

Newton's I and II Laws of Motion

What will happen if...

You apply the same force F to the following objects?



Sumo Wrestler

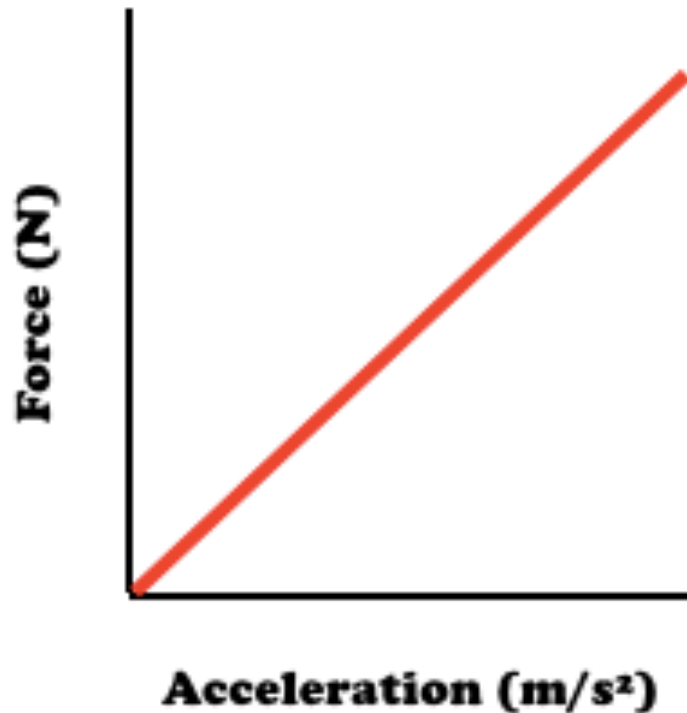


Smurf

The Smurf will experience a greater acceleration than the Sumo Wrestler!

What Have We Learned?

The force applied to an object is proportional to its acceleration.



Object 1 = 1.0 kg

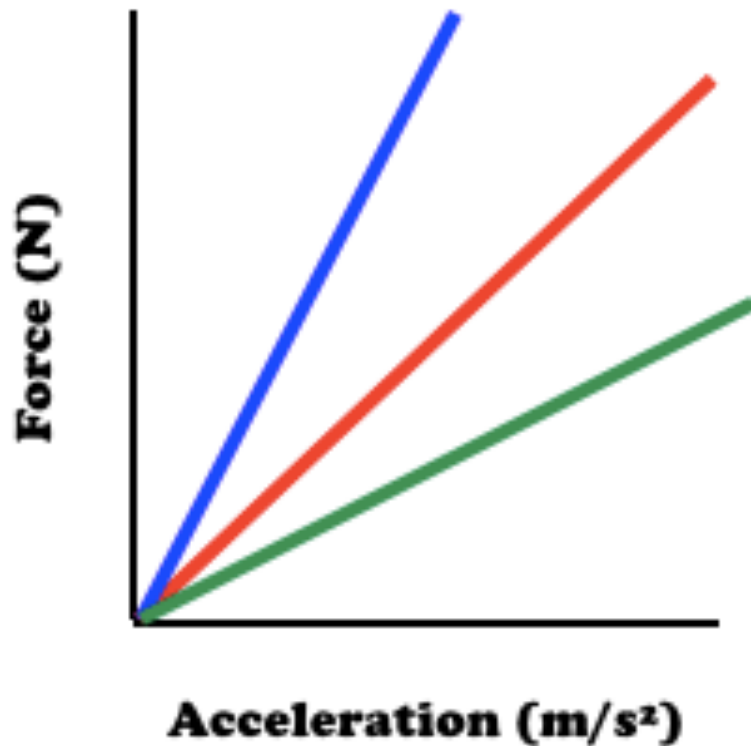
Object 2 = 2.0 kg

Object 3 = 3.0 kg

On your whiteboard, draw a force-acceleration graph for all three objects on the same axes!

What Have We Learned?

When there is a bigger mass, more force is needed to get the same acceleration.



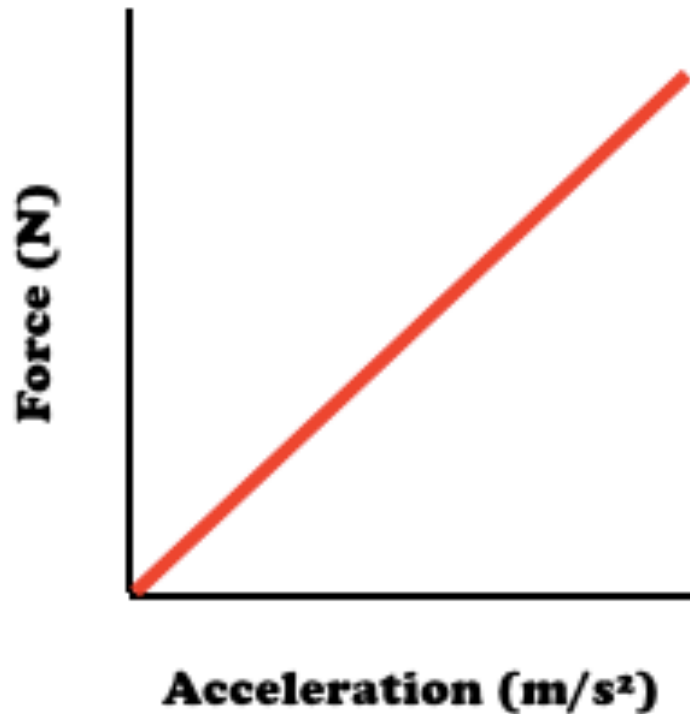
Object 1 = 1.0 kg

Object 2 = 2.0 kg

Object 3 = 3.0 kg

The mass determines how steep the line is on your graph!

What's the Mathematical Model?



$$y = mx$$



$$F_{\text{applied}} = ma$$

$$\text{Newton} = \text{Kg} \cdot \text{m/s}^2$$

$$1 \text{ N} = 0.225 \text{ lbs}$$

This is very similar to Newton's II Law!

The acceleration of an object as produced by a **net force** is directly proportional to the magnitude of the **net force** and in the same direction as the **net force**, while it is inversely proportional to the mass of the object.

What's a Net Force?

Objects often experience multiple forces.

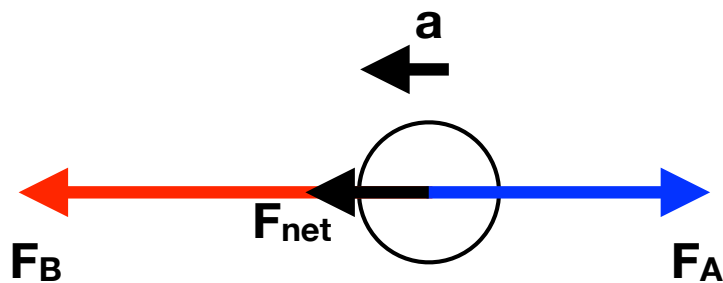


Person A

$$F_A = 25 \text{ N}$$

Person B

$$F_B = 40 \text{ N}$$



$$F_{\text{net}x} = F_A + F_B$$

$$F_{\text{net}} = \Sigma F_x$$

$$\Sigma F_x = \text{Vector sum}$$

What's an Unbalanced Force?

Objects often experience multiple forces.



Person A

$$F_A = 25 \text{ N}$$

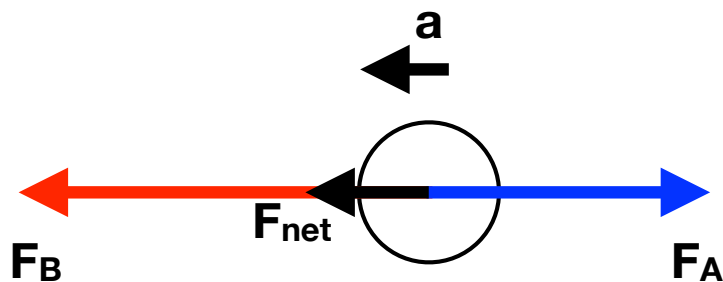
Person B

$$F_B = 40 \text{ N}$$

$$F_{\text{net}x} = ma_x$$

$$F_A + F_B = ma_x$$

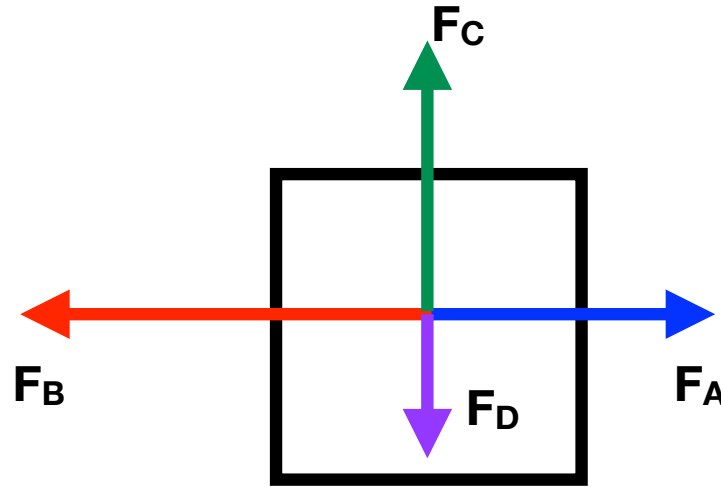
$$a_x = (F_A + F_B)/m$$



$$m = 1.0 \text{ kg}$$

$$a_x = (-25 \text{ N} + 40 \text{ N})/1 \text{ kg} = -15 \text{ m/s}^2$$

What Do We Do Now?

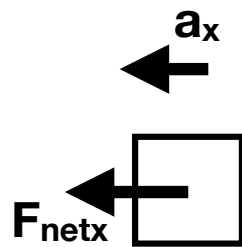


$$F_A = 25 \text{ N}$$

$$F_B = 40 \text{ N}$$

$$F_C = 20 \text{ N}$$

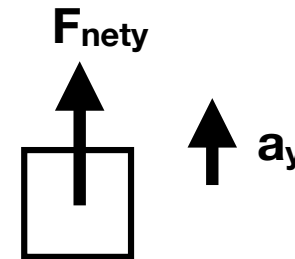
$$F_D = 10 \text{ N}$$



$$F_{\text{net}x} = ma_x$$

$$F_A + F_B = ma_x$$

$$a_x = -15 \text{ m/s}^2$$

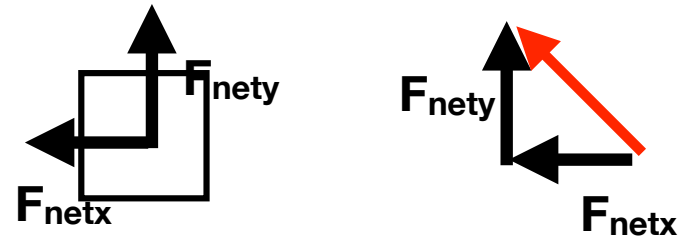
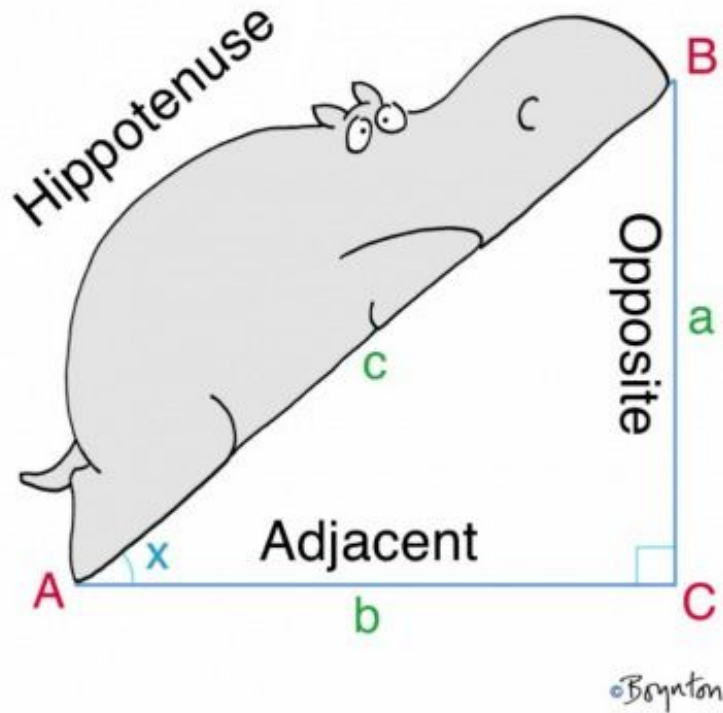


$$F_{\text{net}y} = ma_y$$

$$F_C + F_D = ma_y$$

$$a_y = 10 \text{ m/s}^2$$

Put Them Together!



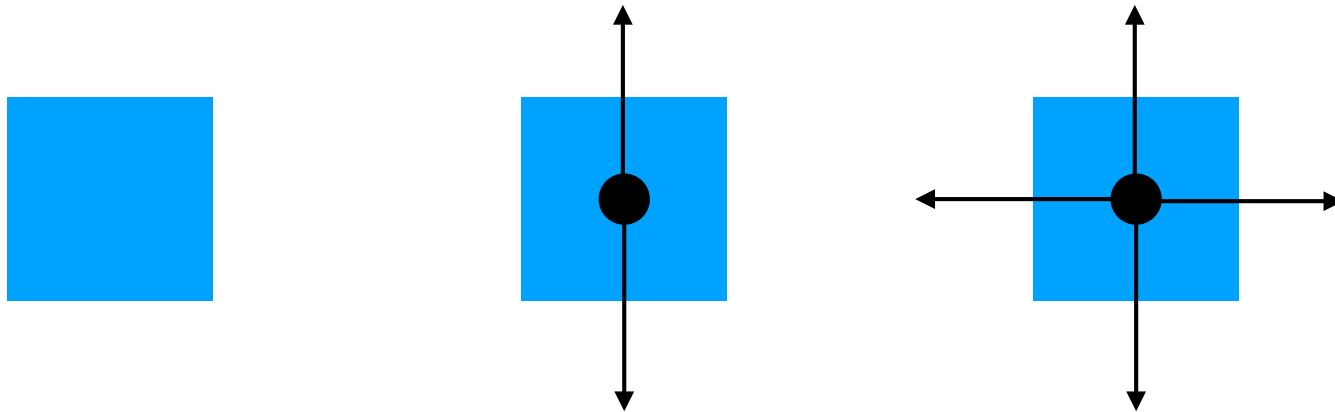
$$a_r^2 = a_x^2 + a_y^2$$

$$\tan \theta = a_y/a_x$$

$$a_r = 18.0 \text{ m/s}^2 \quad \theta = 146^\circ$$

What if the net force is zero?

On your whiteboard, create 2 situations that would have a net force of zero!



What are the objects acceleration in these scenarios?

$$F_{\text{net}} = 0$$

$$F_{\text{net}} = ma$$

$$a = 0 \text{ m/s}^2$$

Describe how the objects are moving!

What if the net force is zero?

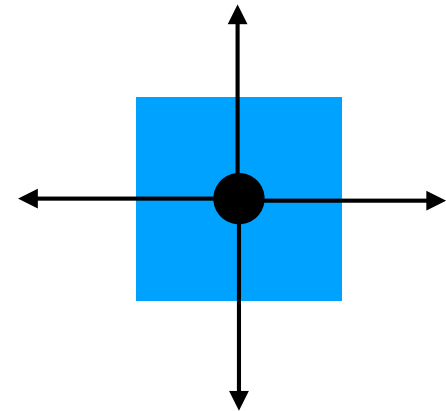
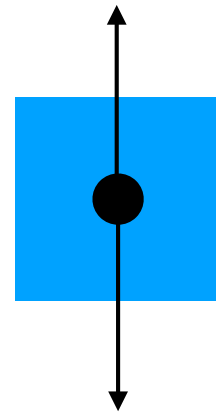
If an object has an acceleration of zero, the object is either:

Not Moving

Moving at constant velocity

Meet Newton's First Law!

Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.

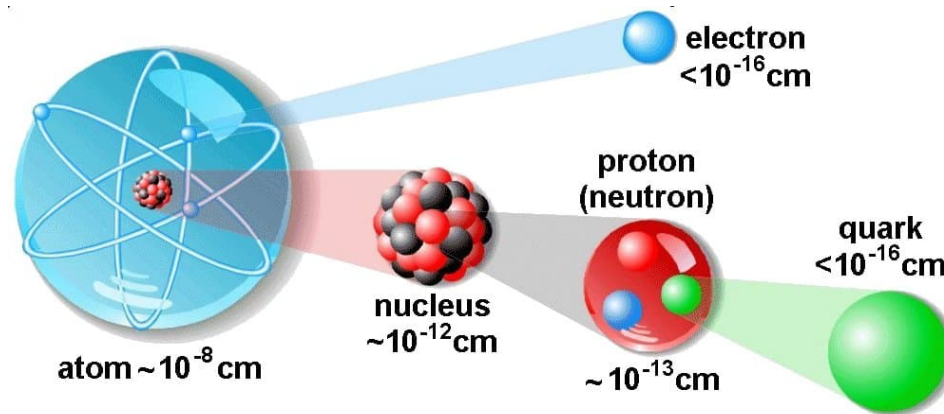


Defining Boundaries

Newton developed three laws of motion that are able to explain many different observable phenomena in a simple way.

Just like all scientific theories, Newton's laws operate under a set of assumptions.

1. The objects that these laws are being applied to are large compared to the diameter of an atom.



At this level, motion is governed by quantum mechanic theory.

Defining Boundaries

2. Objects are moving significantly slower than the speed of light.



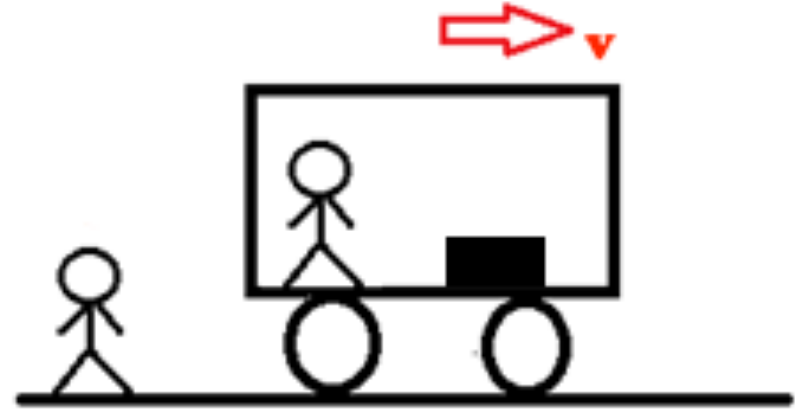
Object must stay at around 20% of the speed of light or slower!

At higher speeds, motion is governed by the theory of relativity.

Defining Boundaries

3. Observations must be made in an inertial reference frame.

A reference frame is defined as a set of coordinates that can be used to determine positions and velocities of objects.

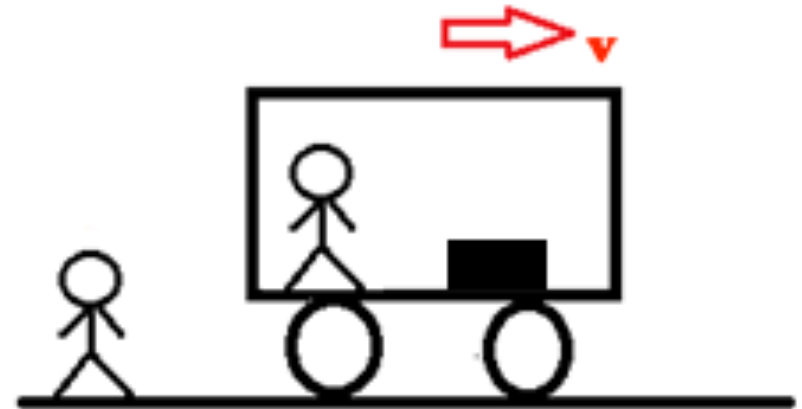


According to the person on the train, the velocity of the box is 0 m/s.

According to the person at the train station, the velocity of the box is v m/s.

Reference Frames

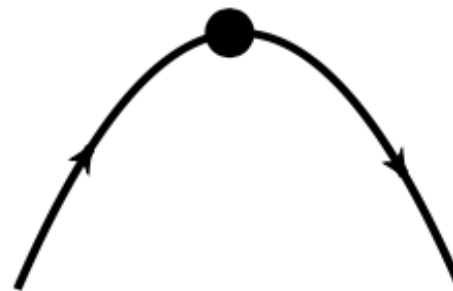
Let's say that the person on the train, tosses a ball into the air.



On your whiteboard, draw what the motion of the ball will look like to a the person on the train and the person on the ground.



Observer on train



Observer at station

Reference Frames

An inertial reference frame is one that is not accelerating.



Physics

Observe one of the physics books sitting on my front table.

Are you observing it from an inertial reference frame?

Are you moving?

Earth as a Reference Frame

Technically, the Earth's surface is not an inertial reference frame.



The Earth's rotation and precession cause us to accelerate.

So why do Newton's laws work so well?

Because the objects we are observing are so small compared to the Earth, the effects of the acceleration is so small that we can assume that we are in an inertial reference frame.

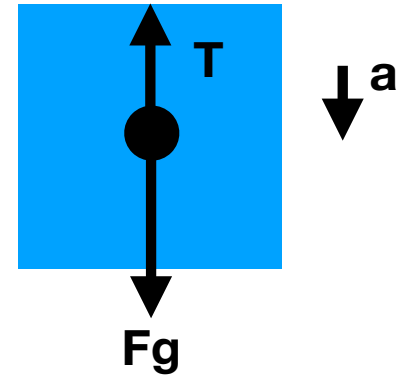
Dynamics Problem Set

Topic	Sections	Questions
Newton's First and Second Law	4.3 & 4.4	1, 3, 10, 12, 14
Newton's Third Law	4.5	16
Types of Forces	4.7 & 4.8	22, 38, 40, 43
Friction	4.9	46, 48
Applications of Newton's Laws	4.10 & 4.11	54, 55, 62, 74, 79

How-To-Guide for Free-body Diagrams!

1. Draw all vectors starting at the dot.

2. The only vectors that are drawn on the object are **FORCES** acting on the object.



3. Make sure that all forces are labeled appropriately.

F_g = Force of Gravity **N = Normal Force** **T = Tension**

f_s = static friction

f_k = kinetic friction

4. Indicate the magnitude of the force using the length of the vectors.

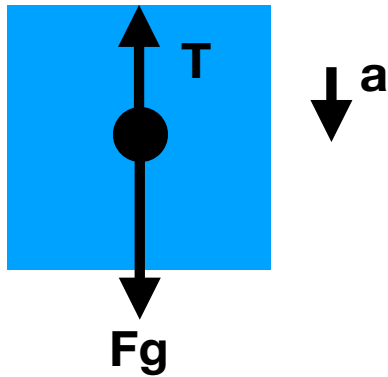
5. Indicate the acceleration of the object using an acceleration vector that is near the object.

What is the process?

Choose one of Newton's Laws

$$F_{\text{net}} = 0 \quad F_{\text{net}} = ma$$

Apply the law you selected



$$F_{\text{net}} = ma$$



$$T + (-F_g) = m(-a)$$

Solve for the appropriate quantity!

$$T - F_g = -ma$$

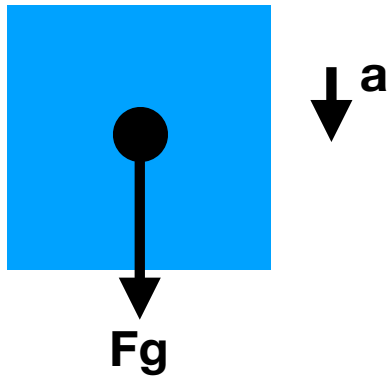
$$T = F_g - ma$$

What is the Force due to Gravity?

Choose one of Newton's Laws

$$F_{\text{net}} = 0 \quad F_{\text{net}} = ma$$

Apply the law you selected



$$F_{\text{net}} = ma$$

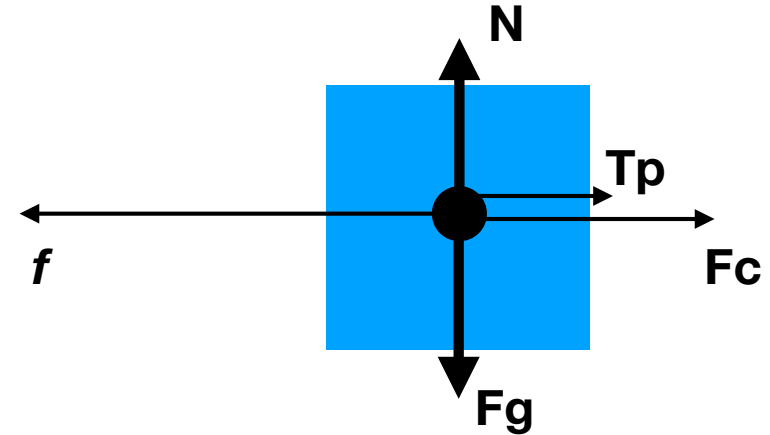
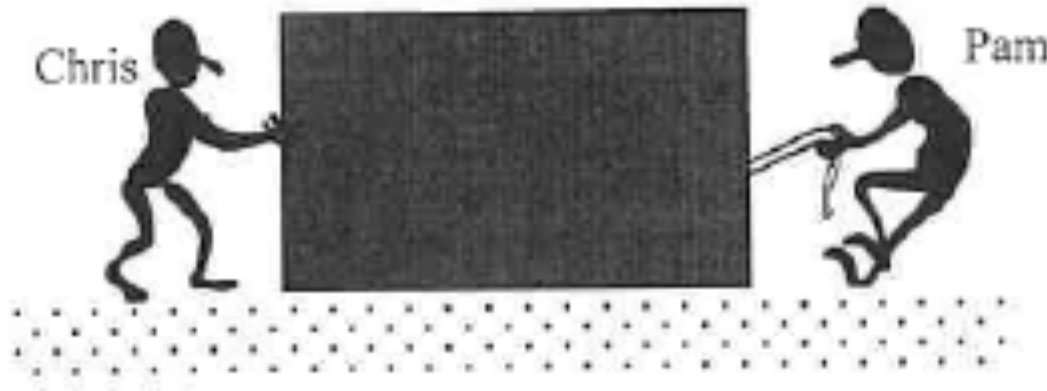


$$-F_g = m(-a)$$

Solve for the appropriate quantity!

$$F_g = ma_g \quad \text{where } a_g = 9.8 \text{ m/s}^2$$

What's the Force of Friction and Normal Force?



x-direction

y-direction

Choose one of Newton's Laws

Choose one of Newton's Laws

$$F_{\text{net}} = 0 \quad F_{\text{net}} = ma$$

$$F_{\text{net}} = 0 \quad F_{\text{net}} = ma$$

Apply the law you selected

Apply the law you selected

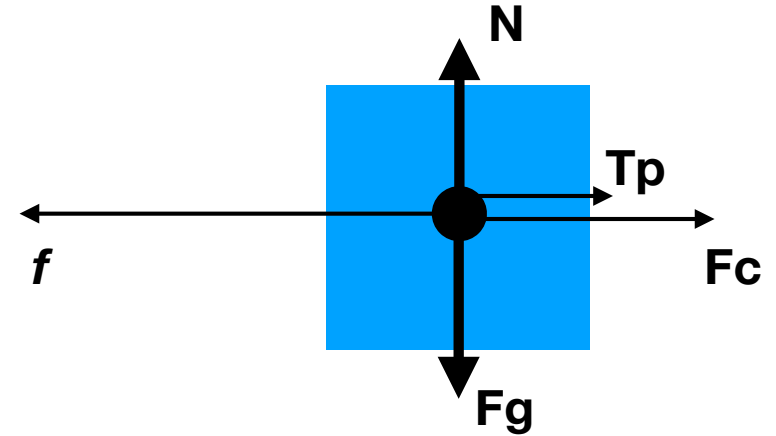
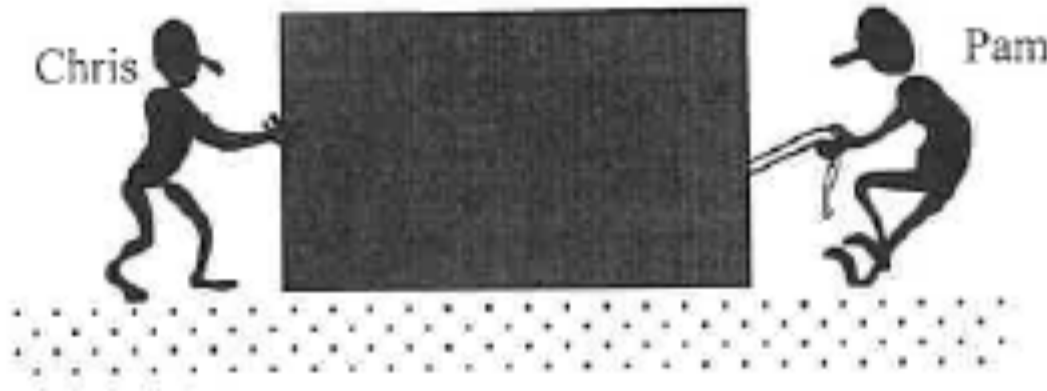
$$F_c + T_p + (-f) = 0$$

$$N + (-F_g) = 0$$

$$f = F_c + T_p \quad f = 50 \text{ N}$$

$$N = F_g \quad F_g = 98 \text{ N}$$

What's the coefficient of friction



$$f = \mu N$$

$$\mu = f/N$$

$$\mu = 50 \text{ N}/98 \text{ N}$$

$$\mu = 0.51$$

Calvin and Hobbes Meet Newton

Hobbes is pulling Calvin on his sled.
Calvin and the sled have a total mass of 20 kilograms and Hobbes can pull with a force of 8.5 N. In addition, there is a frictional force that acts in the opposite direction of Hobbes with a magnitude of 2.0 N. What will Calvin's acceleration be?



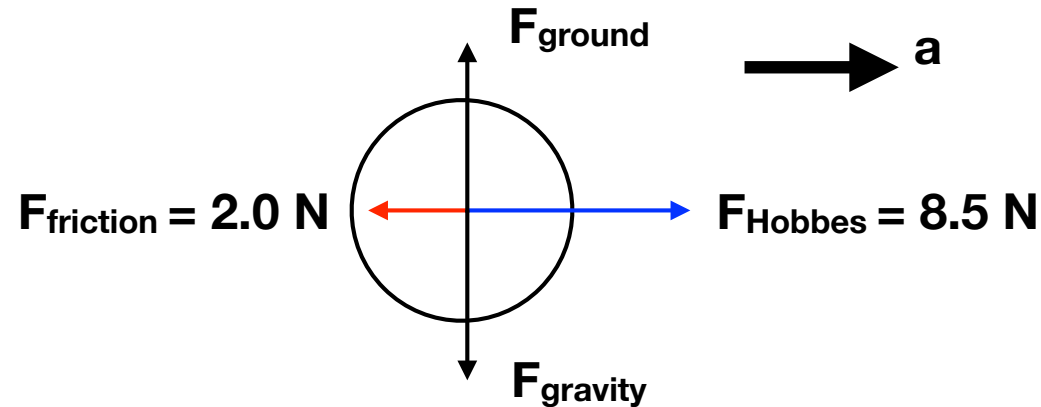
Let's Make PIES!

Calvin and Hobbes Meet Newton

$$F_{\text{Hobbes}} = 8.5 \text{ N}$$

$$F_{\text{Friction}} = 2.0 \text{ N}$$

$$m = 20 \text{ kg}$$



$$F_{\text{net}x} = ma_x$$

$$F_{\text{net}y} = 0$$

$$F_{\text{Hobbes}} + (-F_{\text{friction}}) = ma_x$$

$$a_y = 0 \text{ m/s}^2$$

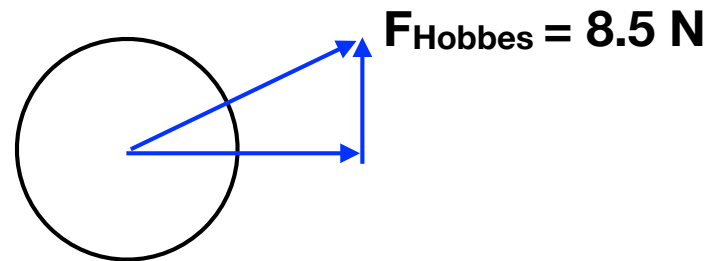
$$F_{\text{Hobbes}} - F_{\text{friction}} = ma_x$$

$$a_x = (F_{\text{Hobbes}} - F_{\text{friction}})/m$$

$$a_x = 0.325 \text{ m/s}^2$$

Calvin and Hobbes Meet Newton

What if Hobbes pulled at a 45° ??



$$F_{\text{Hobbes}x} = 8.5 \text{ N} \cos 45^\circ$$

$$F_{\text{Hobbes}y} = 8.5 \text{ N} \sin 45^\circ$$

$$F_{\text{Hobbes}x} = 6.0 \text{ N}$$

$$F_{\text{Hobbes}y} = 6.0 \text{ N}$$

There is still an acceleration in the x-direction!

There is still no acceleration in the y-direction!

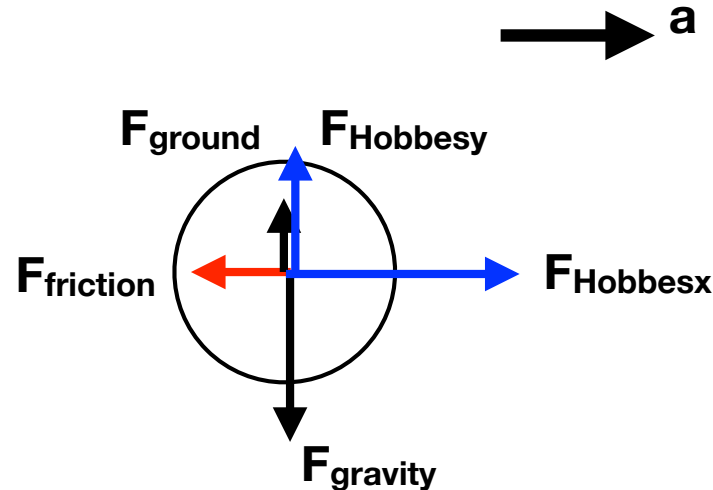
Calvin and Hobbes Meet Newton

$$F_{\text{Hobbes}x} = 6.0 \text{ N}$$

$$F_{\text{friction}} = 2.0 \text{ N}$$

$$F_{\text{Hobbes}y} = 6.0 \text{ N}$$

$$m = 20 \text{ kg}$$



$$F_{\text{net}x} = ma_x$$

$$F_{\text{Hobbes}x} + (-F_{\text{friction}}) = ma_x$$

$$F_{\text{Hobbes}x} - F_{\text{friction}} = ma_x$$

$$a_x = (F_{\text{Hobbes}x} - F_{\text{friction}})/m$$

$$a_x = 0.25 \text{ m/s}^2$$

$$F_{\text{net}y} = 0$$

$$a_y = 0 \text{ m/s}^2$$

Does this make sense?

The sled won't accelerate as much in the x-direction because some of the force is now in the y-direction.