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Progressive Science Initiative

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PSI Physics

Dynamics:
The Laws of motion

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Intro to Dynamics: Thought Experiment

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Intuitive Physics

We all have an intuition about how objects move.

Our beliefs are hard to change since they work well in our day-to-day lives.

But they limit us in developing an understanding of how the world works - we must build on our intuition and move beyond it.

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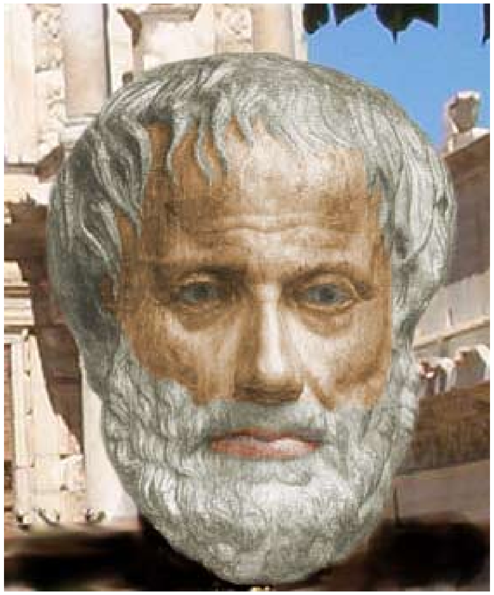
Galileo vs. Aristotle

In our experience, objects must be pushed in order to keep moving. So a force would be needed to have a constant velocity.

This is what Aristotle claimed in his in his seriesof books entitled "*Physics*", written 2400 years ago.



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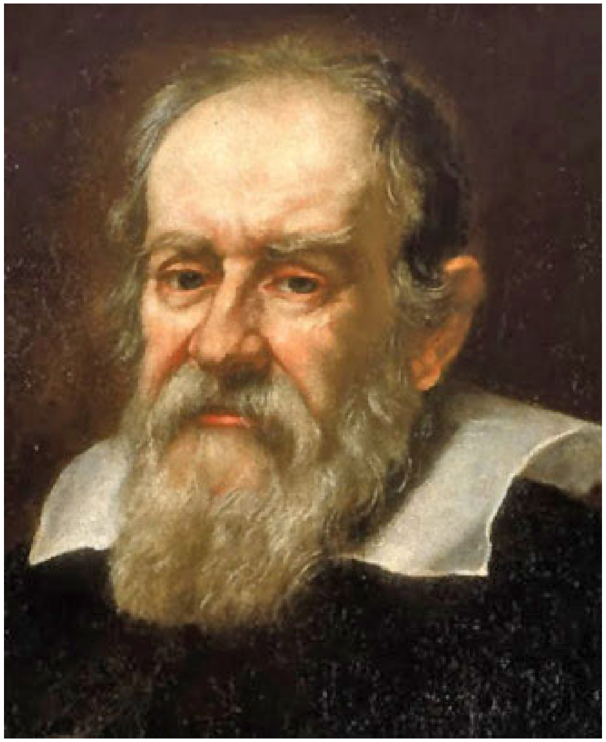
Galileo vs. Aristotle



But 400 years ago, another scientist and astronomer, Galileo, proposed the following thought experiment which revealed another perspective.

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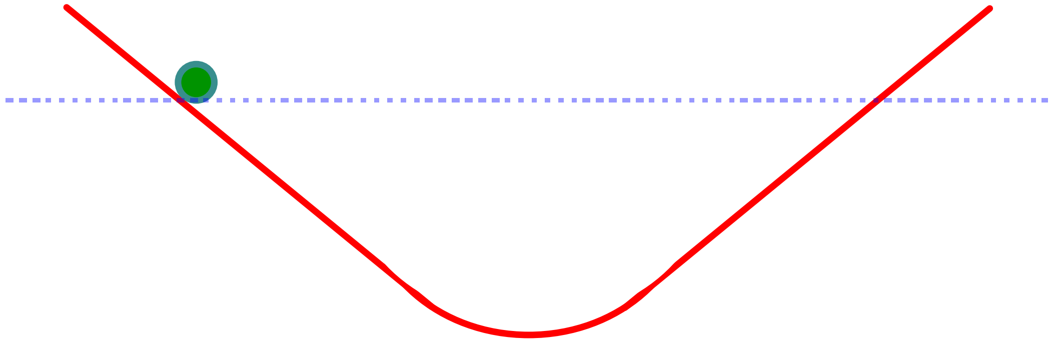
Thought Experiment

Imagine two perfectly smooth ramps connected together by a perfectly smooth surface. If a ball is let go at the top of the one ramp, *what will happen?*



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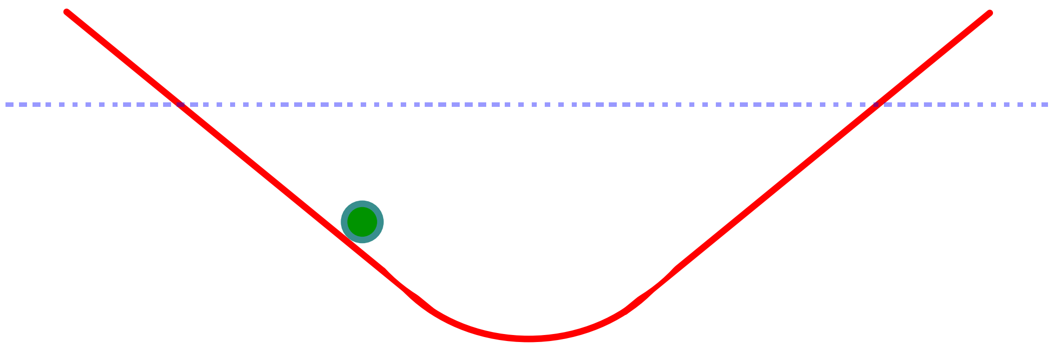

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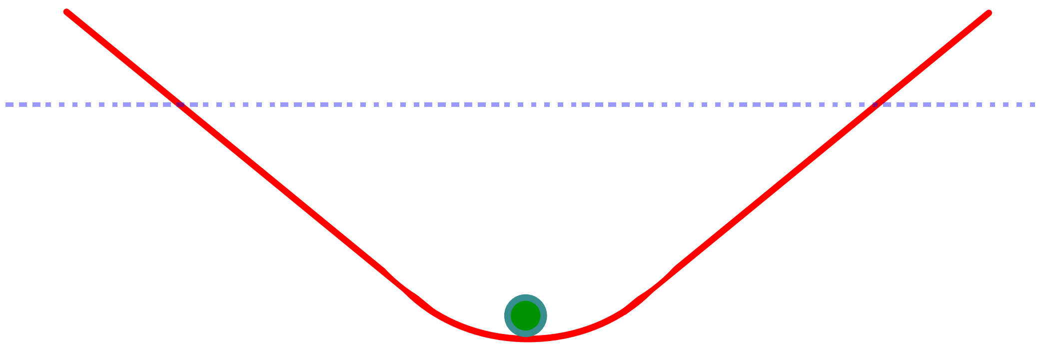

Thought Experiment

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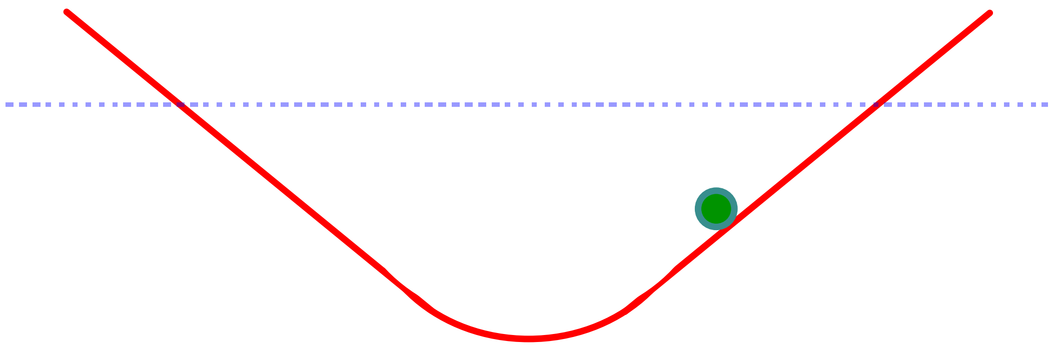
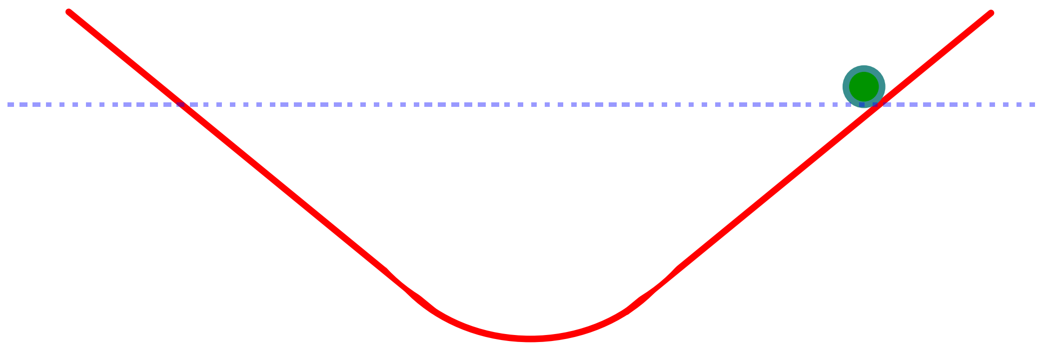


Thought Experiment

If a ball rolls down one ramp, it keeps rolling up the other side until it reaches the same height.



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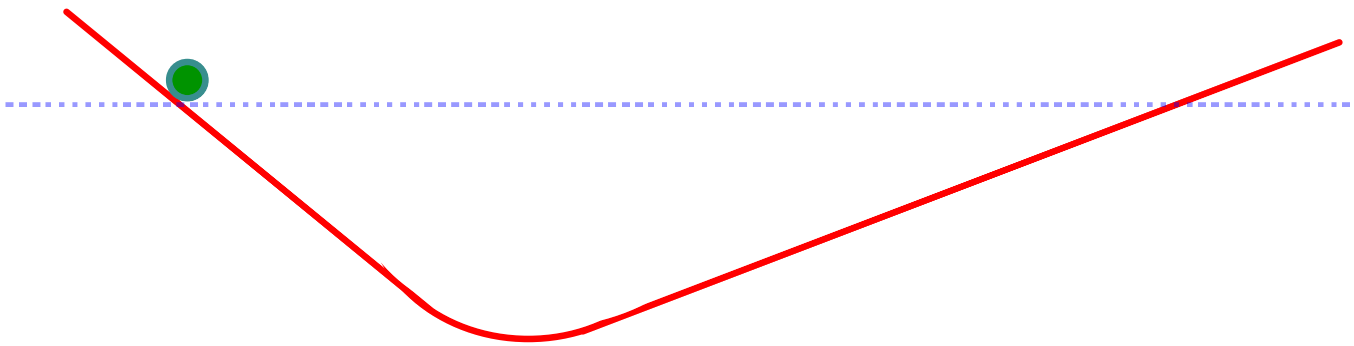
Thought Experiment

Now repeat that experiment, but make the second ramp less steep.

What Will Happen?



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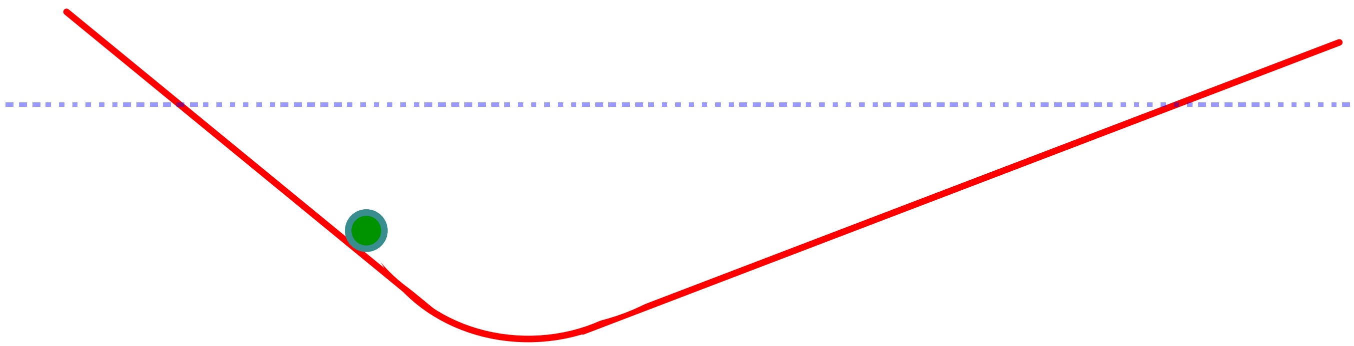

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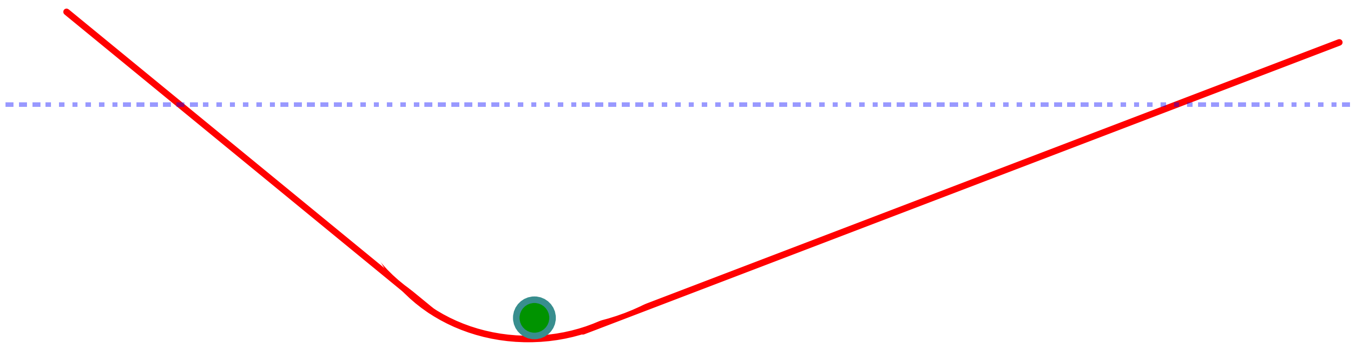

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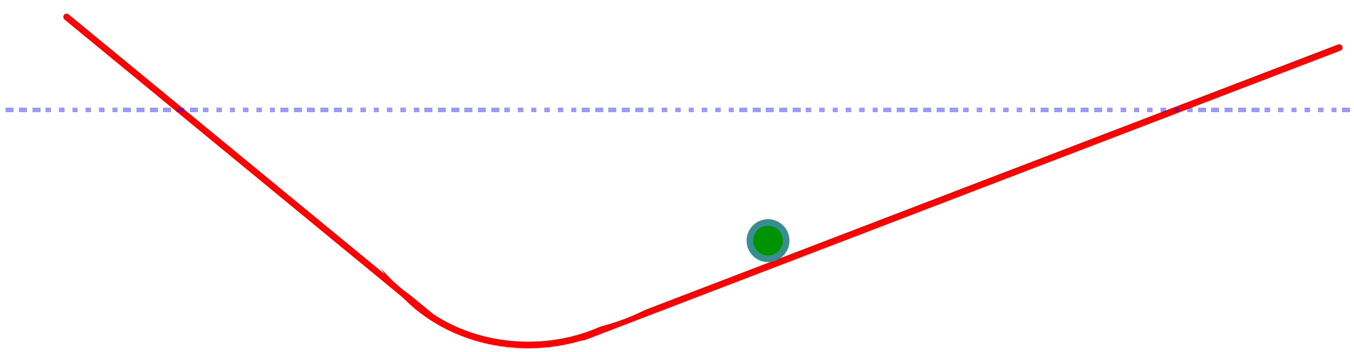
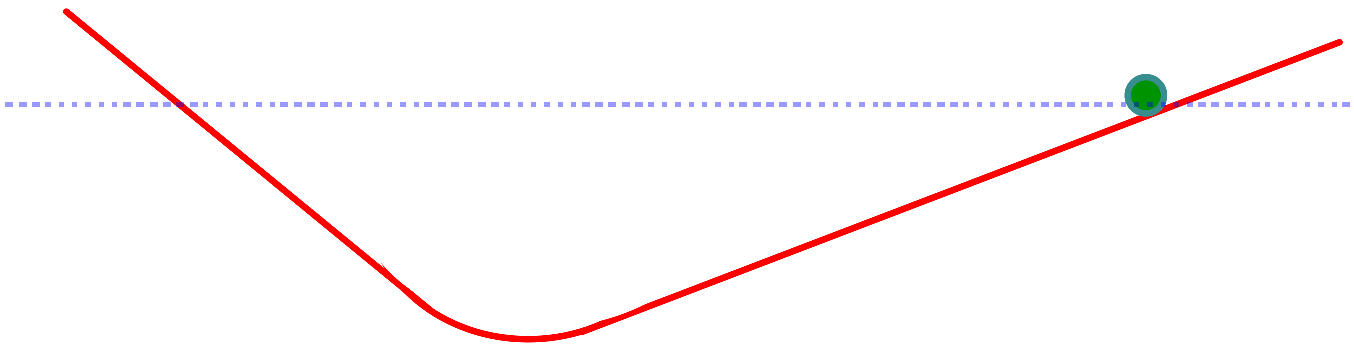


Thought Experiment

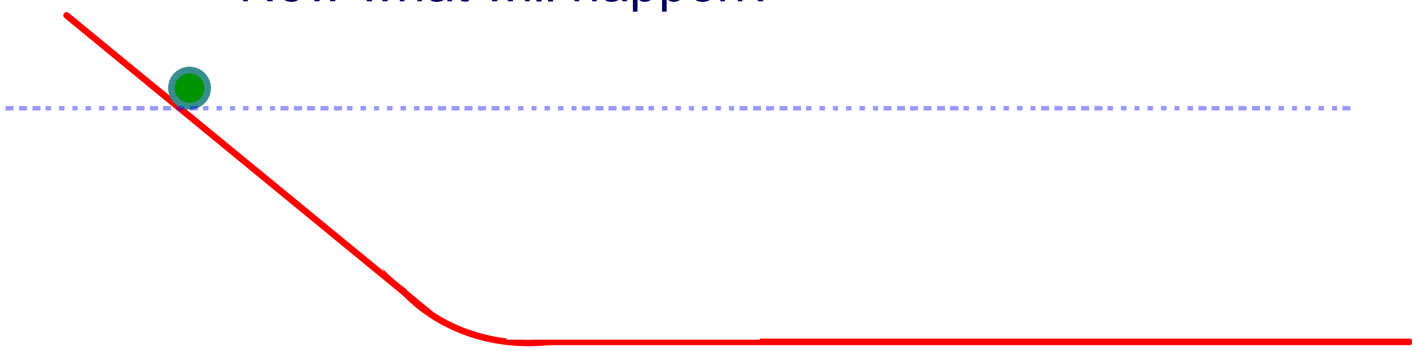
It will still keep rolling until it reaches the same height, but it has to roll farther!



Thought Experiment

Finally, make the ramp flat.

Now what will happen?



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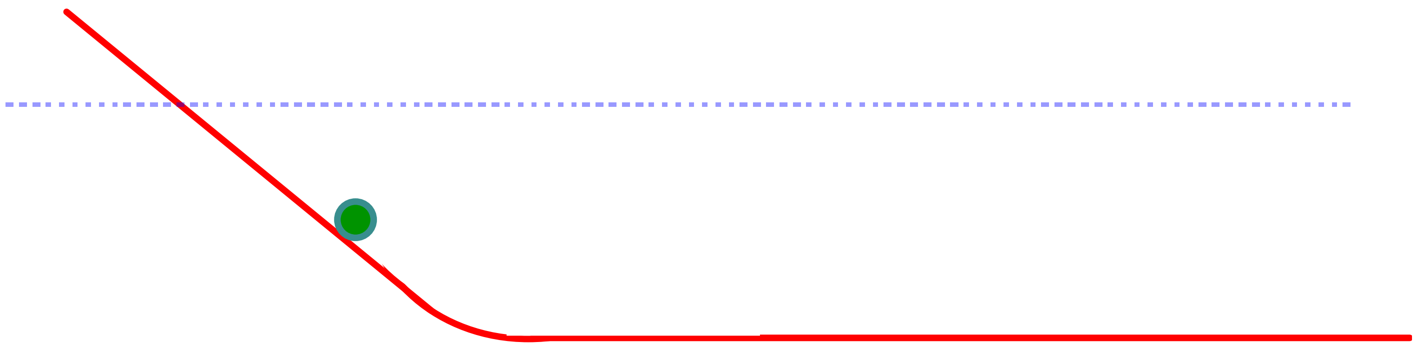

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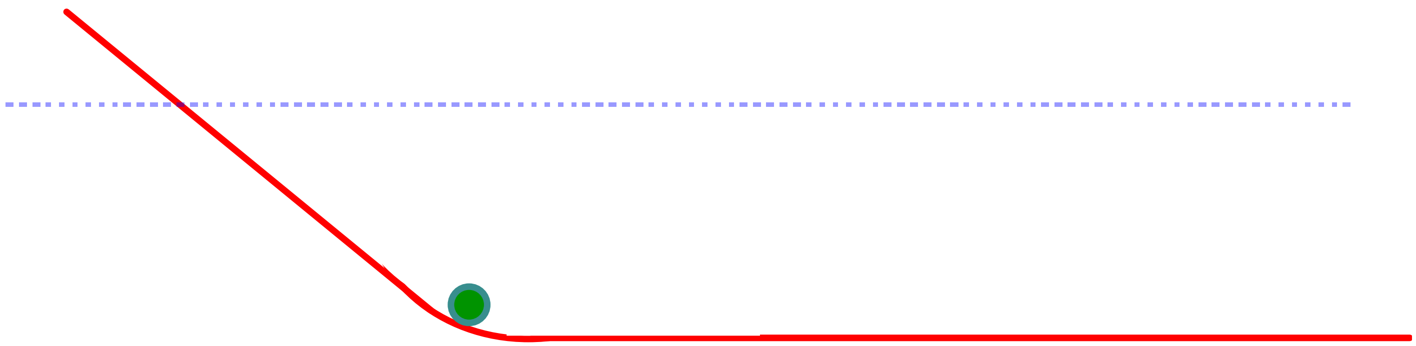

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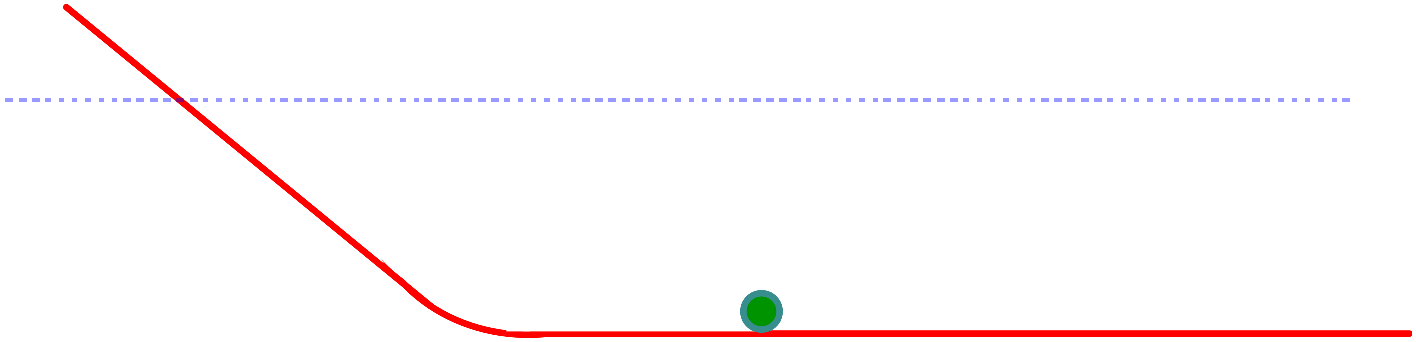

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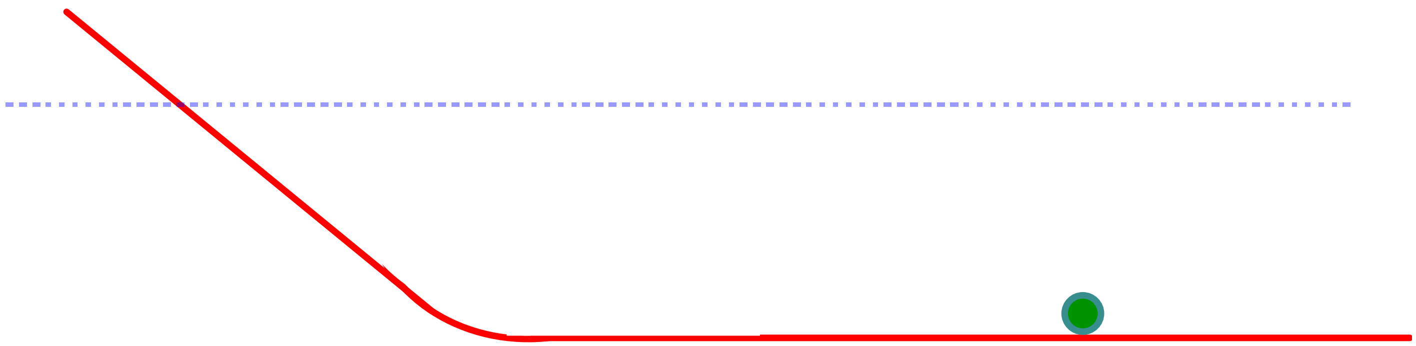

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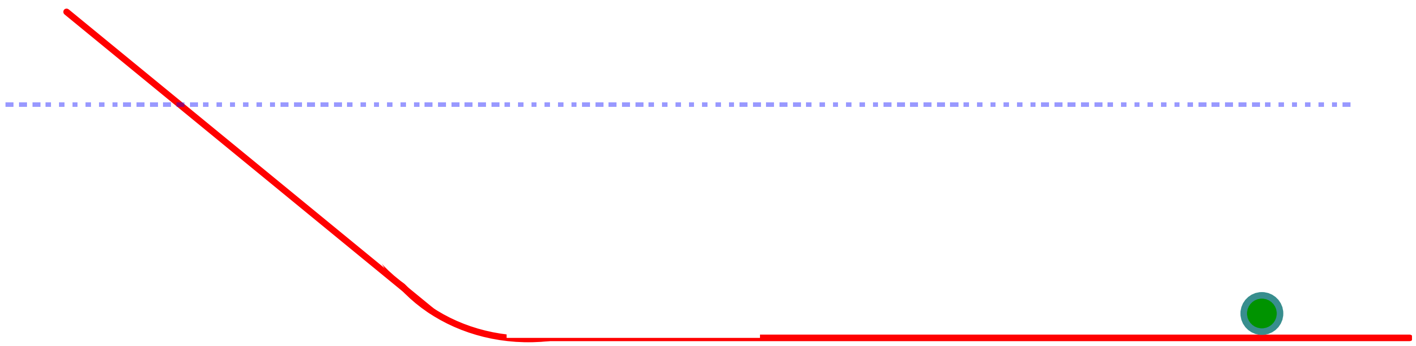
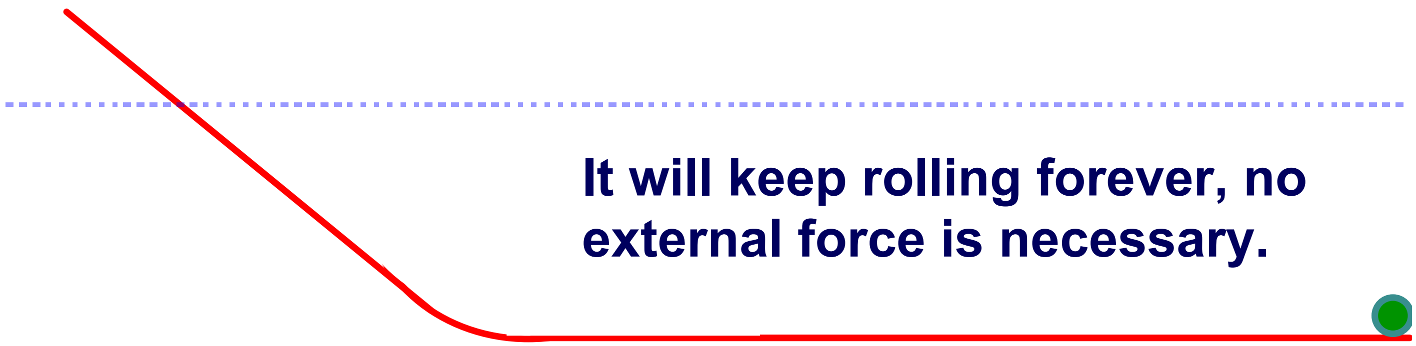


Thought Experiment

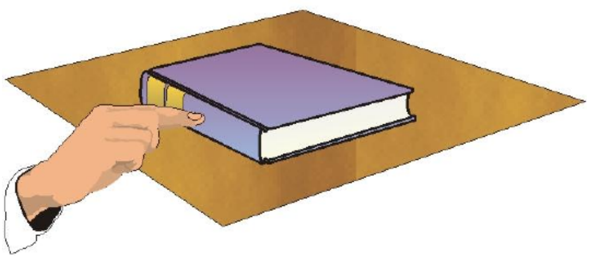


It will keep rolling forever, no external force is necessary.

Galileo vs. Aristotle

It's not that Aristotle was wrong. In everyday life, objects do need to keep being pushed in order to keep moving.

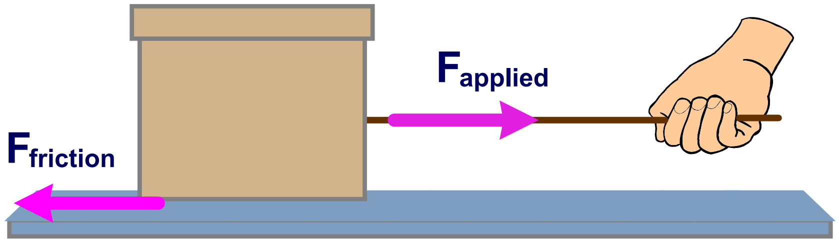
Push a book across the table. When you stop pushing, it stops moving. Aristotle is right in terms of what we see around us every day.



Force and Motion

It's just that Galileo, and later Newton, imagined a world where friction could be eliminated.

Friction represents an external force acting on the object, just as your push is an external force.



In the absence of all external forces, an object's velocity remains constant. Two equal and opposite forces have the same effect, they cancel to create zero net force.

Newton's 1st Law of Motion

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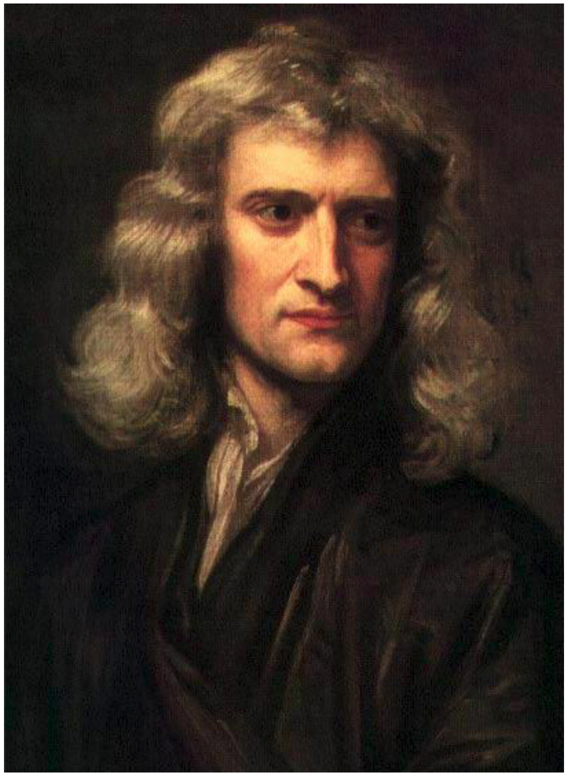
Sir Isaac Newton

Galileo's observations were more fully formed in 1687 by the "*father of physics*," Sir Isaac Newton, who called this observation "The First Law of Motion".



Newton's First Law of Motion

An object at rest remains at rest, and an object in motion remains in motion, unless acted on by a net external force.

In other words, an object maintains its velocity (both speed and direction) unless acted upon by a nonzero net force.

Having zero velocity (being at rest) is not special, it is just one possible velocity…a velocity which is no more special than any other.

A.K.A. The Law of Inertia

This law is often referred to as the "Law of Inertia." The word inertia comes from the latin word *iners* which means idle, or lazy.

Inertia is the tendency of an object to resist any change in motion.

Demo

1 In the absence of an external force, a moving object will

- A stop immediately.
- B slow down and eventually come to a stop.
- C go faster and faster.
- D move with constant velocity.

Answer

2 When the rocket engines on a spacecraft are suddenly turned off while traveling in empty space, the starship will

- A stop immediately.
- B slowly slow down, and then stop.
- C go faster and faster.
- D move with a constant velocity.

Answer

3 When you sit on a chair, the net external force on you is

- A zero
- B dependant on your weight.
- C down.
- D up

Answer

http://njc.tl/8e

4 A rocket moves through empty space in a straight line with constant speed. It is far from the gravitational effect of any star or planet. Under these conditions, the force that must be applied to the rocket in order to sustain its motion is

- A equal to its weight.
- B equal to its mass.
- C dependent on how fast it is moving.
- D zero.

Answer

5 You are standing in a moving bus, facing forward, and you suddenly fall forward. You can infer from this that the bus's

- A velocity decreased.
- B velocity increased.
- C speed remained the same, but it's turning to the right.
- D speed remained the same, but it's turning to the left.

Answer

http://njc.tl/8g

6 You are standing in a moving bus, facing forward, and you suddenly move forward as the bus comes to an immediate stop. What force caused you to move forward?

- A gravity
- B normal force due to your contact with the floor of the bus
- C force due to friction between you and the floor of the bus
- D there is no force leading to your fall.

Answer

http://njc.tl/8h

Inertial Reference Frames

Newton's laws are only valid in inertial reference frames:

An inertial reference frame is one which is not accelerating or rotating. It is an area in which every body remains in a state of rest unless acted on by an external unbalanced force.

Inertial Reference Frames

When your car accelerates, it is not an inertial reference frame.

This is why a drink on the dashboard of a car can suddenly seem to accelerate backwards without any force acting on it.

The drink is not accelerating, it's standing still. The reference frame, the car, is accelerating underneath it.

Click here for a famous video about frames of reference.
watch the first 2:30 of the video

Newton's 2nd Law of Motion

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Newton’s Second Law of Motion

An object doesn't change its velocity unless a force acts on it.

How does an object respond to a force when it is applied?

Newton's Second Law of Motion

$$\underline{\Sigma F} = ma$$

Net Force Mass Acceleration

Newton's second law identifies the relationship between acceleration and force.

When a net force is applied to an object, the object accelerates.

http://njc.tl/8i

word 'net' means overall, or <u>total</u>. We will discuss this in further
il later, but for now just think of ΣF as any force on an object

Units of Force

$$\Sigma F = ma$$

The unit of force in the SI system is the newton (N).

Mass is measured in kilograms (kg).

As we know, acceleration is measured in meters/second^2 (m/s^2).

Therefore, the unit of force, the Newton, can be found from the second law

$$\Sigma F = ma$$

N = kg*m/s^2

http://njc.tl/8i

7 A 3.5 kg object experiences an acceleration of $0.5\ m/s^2$. What net force does the object experience?

Answer

http://njc.tl/8i

8 **What force is required to accelerate a 1000 kg sports car at 6 m/s^2 ?**

Answer

http://njc.tl/8j

9 A 12 N net force acts on a 36 kg object? How much does it accelerate?

Answer

http://njc.tl/8k

10 **A bat strikes a 0.145 kg baseball with force of 5800 N. What acceleration does the baseball experience?**

Answer

http://njc.tl/8l

11 An electric model train is accelerated at a rate of $8\ m/s^2$ by a 12 N force? What is the mass of the train?

Answer

http://njc.tl/8m

12 An Olympic sprinter accelerates at a rate of 3 m/s^2 by applying a force of 189 N. What is the runner's mass?

Answer

http://njc.tl/8n

13 How much net force is required to accelerate a 0.5 kg toy car, initially at rest to a velocity of 2.4 m/s in 6 s?

Answer

http://njc.tl/8o

Newton's Second Law of Motion

$$\Sigma F = ma$$

We can rearrange this equation to better see how force, mass, and acceleration are related.

$$a = \frac{\Sigma F}{m}$$

http://njc.tl/8p

Newton's Second Law of Motion

$$a = \frac{\Sigma F}{m}$$

The acceleration of an object is:

> Directly proportional to (or dependent upon) the net force acting upon the object. As the force acting upon an object is increased, the acceleration of the object is increased.

> Inversely proportional to the mass of the object. As the mass of an object is increased, the acceleration of the object is decreased!

http://njc.tl/8p

14 A net force F accelerates a mass m with an acceleration a. If the same net force is applied to mass 2m, then the acceleration will be

- A 4a
- B 2a
- C a/2
- D a/4

Answer

http://njc.tl/8p

15 A net force F accelerates a mass m with an acceleration a. If the same net force is applied to mass m/2, then the acceleration will be

- A 4a
- B 2a
- C a/2
- D a/4

Answer

16 A constant net force acts on an object. The object moves with:

- A constant acceleration
- B constant speed
- C constant velocity
- D increasing acceleration

Answer

http://njc.tl/8q

17 A net force F acts on a mass m and produces an acceleration a. What acceleration results if a net force 2F acts on mass 4m?

- A a/2
- B 8a
- C 4a
- D 2a

Answer

http://njc.tl/8r

18 The acceleration of an object is inversely proportional to:

- A the net force acting on it.
- B its position.
- C its velocity.
- D its mass.

Answer

http://njc.tl/8s

Net Force
ΣF

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Net Force

$$\Sigma\vec{F} = m\vec{a}$$

Let's look at the left side of this equation first.

$$\Sigma\vec{F}$$

The greek letter sigma "Σ" means "the sum of".

Sometimes ΣF is written as F_{net} , they mean the same thing.

It means you have to add up all the forces acting on an object.

http://njc.tl/8t

Net Force

$$\Sigma\vec{F}$$

The arrow above "F" reminds you that force is a vector. We won't always write the arrow but remember it's there.

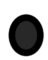
It means that when you add forces, you have to add them like vectors: forces have direction, and they can cancel out.

Net Force

$$\Sigma \vec{F}$$

Example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). What is the net force on the object?

First we'll draw a free body diagram. We will discuss these in more detail later on but for now, follow these simple directions. FBDs consists of a dot, representing the object, and arrows representing the forces. The direction of the arrows represents the direction of the forces...their length is roughly proportional to their size.



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Newton's Second Law of Motion

$$\Sigma\vec{F}$$

Example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). What is the net force on the object?

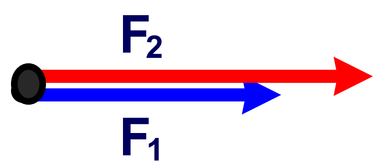
The first force (F_1) acts to the right with a magnitude of 20 N

http://njc.tl/8t

Newton's Second Law of Motion

$$\Sigma\vec{F}$$

Example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). What is the net force on the object?



The second force, F_2, acts to the right also, with a greater magnitude of 30N. This is drawn slightly larger than F_1.

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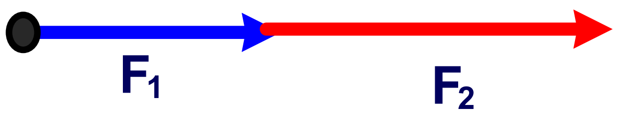
Newton's Second Law of Motion

$$\Sigma\vec{F}$$

Example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). What is the net force on the object?

To add vectors, move the second vector so it starts where the first one ends.



ım is a vector which starts where the first vector started, and vhere the last one ends.

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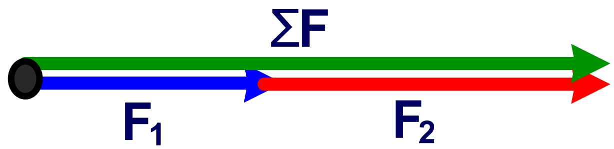
Newton's Second Law of Motion

$$\Sigma\vec{F}$$

Example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). What is the net force on the object?

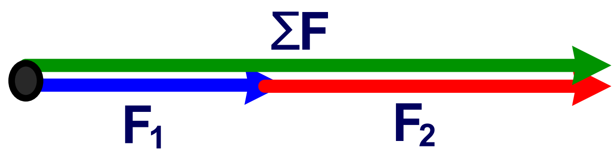


These free body diagrams are critically important to our work. Once done, the problem can be translated into an algebra problem.

http://njc.tl/8t

Newton's Second Law of Motion

For example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). What is the net force on the object?



First we will define "to the right" as positive.

Then we can interpret our diagram to read:

$\Sigma F = F_1 + F_2$

$\Sigma F = 20\text{ N} + 30\text{ N}$

$\Sigma F = 50\text{N}$ to the right

get the direction from our diagram and from our positive answer, which we defined as meaning "to the right")

http://njc.tl/8t

19 Two forces act on an object. One force is 40N to the west and the other force is 40N to the east. What is the net force acting on the object?

Answer

http://njc.tl/8t

20 **Two forces act on an object. One force is 8.0N to the north and the other force is 6.0N to the south. What is the net force acting on the object?**

Answer

http://njc.tl/8u

Newton's Second Law of Motion

$$m\vec{a}$$

Now let's look at the right side of our equation, $m\vec{a}$.

Mass is a scalar...it does not have a direction.

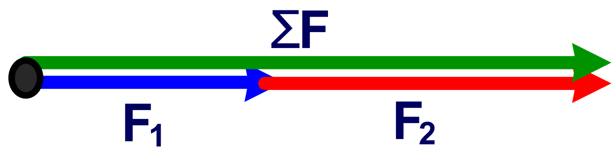
But acceleration does have a direction...it is a vector.

<u>The direction of the acceleration vector is always the same as the direction of the net force, ΣF, vector.</u>

http://njc.tl/8v

Newton’s Second Law of Motion

For example: A 5.0 kg object is being acted on by a 20N force to the right (F_1), and a 30N force, also to the right (F_2). We found the net force on the object to be 50N to the right.



Now let's find its acceleration.

Answer

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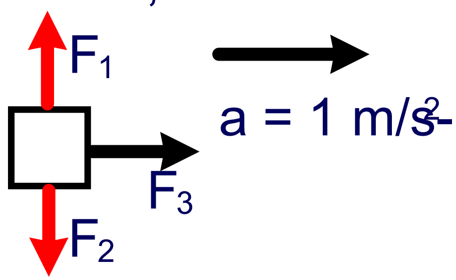
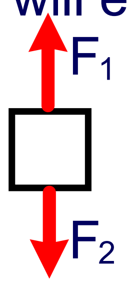
Newton's Second Law of Motion

Force is a vector, so $\Sigma F = ma$ is true along each coordinate axis.



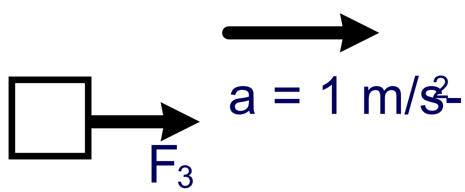
That means we can add up all the forces in the vertical direction and those will equal "ma" in the vertical direction.



$F_1 + (-F_2) = ma$ (vertical)

$F_1 - F_2 = 0$

And then can do the same thing in the horizontal direction.



$F_3 = ma$

$F_3 = (2kg)(1\ m/s^2)$

$F_3 = 2\ N$

http://njc.tl/8v

21 **A force F_1 = 50N acts to the right on a 5 kg object. Another force on the object, F_2 = 30N, acts to the left. Find the acceleration of the object.**

Answer

http://njc.tl/8x

22 A force F_1 = 350N pushes upward on 20 kg object. Another force, F_2 = 450N pulls downward on the object. Find the acceleration of the object.

Answer

http://njc.tl/8y

23 **An object accelerates downward at a rate of 4.9 m/s^2. If the downward force on the object is 500N and the upward force is 250N, what is the mass of the object?**

Answer

Mass, Weight, and Normal Force

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The case of mass versus weight

Mass is the measure of the inertia of an object, the resistance of an object to accelerate. In the SI system, mass is measured in kilograms.

Mass is not weight!
Mass is a property of an object.
It doesn't depend on where the object is located.

Weight is the force exerted on that object by gravity.
If you go to the moon, whose gravitational acceleration is about 1/6 *g*, you will weigh much less. Your mass, however, will be the same.

Click on this link to see a *Veritasium* video about mass and weight!

Weight – the Force of Gravity

Weight is the force exerted on an object by gravity. Close to the surface of Earth, where the gravitational force is nearly constant, weight can be calculated with:

$$\overrightarrow{F_G} = m\vec{g}$$

$$or$$

$$W = mg$$

Near the surface of Earth, g is 9.8 m/s^2 *downwards*.

24 Determine the Force of Gravity (weight) on a 6.0 kg bowling ball.

Answer

25 Determine the weight of a small car with a mass of 900 kg.

Answer

http://njc.tl/90

26 **Using a spring scale, you find that the weight of a friction block in the lab is around 24 N. What is the mass of the block in kilograms?**

Answer

http://njc.tl/91

27 **An object located near the surface of Earth has a weight of a 245 N object? What is the mass of the object?**

Answer

28 Which of the following properties of an object is likely to change on another planet?

- A Mass
- B Weight
- C Color
- D Volume (size and shape)

Answer

http://njc.tl/93

29 The acceleration due to gravity is lower on the Moon than on Earth. Which of the following is true about the mass and weight of an astronaut on the Moon's surface, compared to Earth?

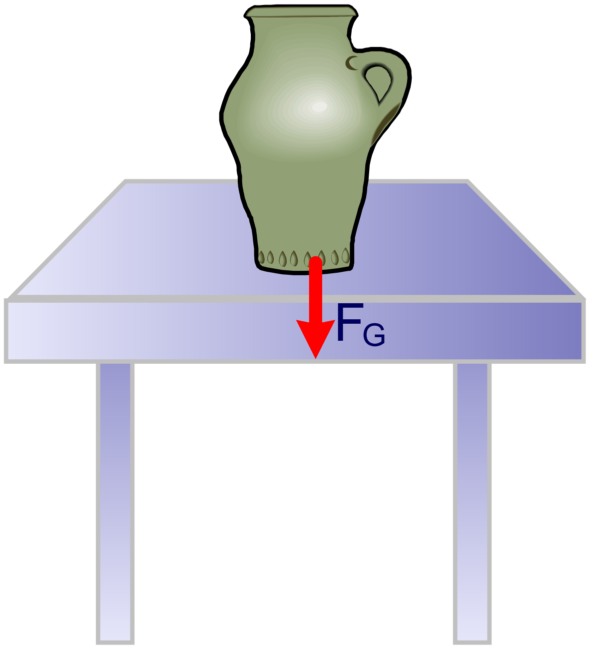
- A Mass is less, weight is same
- B Mass is same, weight is less
- C Both mass and weight are less
- D Both mass and weight are the same

Answer

Weight – the Force of Gravity

An object at rest must have no net force on it.

If it is sitting on a table, the force of gravity is still there...

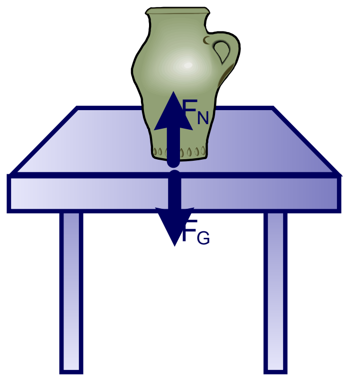


but additionally, *what other force is there?*

http://njc.tl/95

The Normal Force

What is the other force?



The force exerted perpendicular to a surface is called the normal force.

The normal force is exactly as large as needed to balance the force from the object. (if the required force gets too big, something breaks!)

The words "normal" and "perpendicular" are synonyms.

http://njc.tl/95

30 A 14 N brick is sitting on a table. What is the normal force supplied by the table?

- A 14 N upwards
- B 28 N upwards
- C 14 N downwards
- D 28 N downwards

Answer

http://njc.tl/96

31 What normal force is supplied by adesk to a 2.0 kg box sitting on it?

Answer

Newton's 3rd Law of Motion

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Table of
Contents

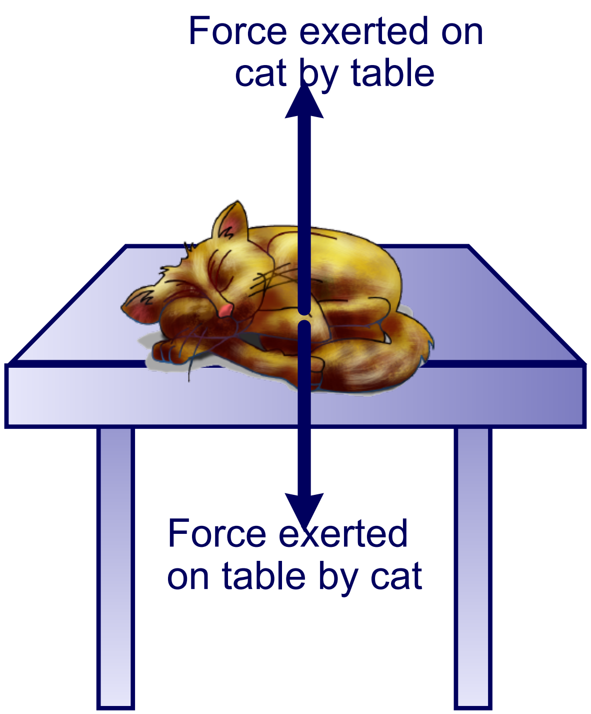
Newton's Third Law of Motion

Any time a force is exerted on an object, that force is caused by another object.

<u>There must be two objects involved to have a force</u>

Newton's third law:

Whenever one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first object.



http://njc.tl/98

Newton's Third Law of Motion

Whenever one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first object.

Another way to state Newton's 3rd Law...

For every action, there is an equal, opposite reaction.

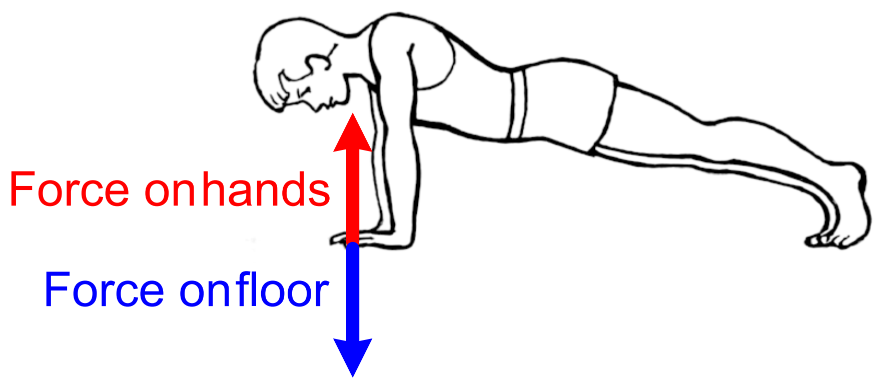
Remember: forces (or actions) are always applied to two different objects.

http://njc.tl/98

Newton's Third Law of Motion

A key to the correct application of the third law is that *the forces are exerted on different objects*.

Make sure you don't use them as if they were acting on the *same* object. Then they would add to zero!



http://njc.tl/98

Newton's Third Law of Motion

Rocket propulsion can also be explained using Newton's third law.

Hot gases from combustion spew out of the tail of the rocket at high speeds. The reaction force is what propels the rocket.

Note that the rocket does not need anything (like the earth) to "push" against.

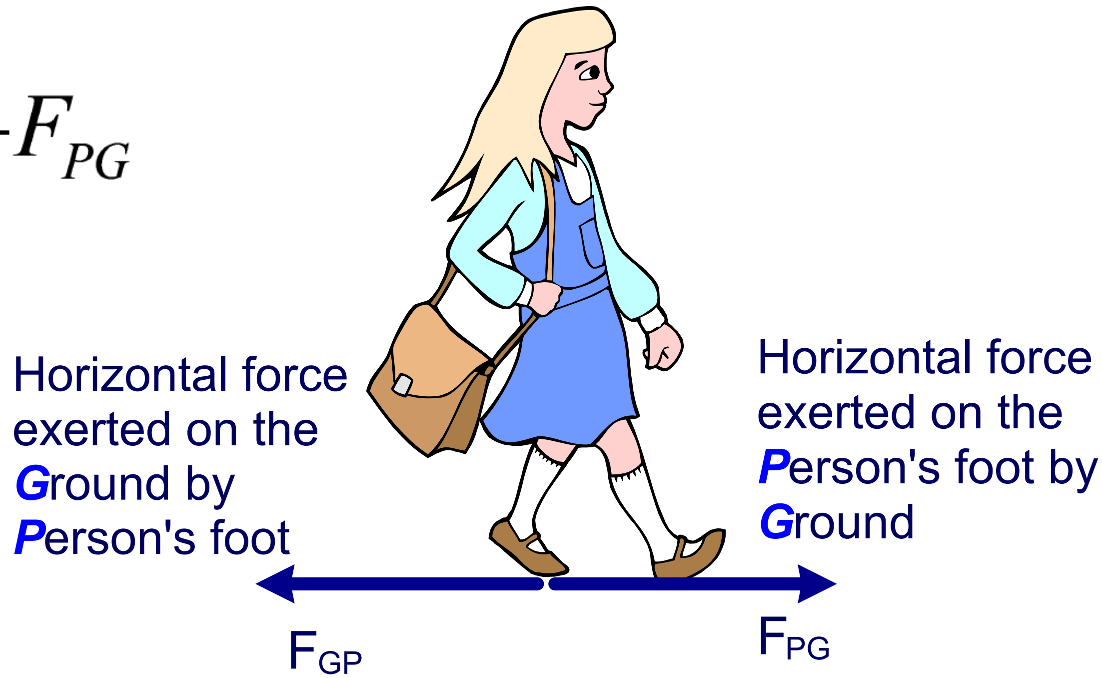
http://njc.tl/98

Newton's Third Law of Motion

Subscripts help keep your ideas and equations clear.

- the first subscript is the object that the force is being exerted on;
- the second is the source of that force.

$$F_{GP} = -F_{PG}$$



http://njc.tl/98

32 An object of mass m sits on a flat table. The Earth pulls on this object with force mg, which we will call the action force. What is the reaction force?

- A The table pushing up on the object with force mg
- B The object pushing down on the table with force mg
- C The table pushing down on the floor with force mg
- D The object pulling upward on the Earth with force mg

Answer

http://njc.tl/99

33 A 20-ton truck collides with a 1500-lb car and causes a lot of damage to the car. Since a lot of damage is done on the car

- A the force on the truck is greater then the force on the car
- B the force on the truck is equal to the force on the car
- C the force on the truck is smaller than the force on the car
- D the truck did not slow down during the collision

Answer

http://njc.tl/9a

34 As you are sitting in a chair, you feel the chair pushing up on you. The reaction force in this situation is:

- A The chair pushing down on the ground
- B Gravity pulling down on you
- C You pushing down on the chair
- D The ground pushing up on the chair

Answer

http://njc.tl/9b

35 A student is doing a hand-stand. A reaction pair of forces is best described as:

- A The student pushes down on the ground - The ground pushes up on the student
- B Gravity is pulling the student down - The ground is pushing the student up
- C Gravity is pulling the student down - The student's arms push the student up
- D The student's hands push down on the ground - The students arms push the student up

Answer

http://njc.tl/9c

36 Which of Newton's laws best explains why motorists should wear seat belts?

- A the first law
- B the second law
- C the third law
- D the law of gravitation

Answer

http://njc.tl/7p

37 If you blow up a balloon, and then release it, the balloon will fly away. This is an illustration of: *(Note: there may be more than one answer. Be prepared to explain WHY!)*

- A Newton's first law
- B Newton's second law
- C Newton's third law
- D Galileo's law of inertia

Answer

http://njc.tl/9d

Free Body Diagrams

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Contents

Free Body Diagrams

A free body diagram is a drawing physicists use in order to show all the forces acting on an object. Drawing free body diagrams can help when trying to solve for unknown forces or showing the motion of the object.

Click here for a *Veritasium* video on free body diagrams and reviewing Normal Force!

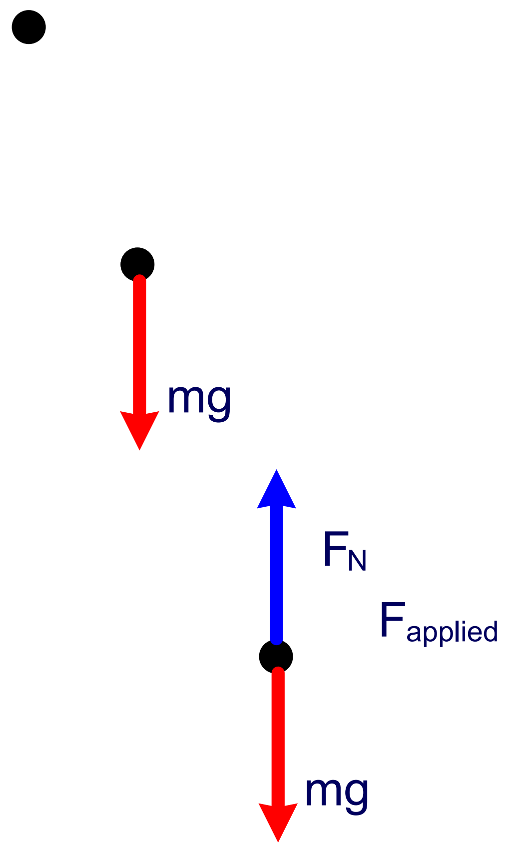
http://njc.tl/9e

Free Body Diagrams

1. Draw and label a dot to represent the first object.

2. Draw an arrow from the dot pointing in the direction of one of the forces that is acting on that object. Label that arrow with the name of the force.

3. Repeat for every force that is acting on the object. Try to draw each of the arrows to roughly the same scale, bigger forces getting bigger arrows.



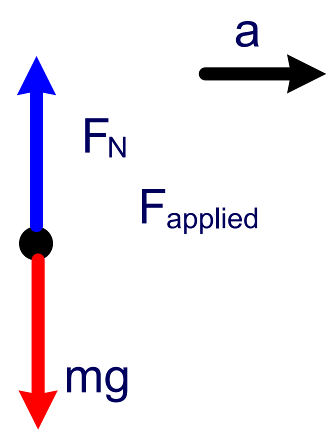
http://njc.tl/9e

Free Body Diagrams

4. Once you have finished your free body diagram, recheck it to make sure that you have drawn and labeled an arrow for every force. This is no time to forget a force.

5. Draw a separate arrow next to your free body diagram indicating the likely direction of the acceleration of the object. This will help you use your free body diagram effectively.

6. Repeat this process for every object in your sketch.



http://njc.tl/9e

38 **Draw the free body diagram for a cat sitting on a chair.**

Answer

39 Draw the free diagram for a sled being pulled across an icy pond.

Answer

http://njc.tl/9f

Friction

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Contents

Friction - A Resistive Force

There are many different types of forces that occur in nature, but perhaps none is more familiar to us than the force of friction (F_{fr}).

Friction is a resistive force that opposes the motion of an object.

What does sandpaper have to do with friction?

http://njc.tl/9g

Friction - A Resistive Force

Friction is the reason objects stop rolling or sliding along a surface. It is the reason it is difficult to start pushing a heavy box along the floor.

There are many different types of friction:

Friction between solid objects and air is often called air resistance.

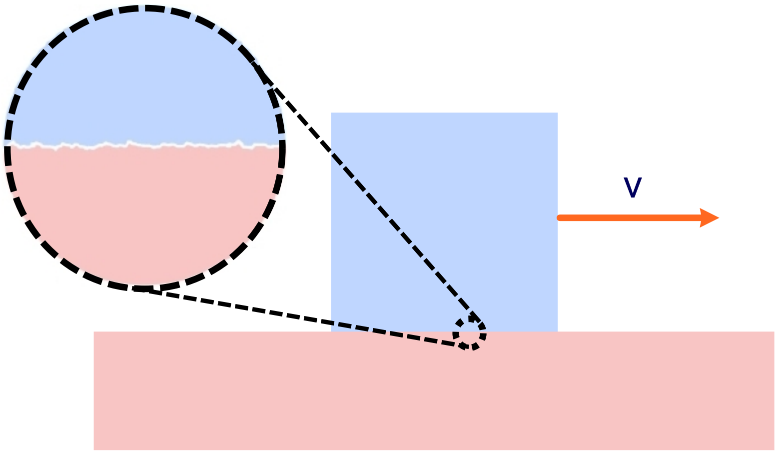
Friction between two fluids ...led viscosity.

http://njc.tl/9g

Kinetic Friction Force

Where does friction come from?

On a microscopic scale, most surfaces are rough.
This leads to complex interactions between them that we don't need to consider yet, but the force can be modeled in a simple way.



http://njc.tl/9g

Kinetic Friction Force

Friction that acts on an object that is already in motion is called kinetic friction.

For kinetic – or sliding – friction, we write: $F_{fr} = \mu_k F_N$

Kinetic friction is the product of two things: μ_k is called the coefficient of kinetic friction, and is different for every pair of surfaces. F_N is simply the Normal Force, which, on flat surfaces, is equal to the weight of the object.

http://njc.tl/9g

Kinetic Friction Force

A larger coefficient of friction means a greater frictional force.

Notice the friction that occurs between different materials in the table below:

Surface	**Coefficient of Kinetic Friction**
Wood on Wood	0.2
Ice on Ice	0.03
metal on metal (lubricated)	0.07
Steel on steel (unlubricated)	0.6
Rubber on dry concrete	0.7
Rubber on wet concrete	0.6
Rubber on other solid surface	0.5 - 0.9
Teflon on Teflon	0.05
Human Joints in limbs	0.01

A man accelerates a crate along a rough surface.

Draw the crate's free body diagram:

Determine ΣF in the x and y directions

http://njc.tl/9g

40 A brick is sliding to the right on a horizontal surface. What are the directions of the two surface forces: the friction force and the normal force?

- A right, down
- B right, up
- C left, down
- D left, up

Answer

http://njc.tl/9h

41 A 4.0kg brick is sliding on a surface. The coefficient of kinetic friction between the surfaces is 0.25. What it the size of the force of friction?

Answer

http://njc.tl/9i

42 **A 50 kg crate is being pushed across a warehouse floor. The coefficient of kinetic friction between the crate and the floor is 0.4. What it the size of the force of friction?**

Answer

http://njc.tl/9j

43 A 50 kg crate is pushed across a warehouse floor with a force of 100 N, accelerating at a rate of 1 m/s. What is the coefficient of friction between the floor and crate?

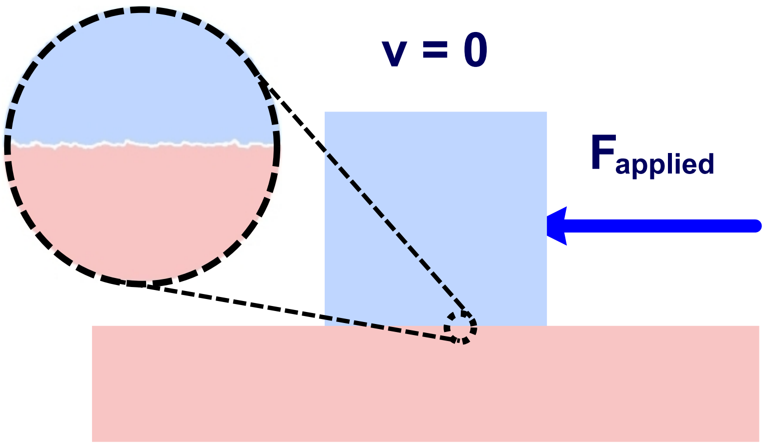
Answer

http://njc.tl/9k

**Static Friction Force

Static friction is the frictional force between two surfaces that are not moving along each other.

Static friction keeps objects from moving when a force is first applied.



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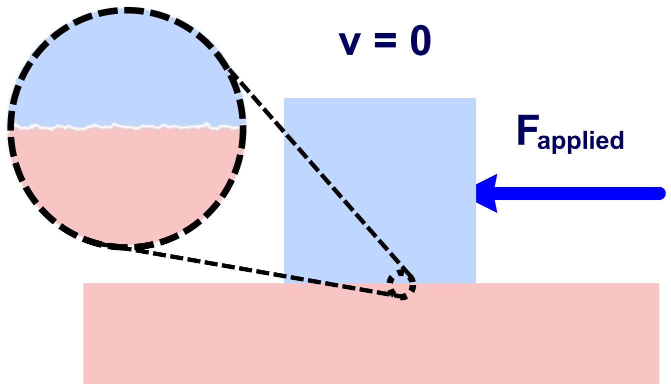
**Static Friction Force

$$F_{fr} \leq \mu_s F_N$$

μ_s is the coefficient of static friction, and is different for every pair of surfaces.



** Static Friction Force

$$F_{fr} \leq \mu_s F_N$$

Note the ≤ symbol in this equation.

Imagine pushing on a box until it moves. You can apply a small force... nothing happens. You apply more and more force until the box finally starts moving - this is the maximum amount of static friction.

The friction can be LESS than the maximum amount or EQUAL to the maximum amount, but never greater. The force of friction is equal to $\mu_s F_N$ at the instant when the object starts to move.

Then what happens?

http://njc.tl/9l

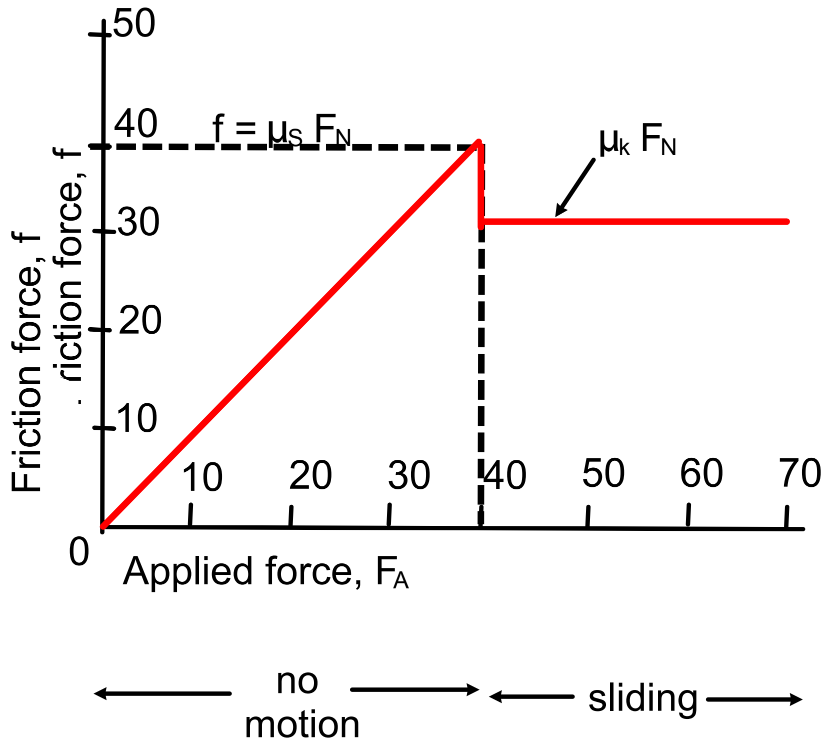
** Friction Force

The static frictional force increases as the applied force increases, always equal to the net applied force.

Until it reaches its maximum, $\mu_s F_N$.

Then the object starts to move, and the kinetic frictional force takes over,

.



http://njc.tl/9l

** Friction Force

The static frictional force increases as the applied force increases, always equal to the net applied force.

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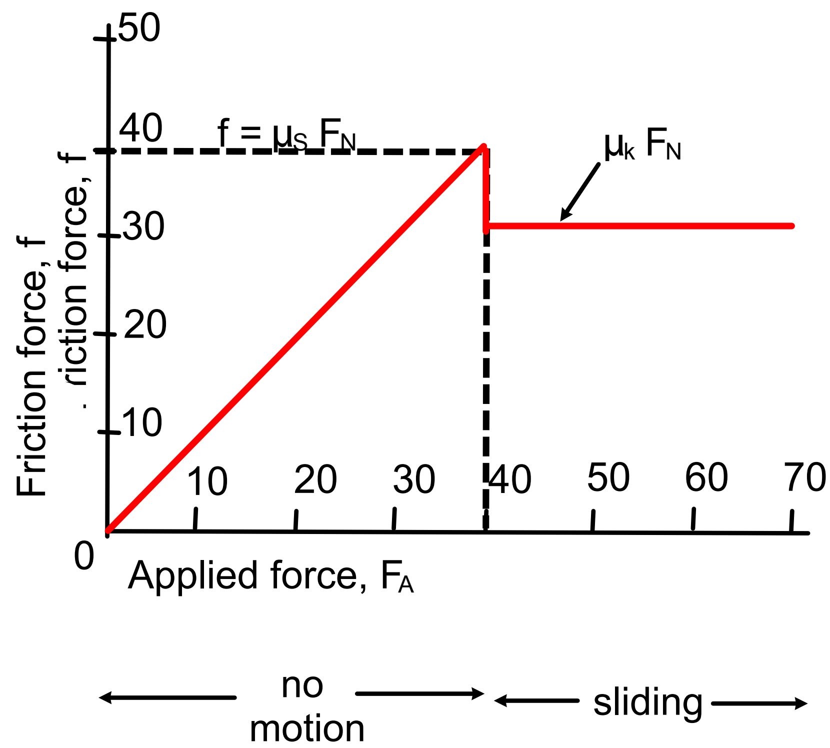

.

http://njc.tl/9l

**Friction Force

The table below shows values for both static and kinetic coefficients of friction.

Surface	Coefficient of Static Friction	Coefficient of Kinetic Friction
Wood on wood	0.4	0.2
Ice on ice	0.1	0.03
Metal on metal(lubricated)	0.15	0.07
Steel on steel (unlubricated)	0.7	0.6
Rubber on dry concrete	1.0	0.8
Rubber on wet concrete	0.7	0.5
Rubber on other solid surfaces	1-4	1
Teflon on Teflon in air	0.04	0.04
Joints in human limbs	0.01	0.01

Notice that static friction is greater than kinetic friction.
Once an object is in motion, it is easier to keep it in motion.

**44 A 4.0 kg brick is sitting on a table. The coefficient of static friction between the surfaces is 0.45. What is the largest force that can be applied horizontally to the brick before it begins to slide?

Answer

http://njc.tl/9l

45 A 4.0kg brick is sitting on a table. The coefficient of static friction between the surfaces is 0.45. If a 10 N horizontal force is applied to the brick, what will be the force of friction?

Answer

http://njc.tl/9m

Tension

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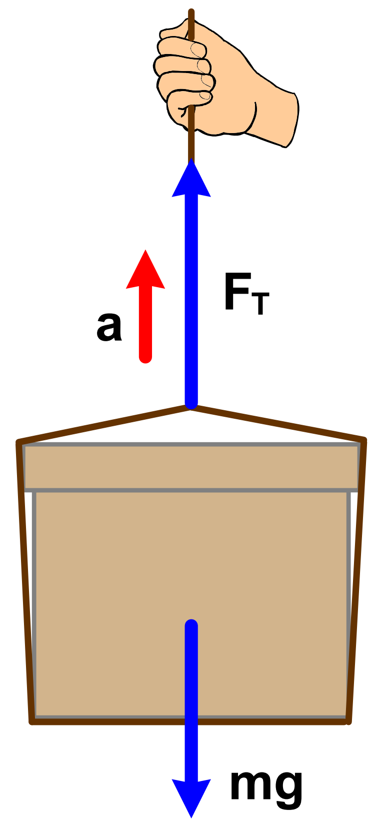
Tension Force

When a cord, rope or chain pulls on an object, it is said to be under tension, and the force it exerts is called a tension force, F_T.

The tension force is the same throughout the cord, rope or chain (when assumed to be massless).

Any object that is hanging or suspended is considered to have tension acting upward.



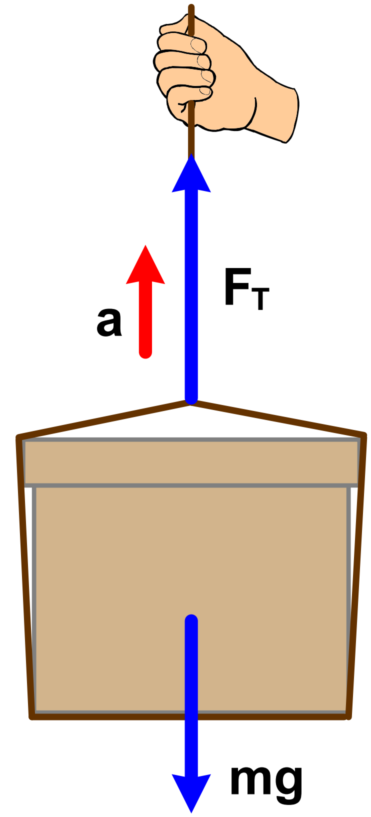
ject that is pulled is considered to ension acting on it.

http://njc.tl/9n

Tension Force

There is no special formula to find the force of tension.

We need to use force diagrams and net force equations to solve for it!



46 A 25 kg lamp is hanging from a rope. What is the tension force being supplied by the rope?

Answer

http://njc.tl/9n

47 A crane is lifting a 60 kg load at a constant velocity. Determine the tension force in the cable.

Answer

48 **A 90 kg climber rappels from the top of a cliff with an acceleration of 1 m/s^2. Determine the tension in the climber's rope.**

Answer

http://njc.tl/9p

49 A crane lifts a 400 kg crate upward with an acceleration of 3 m/s^2. Determine the tension in the crane.

Answer

http://njc.tl/9q

General Problems

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Problem Solving – A General Approach

- Read the problem carefully; then read it again.
- Draw a sketch, and then a free-body diagram.
- Choose a convenient coordinate system.
- List the known and unknown quantities;
- Find relationships between the knowns and unknowns.
- Estimate the answer.
- Solve the problem without numbers, algebraically.
- Then put the numbers in and solve for a numerical answer.
- Keep track of dimensions.
- Make sure your answer is reasonable.

Problem 1

An 1800 kg elevator moves up and down on a cable. Calculate the tension force in the cable for the following cases:

a) the elevator moves at a constant speed upward.
b) the elevator moves at a constant speed downward.
c) the elevator accelerates upward at a rate of 2.4 m/s^2.
d) the elevator accelerates downward at a rate of 2.4 m/s^2.

http://njc.tl/9r

Problem 1

An 1800 kg elevator moves up and down on a cable. Calculate the tension force in the cable for the following cases:

a) the elevator moves at a constant speed upward.

Answer

http://njc.tl/9r

Problem 1

An 1800 kg elevator moves up and down on a cable. Calculate the tension force in the cable for the following cases:

b) the elevator moves at a constant speed downward.

No different than if the constant speed is upward!

Answer

http://njc.tl/9r

Problem 1

An 1800 kg elevator moves up and down on a cable. Calculate the tension force in the cable for the following cases:

c) the elevator accelerates upward at a rate of 2.4 m/s^2.

Answer

http://njc.tl/9r

Problem 1

An 1800 kg elevator moves up and down on a cable. Calculate the tension force in the cable for the following cases:

d) the elevator accelerates downward at a rate of 2.4 m/s^2.

Answer

http://njc.tl/9r

Problem 2

A 50 kg man stands on a scale inside an elevator. State the scale measurement for the following cases:

a) the elevator moves at a constant speed upward.
b) the elevator moves at a constant speed downward.
c) the elevator accelerates upward at a rate of 1.4 m/s^2.
d) the elevator accelerates downward at a rate of 1.4 m/s^2.

Problem 2

A 50 kg man stands on a scale inside an elevator. State the scale measurement for the following cases:

a) the elevator moves at a constant speed upward.

Answer

Problem 2

A 50 kg man stands on a scale inside an elevator. State the scale measurement for the following cases:

b) the elevator moves at a constant speed downward.

Answer

http://njc.tl/9s

Problem 2

A 50 kg man stands on a scale inside an elevator. State the scale measurement for the following cases:

c) the elevator accelerates upward at a rate of 1.4 m/s^2.

Answer

http://njc.tl/9s

Problem 2

A 50 kg man stands on a scale inside an elevator. State the scale measurement for the following cases:

d) the elevator accelerates downward at a rate of 1.4 m/s^2.

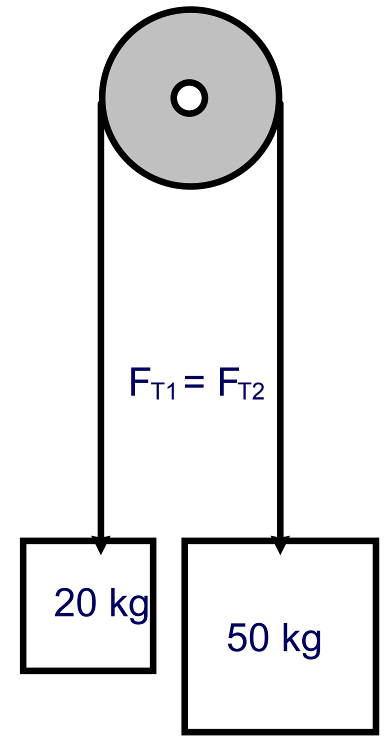
Answer

http://njc.tl/9s

Tension Force

The tension in a rope is the same everywhere in the rope.

If two masses hang down from either side of a cable, for instance, the tension in both sides must be the same.

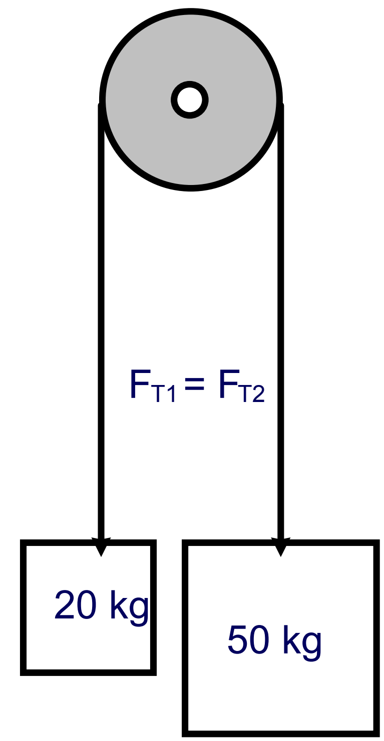


"Atwood Machine"

http://njc.tl/9t

Problem 3 - Tension Force

A 50 kg mass hangs from one end of a rope that passes over a small frictionless pulley. A 20 kg weight is suspended from the other end of the rope.



"Atwood Machine"

Which way will the 50 kg mass accelerate?

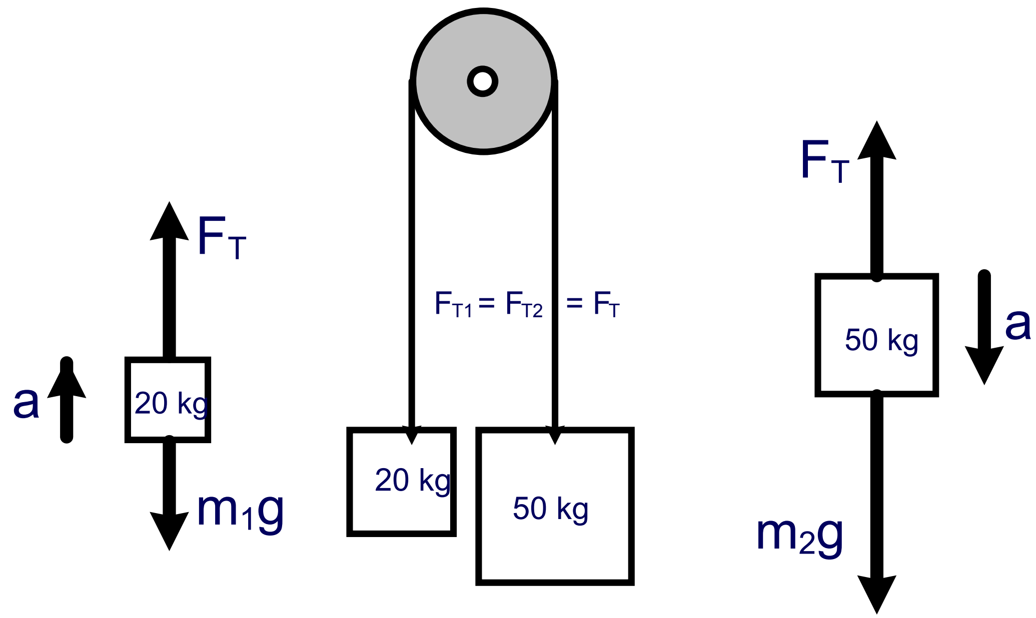
Which way will the 20 kg mass accelerate?

a) Draw a Free Body Diagram for each mass
b) Write the Net Force equation for each mass
c) Find the equations for the tension force F_T
d) Find the equation for acceleration
e) Find the value of the acceleration
d the value of the tension

http://njc.tl/9t

Problem 3 - Tension Force

a) Draw a Free Body Diagram for each mass



Answer

Remember the tension in the rope is the same everywhere, so F_T is the same for both masses. The *direction* of acceleration lso different. What about the *magnitude* of acceleration?

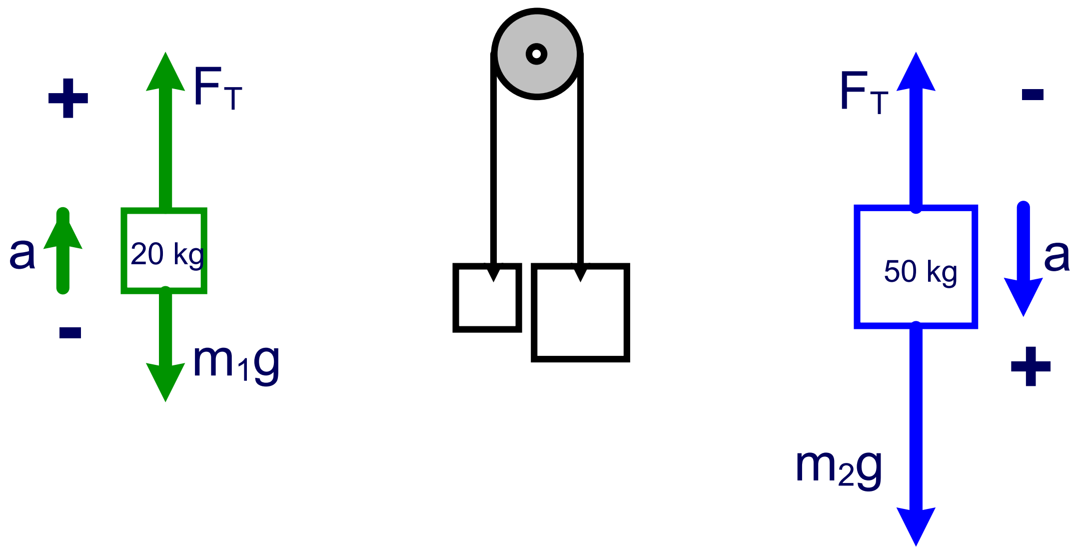
http://njc.tl/9t

Problem 3 - Tension Force

b) Write the Net Force equation for each mass

Remember there is no special equation for tension. We need to use net force to find the tension.

Below each diagram, write the Net Force equation for each mass:

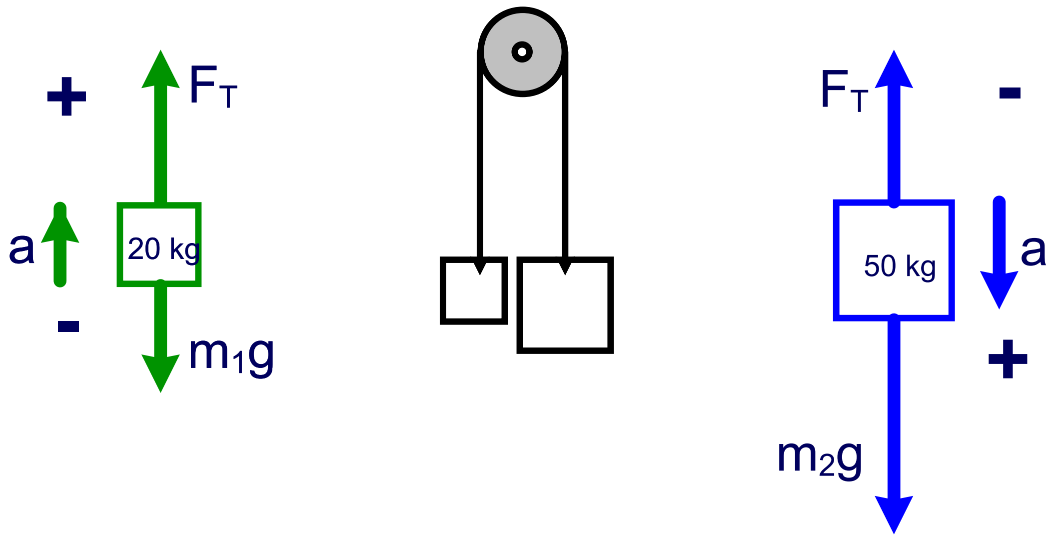


Answer

http://njc.tl/9t

Problem 3 - Tension Force

b) Write the Net Force equation for each mass



$\Sigma F = m_1 a$

$F_T - m_1 g = +m_1 a$

$\Sigma F = m_2 a$

$-F_T + m_2 g = +m_2 a$

http://njc.tl/9t

What is different about each formula?
Why aren't they the same?

Problem 3 - Tension Force

c) Find the equations for the tension force F_T

We have two equations (one for each mass) and two unknowns (F_T and a). This means we can combine the equations together to solve for each variable!

$m_1g - F_T = m_1a$ $\qquad$ $F_T - m_2g = m_2a$

First we'll solve each one for F_T:

$m_1g - F_T = m_1a$

$m_1g = m_1a + F_T$

$\mathbf{m_1g - m_1a = F_T}$

$F_T - m_2g = m_2a$

$\mathbf{F_T = m_2g + m_2a}$

http://njc.tl/9t

Now we can set them equal to one another:

$m_1g - m_1a = m_2g + m_2a$

Problem 3 - Tension Force

d) Find the equation for acceleration

Now we can combine the tension equations

$m_1g - m_1a = F_T \qquad F_T = m_2g + m_2a$

There is only one unknown (a) here. Solve for a:

$m_1g - m_1a = m_2g + m_2a$

Add m_1a to both sides:

$m_1g = m_2g + m_2a + m_1a$

subtract m_2g from both sides:

$m_1g - m_2g = m_2a + m_1a$

factor out 'a' :
(remember factoring is just
posite of distributing!)

$m_1g - m_2g = a\,(m_2 + m_1)$

by $(m_1 + m_2)$:

$$\frac{m_1g - m_2g}{(m_2 + m_1)} = a$$

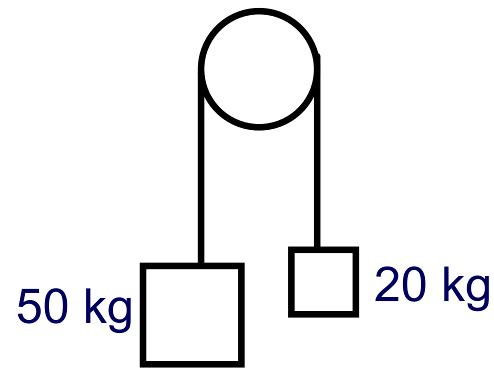
http://njc.tl/9t

Problem 3 - Tension Force

e) Find the value of the acceleration

Substitute and solve:

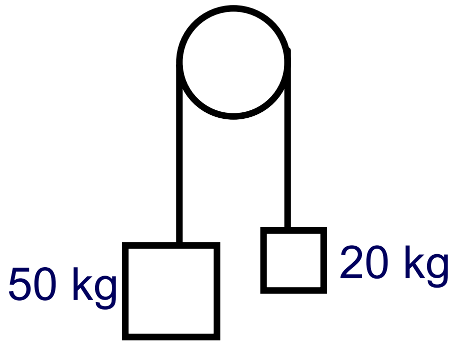
Remember: this is the acceleration for both m_1 and m_2.



Answer

http://njc.tl/9t

Problem 3 - Tension Force



f) Find the value of the tension

Now we can use either equation to solve for Tension:

Answer

http://njc.tl/9t

Problem 4

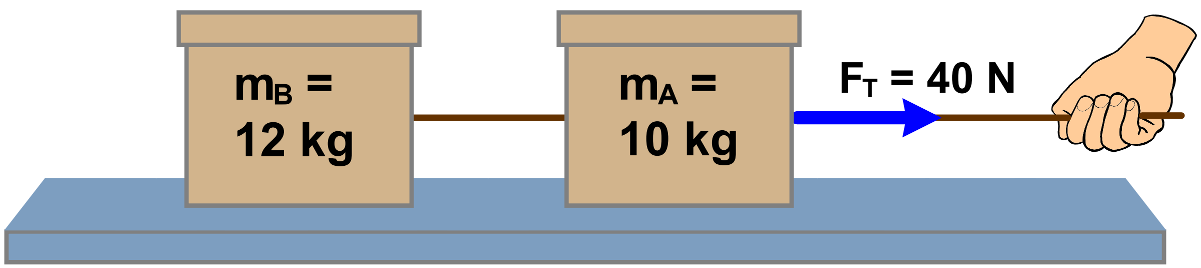
Two boxes are connected by a cord. A person pulls horizontally on box A with force F = 40.0 N. The boxes have masses of 10 kg and 12 kg. Ignore friction between the boxes and the tabletop.

a) Show the free-body diagram of the box B.

b) Show the free-body diagram of the box A.

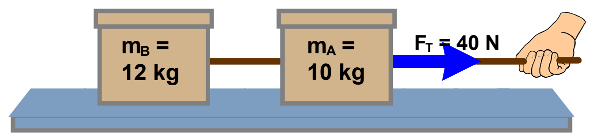
c) Find the acceleration of the system.

d) Find the tension in the cord.



Problem 4

Two boxes are connected by a cord. A person pulls horizontally on box A with force F = 40.0 N. The boxes have masses of 10 kg and 12 kg. Ignore friction between the boxes and the tabletop.

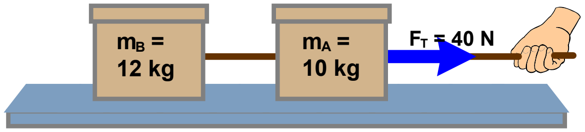


a) Show the free-body diagram of the box B.

Answer

Problem 4

Two boxes are connected by a cord. A person pulls horizontally on box A with force F = 40.0 N. The boxes have masses of 10 kg and 12 kg. Ignore friction between the boxes and the tabletop.

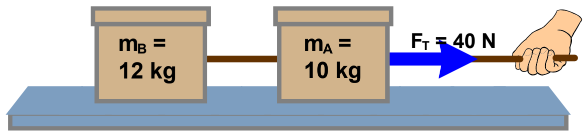


b) Show the free-body diagram of the box A.

Answer

Problem 4

Two boxes are connected by a cord. A person pulls horizontally on box A with force F = 40.0 N. The boxes have masses of 10 kg and 12 kg. Ignore friction between the boxes and the tabletop.

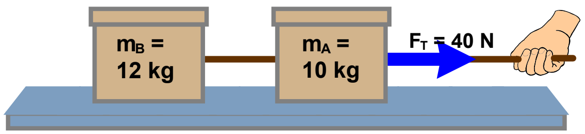


c) Find the acceleration of the system.

Answer

Problem 4

Two boxes are connected by a cord. A person pulls horizontally on box A with force F = 40.0 N. The boxes have masses of 10 kg and 12 kg. Ignore friction between the boxes and the tabletop.



d) Find the tension in the cord.

Answer

Problem 5

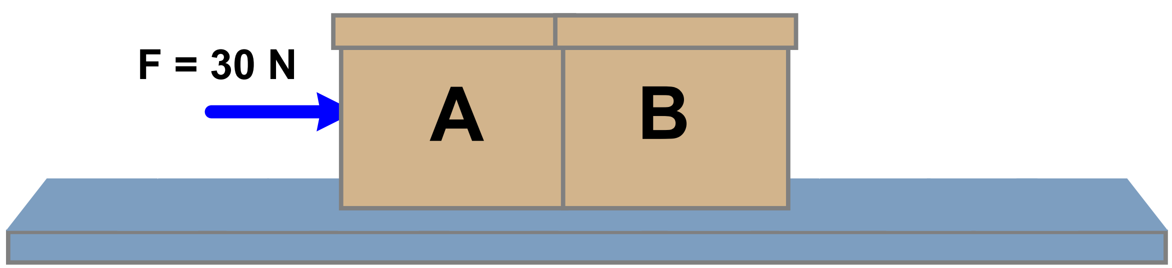
Two boxes are place on a table. A person pushes horizontally on box A with force F = 30.0 N. The boxes A and B have masses of 5 kg and 8 kg. Ignore friction between the boxes and the tabletop.

a) Show the free-body diagram of the box B.

b) Show the free-body diagram of the box A.

c) Find the acceleration of the system.

d) Find the force of A on B

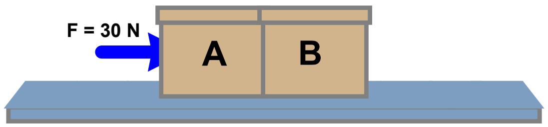


http://njc.tl/9u

Problem 5

Two boxes are place on a table. A person pushes horizontally on box A with force F = 30.0 N. The boxes A and B have masses of 5 kg and 8 kg. Ignore friction between the boxes and the tabletop.

a) Show the free-body diagram of the box B.



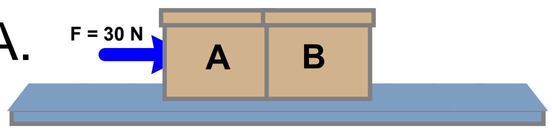
Answer

http://njc.tl/9u

Problem 5

Two boxes are place on a table. A person pushes horizontally on box A with force F = 30.0 N. The boxes A and B have masses of 5 kg and 8 kg. Ignore friction between the boxes and the tabletop.

b) Show the free-body diagram of the box A.



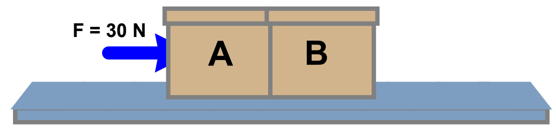
Answer

http://njc.tl/9u

Problem 5

Two boxes are place on a table. A person pushes horizontally on box A with force F = 30.0 N. The boxes A and B have masses of 5 kg and 8 kg. Ignore friction between the boxes and the tabletop.

c) Find the acceleration of the system.



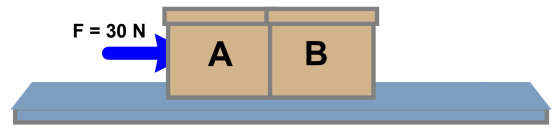
Answer

http://njc.tl/9u

Problem 5

Two boxes are place on a table. A person pushes horizontally on box A with force F = 30.0 N. The boxes A and B have masses of 5 kg and 8 kg. Ignore friction between the boxes and the tabletop.

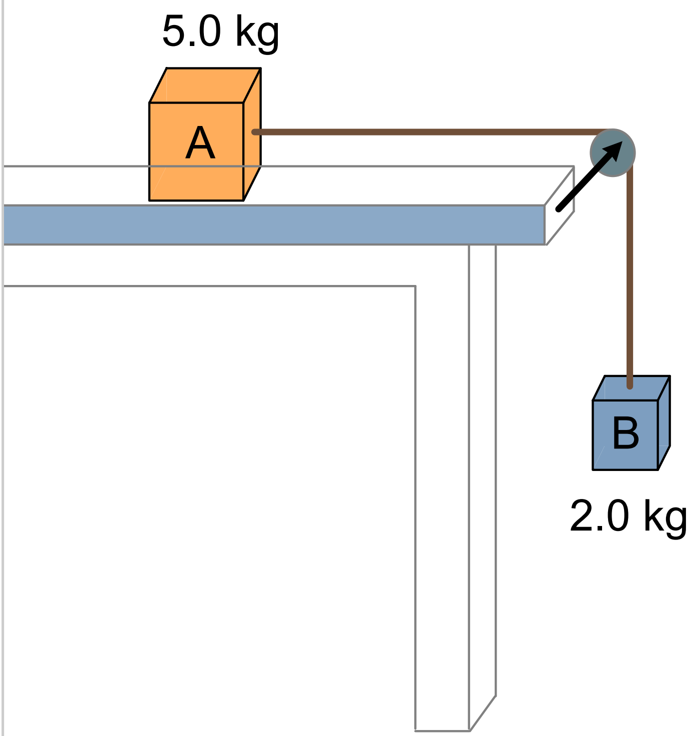
d) Find the force of A on B



Answer

http://njc.tl/9u

Problem 6



Two boxes are connected by a cord running over a pulley. The coefficient of kinetic friction between box A and the table is 0.2

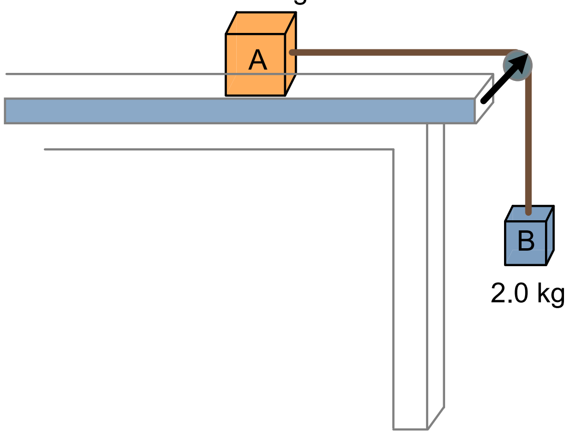
a) Show the free-body diagrams of box A and box B

b) Find the acceleration of the system of two boxes

c) Find the tension in the cord

http://njc.tl/9w

Problem 6



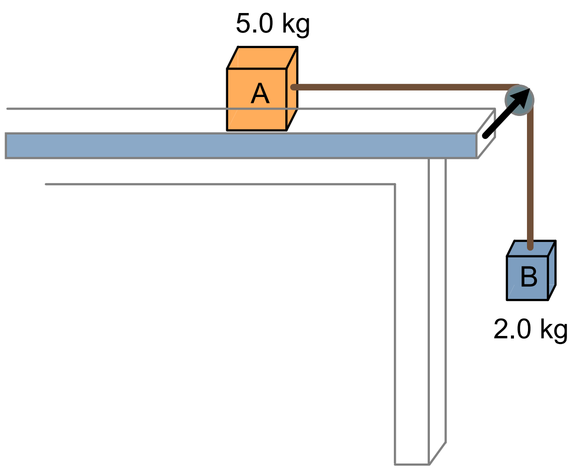
Two boxes are connected by a cord running over a pulley. The coefficient of kinetic friction between box A and the table is 0.2

a) Show the free-body diagrams of box A and box B

Answer

http://njc.tl/9w

Problem 6



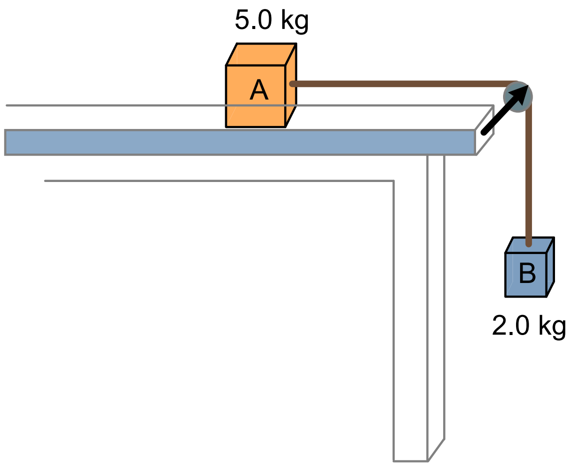
Two boxes are connected by a cord running over a pulley. The coefficient of kinetic friction between box A and the table is 0.2

b) Find the acceleration of the system of two boxes

Answer

http://njc.tl/9w

Problem 6



Two boxes are connected by a cord running over a pulley. The coefficient of kinetic friction between box A and the table is 0.2

c) Find the tension in the cord

Answer

http:/ / njc.tl/ 9w