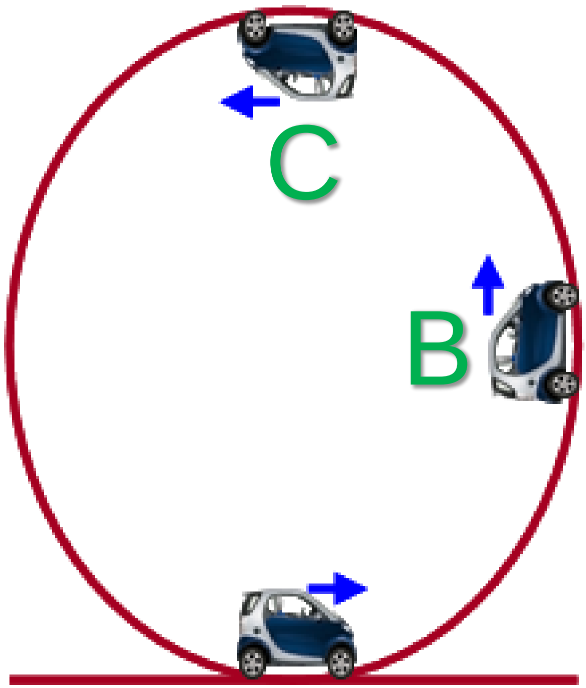


A stunt car goes around a loop-the-loop at a constant speed. Which of the below is the best FBD for the car when it is at point B?

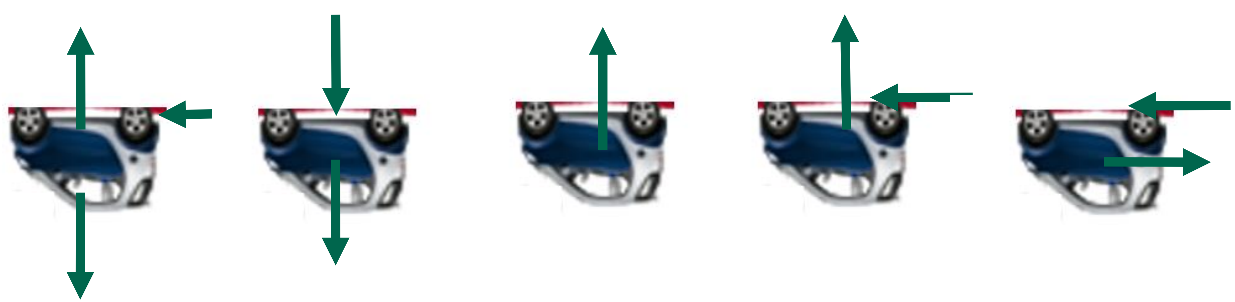


A B C D E

Question



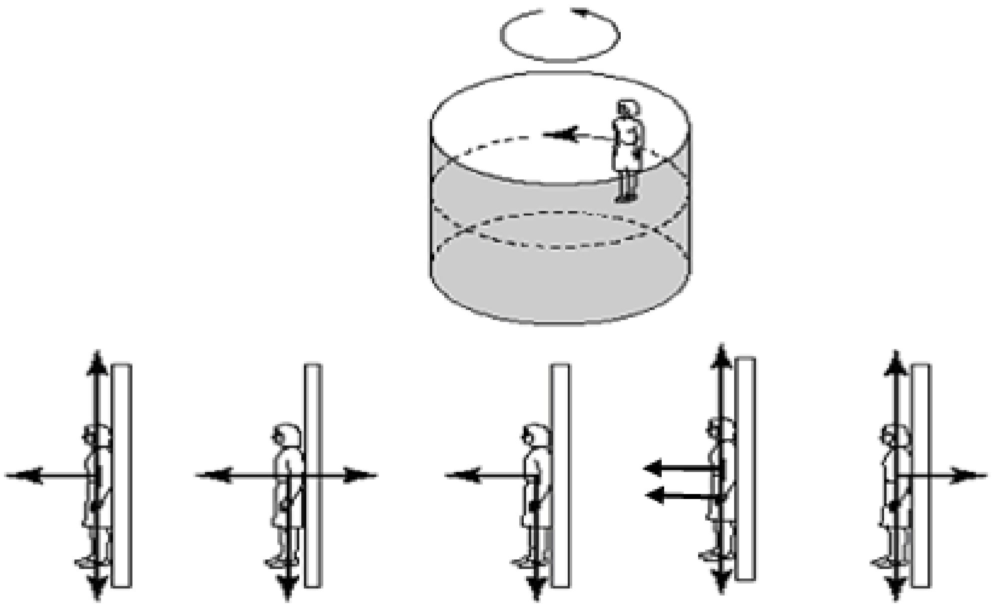
A stunt car goes around a loop-the-loop at a constant speed. Which of the below is the best FBD for the car when it is at point C?



A B C D E

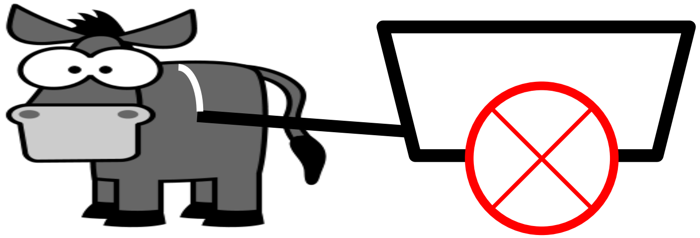
Question

A rider in a “barrel of fun” finds herself stuck with her back to the wall. Which freebody diagram correctly shows the forces acting on her?



A B C D E

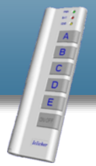
The Physics Donkey



Because you're tired of hauling your TI-83 all over campus, you decide to bring your donkey and cart with you to COD.

After physics class, you load all your books and stuff into the cart and tell the donkey to head off to Calc III. But the donkey replies (it's a talking physics donkey) "*There's no point in me trying. According to Newton's 3rd Law, no matter how hard I pull on the cart, the cart will pull back on me with an equal and opposite force. The two forces add up to zero and the cart won't accelerate. Since the cart isn't moving now, and a=0, it will never move.*" The donkey lays down and takes a nap.

Question



Why is the physics donkey wrong?

A. Because the donkey is less massive so the force of the donkey on the cart is always greater than the force of the cart on the donkey.

B. Because the force of the donkey on the cart is greater than the force of the cart on the donkey for the brief instant of time when the donkey takes his first step.

C. The donkey is correct that the forces are the same, but it doesn't matter in this case.

D. Because the cart is more massive so the force of gravity is greater on the cart than on the donkey.

E. The donkey is correct and the cart can not accelerate without an additional push.