#10 Newton's 1st and 2nd Laws Pre-class

Due: 11:00am on Friday, September 14, 2012

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

Newton's 1st Law

Learning Goal:

To understand Newton's 1st law.

Newton's *Principia* states this first law of motion:
An object subject to no net force maintains its state of motion, either at rest or at constant speed in a right line.
This law may be stated as follows: If the sum of all forces acting on an object is zero, then the acceleration of that object is zero. Mathematically this is just a special case of the 2nd law of motion, $\vec{F} = m\vec{a}$ when $\vec{F} = 0$, prompting scholars to advance the following reasons (among others) for Newton's spelling it out separately:

1. This expression only holds in an inertial coordinate system--one that is not accelerating--and this law really says you have to use this type of coordinate system (i.e., Newton's laws won't work inside an accelerating rocket ship.)
2. This was a direct challenge to the Impetus theory of motion, described as follows:
   A mover, while moving a body, impresses on it a certain impetus, a certain power capable of moving this body in the direction in which the mover set it going, whether upwards, downwards, sideways or in a circle. By the same amount that the mover moves the same body swiftly, by that amount is the impetus that is impressed on it powerful. It is by this impetus that the stone is moved after the thrower ceases to move it; but because of the resistance of the air and the gravity of the stone, which inclines it to move in a direction opposite to that towards which the impetus tends to move it, this impetus is continually weakened. Therefore the movement of the stone will become continually slower, and at length, the impetus is so diminished or destroyed that the gravity of the stone prevails over it and moves the stone down towards its natural place.

   A. C. Crombie, *Medieval and Early Modern Science*</>

   This theory is sometimes called the Animistic theory of motion since it envisions a "life force" being associated with motion.

Newton's 1st law is often very difficult to grasp because it contradicts various common-sense ideas of motion that they have acquired from experinece in everyday life. For example, unaccounted for forces like friction might cause a ball rolling on the playground to eventually stop, even though no obvious forces seem to be acting.
When studying Newtonian mechanics, it is best to remember this as two laws:

1. If the *net* force (i.e., sum of all forces) acting on an object is zero, the object will keep moving with constant velocity (which may be zero).
2. If an object is moving with constant velocity (not speed), that is, with zero acceleration, then the net force acting on that object must be zero.

Complete the following sentences to see if you can apply these ideas.

Part A

If a car is moving to the left with constant velocity, one can conclude that

ANSWER:

- there must be no forces applied to the car.
- the net force applied to the car is directed to the left.
- (selected) the net force applied to the car is zero.
- there is exactly one force applied to the car.

Correct

Part B

An object cannot remain at rest unless

ANSWER:

- there are no forces at all acting on it.
- (selected) the net force acting on it is zero.
- the net force acting on it is constant.
- there is only one force acting on it.

Correct

Part C

An object will have constant acceleration if

Select the most general response.

Hint 1. More help from Newton

To solve this, you have to invoke Newton's 2nd law, $\Sigma \vec{F}_i = m\vec{a}$.

ANSWER:

- there are no forces at all acting on it.
- the net force acting on it is zero.
- the net force acting on it is constant in magnitude and direction.
- there is only one force acting on it.

Correct

Free-Body Diagrams: Introduction

Learning Goal:

To learn to draw free-body diagrams for various real-life situations.

Imagine that you are given a description of a real-life situation and are asked to analyze the motion of the objects involved. Frequently, that analysis involves finding the *acceleration* of the objects, which, in turn, requires that you find the *net force*.

To find the net force, you must first identify all of the forces acting on the object and then add them as vectors. Such a procedure is not always trivial. It is helpful to replace the sketch of the situation by a drawing of the object (represented as a particle) and all the forces applied to it. Such a drawing is called a *free-body diagram*. This problem will walk you through several examples of free-body diagrams and will demonstrate some of the possible pitfalls.
Here is the general strategy for drawing free-body diagrams:

- *Identify the object of interest.* This may not always be easy: A sketch of the situation may contain many objects, each of which has a different set of forces acting on it. Including forces acting on different objects in the same diagram will lead to confusion and a wrong solution.
- *Draw the object as a dot. Draw and clearly label all the forces acting on the object of interest. The forces should be shown as vectors*

originating from the dot representing the object of interest. There are two possible difficulties here: omitting some forces and drawing the forces that either don't exist at all or are applied to other objects. To avoid these two pitfalls, remember that every force must be applied *to* the object of interest *by* some other object.

- *Once all of the forces are drawn, draw the coordinate system.* The origin should coincide with the dot representing the object of interest and the axes should be chosen so that the subsequent calculations of vector components of the forces will be relatively simple. That is, as many forces as possible must be either parallel or perpendicular to one of the axes.

Even though real life can present us with a wide variety of situations, we will be mostly dealing with a very small number of forces. Here are the principal ones of interest:

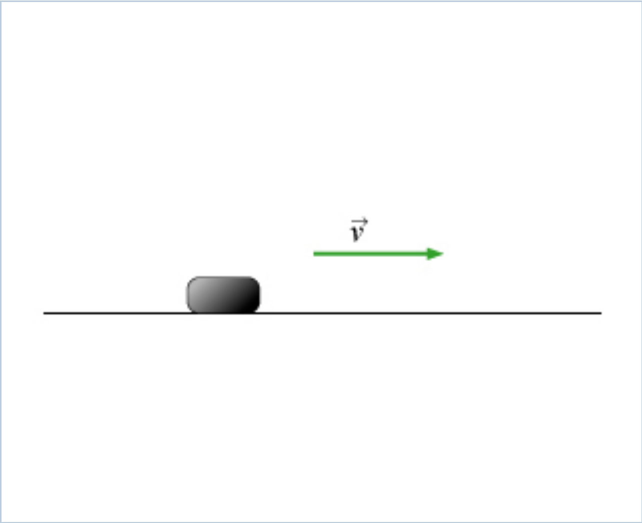
- *Weight, or the force due to gravity.* Weight acts on every object and is directed straight down unless we are considering a problem involving the nonflat earth (e.g., satellites).
- *Normal force.* The normal force exists between two surfaces that are pressed against each other; it is always perpendicular to the surfaces.
- *Force of tension.* Tension exists in strings, springs, and other objects of finite length. It is directed along the string or a spring. Keep in mind that a spring can be either compressed or stretched whereas a string can only be stretched.
- *Force of friction.* A friction force exists between two surfaces that either move or have a tendency to move relative to each other. Sometimes, the force of *air drag*, similar in some ways to the force of friction, may come into play. These forces are directed so that they resist the relative motion of the surfaces. To simplify problems you often assume that friction is negligible on *smooth* surfaces and can be ignored. In addition, the word friction commonly refers to resistive forces other than air drag that are caused by contact between surfaces, so you can ignore air drag in problems unless you are explicitly told to consider its effects.

The following examples should help you learn to draw free-body diagrams. We will start with relatively simple situations in which the object of interest is either explicitly suggested or fairly obvious.

Part A

A hockey puck slides along a horizontal, smooth icy surface at a constant velocity as shown. Which of the following forces act on the puck?

Check all that apply.

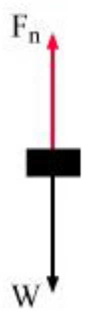


ANSWER:

- [ ] acceleration
- [ ] force of velocity
- [x] normal force
- [ ] friction
- [ ] air drag
- [x] weight
- [ ] force of push

Correct

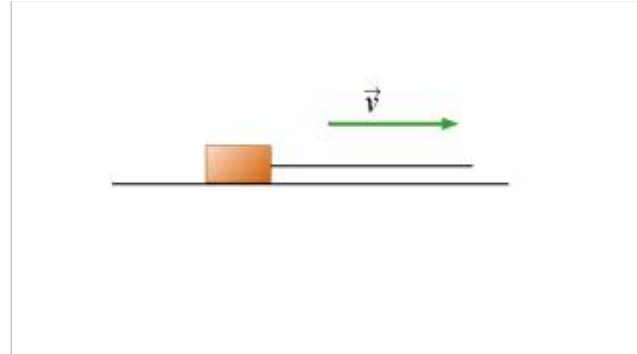
There is no such thing as "the force of velocity." If the puck is not being pushed, there are no horizontal forces acting on it. Of course, some horizontal force must have acted on it before, to impart the velocity--however, in the situation described, no such "force of push" exists. Also, the air drag in such cases is assumed to be negligible. Finally, the word "smooth" usually implies negligible surface friction. Your free-body diagram should look like the one shown here.



Part B

Consider a block pulled by a horizontal rope along a horizontal surface at a constant velocity as shown. There is tension in the rope. Which of the following forces act on the block?

Check all that apply.

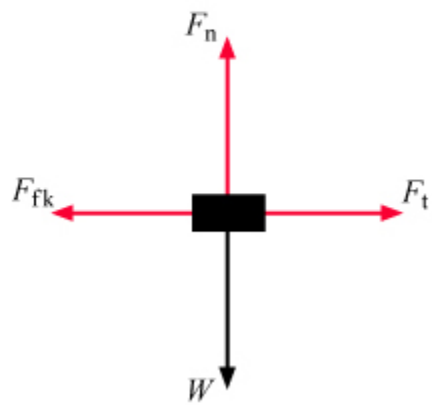


ANSWER:

- [x] force of tension
- [ ] acceleration
- [x] normal force
- [x] weight
- [x] friction
- [ ] force of velocity
- [ ] air drag

Correct

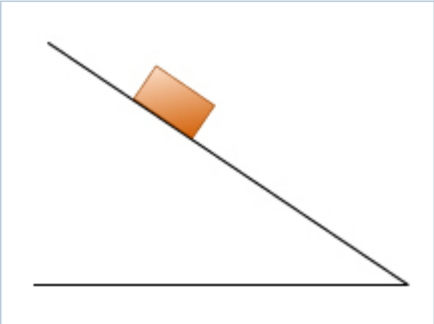
Because the velocity is constant, there must be a force of friction opposing the force of tension. Since the block is moving, it is *kinetic* friction. Your free-body diagram should look like that shown here.



Part C

A block is resting on an slope. Which of the following forces act on the block?

Check all that apply.



ANSWER:

- [x] static friction
- [x] normal force
- [x] weight
- [ ] kinetic friction
- [ ] force of push

Correct

Part D

Draw the free-body diagram for the block resting on a slope.

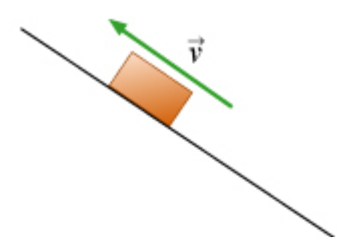
Draw the force vectors such that their tails align with the center of the block (indicated by the black dot). The orientations of your vectors will be graded but not the lengths.

ANSWER:

Correct

Part E

Now consider a block sliding up a rough slope *after* having been given a quick push as shown . Which of the following forces act on the block?



Check all that apply.

ANSWER:

- [x] weight
- [x] kinetic friction
- [ ] static friction
- [ ] force of push
- [x] normal force
- [ ] the force of velocity

All attempts used; correct answer displayed

The word "rough" implies the presence of friction. Since the block is in motion, it is *kinetic* friction. Once again, there is no such thing as "the force of velocity." However, it seems a tempting choice to some students since the block *is* going up.

Part F

Draw the free-body diagram for the block sliding up a rough slope *after* having been given a quick push.

Draw the force vectors such that their tails align with the center of the block (indicated by the black dot). The orientations of your vectors will be graded but not the lengths.

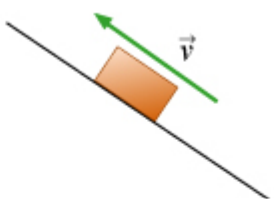
ANSWER:

Correct

Part G

Now consider a block *being pushed* up a *smooth* slope. The force pushing the block is parallel to the slope. Which of the following forces are acting on the block?

Check all that apply.

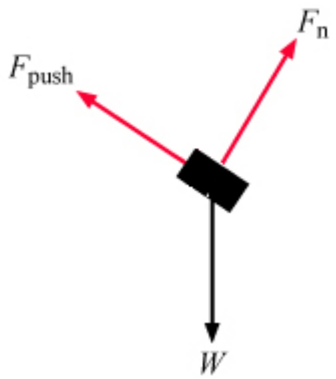


ANSWER:

- ☑ weight
- ☐ kinetic friction
- ☐ static friction
- ☑ force of push
- ☑ normal force

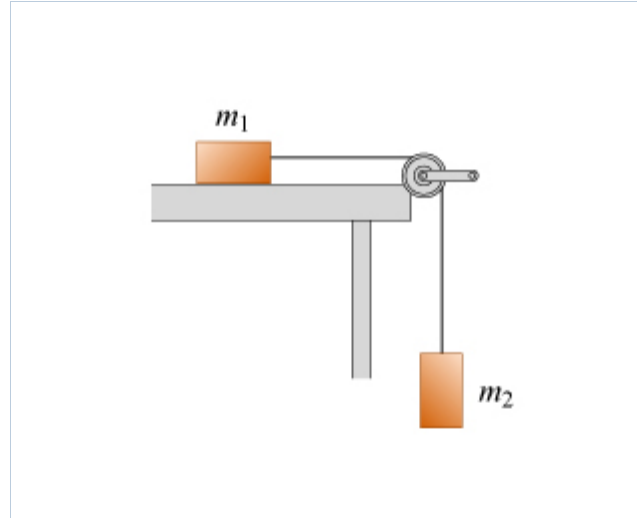
Correct

Your free-body diagram should look like the one shown here.



The force of push is the normal force exerted, possibly, by the palm of the hand of the person pushing the block.

In all the previous situations just described, the object of interest was explicitly given. In the remaining parts of the problem, consider a situation where choosing the objects for which to draw the free-body diagrams is up to you.
Two blocks of masses m_1 and m_2 are connected by a light string that goes over a light frictionless pulley. The block of mass m_1 is sliding to the right on a rough horizontal surface of a lab table.



Part H

To solve for the acceleration of the blocks, you will have to draw the free-body diagrams for which objects?

Check all that apply.

ANSWER:

- [x] the block of mass m_1
- [x] the block of mass m_2
- [ ] the connecting string
- [ ] the pulley
- [ ] the table
- [ ] the earth

Correct

Part I

Draw the free-body diagram for the block of mass m_1 and draw a free-body diagram for the block of mass m_2.

Draw the force vectors acting on m_1 such that their tails align with the center of the block labeled m_1 (indicated by the black dot). Draw the force vectors acting on m_2 with their tails aligned with the center of the block labeled m_2. The orientations of your vectors will be graded but not the lengths.

ANSWER:

Correct

Free-Body Diagrams

Learning Goal:

To gain practice drawing free-body diagrams

Whenever you face a problem involving forces, always start with a free-body diagram.
To draw a free-body diagram use the following steps:

1. Isolate the object of interest. It is customary to represent the object of interest as a point in your diagram.
2. Identify all the forces acting on the object and their directions. Do not include forces acting on other objects in the problem. Also, do not

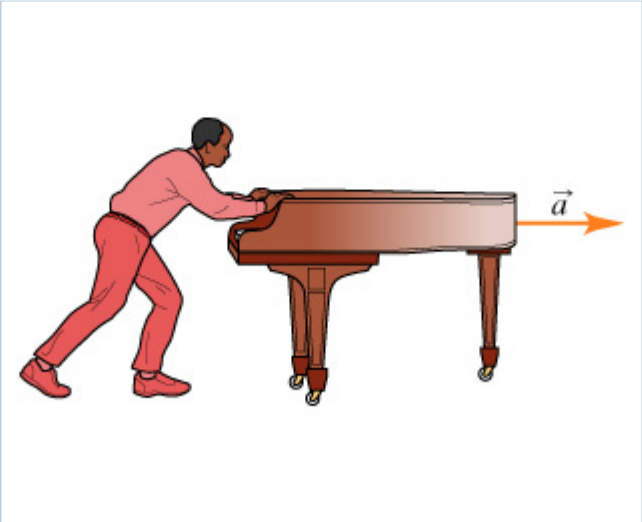
include quantities, such as velocities and accelerations, that are not forces.

3. Draw the vectors for each force acting on your object of interest. When possible, the length of the force vectors you draw should represent the relative magnitudes of the forces acting on the object.

In most problems, after you have drawn the free-body diagrams, you will explicitly label your coordinate axes and directions. Always make the object of interest the origin of your coordinate system. Then you will need to divide the forces into *x* and *y* components, sum the *x* and *y* forces, and apply Newton's first or second law.

In this problem you will only draw the free-body diagram.

Suppose that you are asked to solve the following problem:
Chadwick is pushing a piano across a level floor (see the figure). The piano can slide across the floor without friction. If Chadwick applies a horizontal force to the piano, what is the piano's acceleration?
To solve this problem you should start by drawing a free-body diagram.



Part A

Determine the object of interest for the situation described in the problem introduction.

Hint 1. How to approach the problem

You should first think about the question you are trying to answer: What is the acceleration of the piano? The object of interest in this situation will be the object whose acceleration you are asked to find.

ANSWER:

For this situation you should draw a free-body diagram for

- ○ the floor.
- ○ Chadwick.
- ◉ the piano.

Correct

Part B

Identify the forces acting on the object of interest. From the list below, select the forces that act on the piano.

Check all that apply.

ANSWER:

- ☐ acceleration of the piano
- ☑ gravitational force acting on the piano (piano's weight)
- ☐ speed of the piano
- ☐ gravitational force acting on Chadwick (Chadwick's weight)
- ☑ force of the floor on the piano (normal force)
- ☐ force of the piano on the floor
- ☑ force of Chadwick on the piano
- ☐ force of the piano pushing on Chadwick

Correct

Now that you have identified the forces acting on the piano, you should draw the free-body diagram. Draw the length of your vectors to represent the relative magnitudes of the forces, but you don't need to worry about the exact scale. You won't have the exact value of all of the forces until you finish solving the problem. To maximize your learning, you should draw the diagram yourself before looking at the choices in the next part. You are on your honor to do so.

Part C

Select the choice that best matches the free-body diagram you have drawn for the piano.

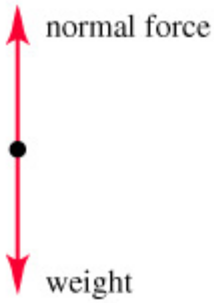
Hint 1. Determine the directions and relative magnitudes of the forces

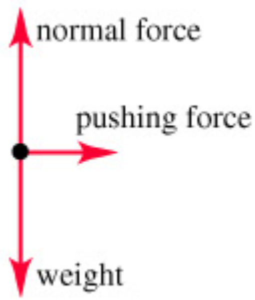
Which of the following statements best describes the correct directions and relative magnitudes of the forces involved?

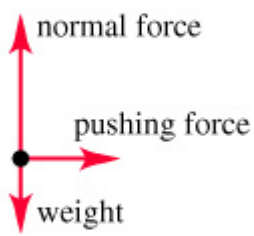
ANSWER:

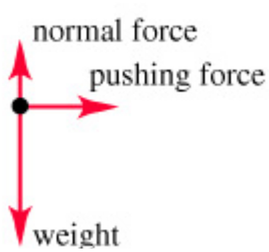
- ○ The normal force and weight are both upward and the pushing force is horizontal.
- ○ The normal force and weight are both downward and the pushing force is horizontal.
- ○ The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force has a greater magnitude than the weight.
- ◉ The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force and weight have the same magnitude.
- ○ The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force has a smaller magnitude than the weight.

ANSWER:


normal force
weight


normal force
pushing force
weight

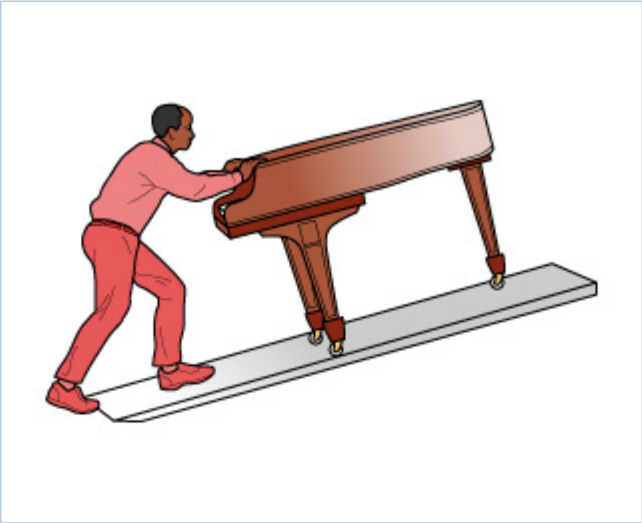

normal force
pushing force
weight


normal force
pushing force
weight

Correct

If you were actually going to solve this problem rather than just draw the free-body diagram, you would need to define the coordinate system. Choose the position of the piano as the origin. In this case it is simplest to let the y axis point vertically upward and the x axis point horizontally to the right, in the direction of the acceleration.

Chadwick now needs to push the piano up a ramp and into a moving van. at left. Is Chadwick strong enough to push the piano up the ramp alone or must he get help? Estimate the force needed to push the piano up the ramp. Neglect friction.



Part D

Determine the object of interest for this situation.

ANSWER:

For this situation, you should draw a free-body diagram for

- the ramp.
- Chadwick.
- the piano.

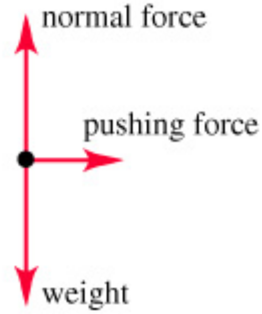
Correct

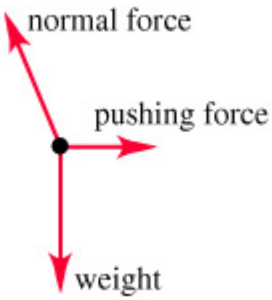
Now draw the free-body diagram of the piano in this new situation. Follow the same sequence of steps that you followed for the first situation. Again draw your diagram before you look at the choices below.

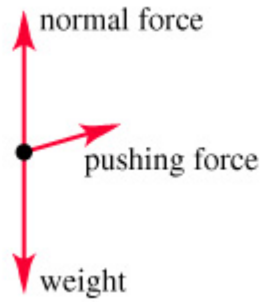
Part E

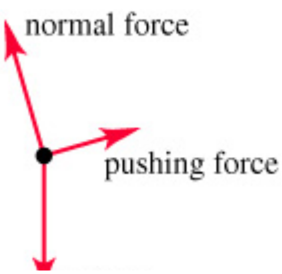
Which diagram accurately represents the free-body diagram for the piano?

ANSWER:


normal force
pushing force
weight


normal force
pushing force
weight


normal force
pushing force
weight


normal force
pushing force

Correct

In working problems like this one that involve an incline, it is most often easiest to select a coordinate system that is not vertical and horizontal. Instead, choose the *x* axis so that it is parallel to the incline and choose the *y* axis so that it is perpendicular to the incline.

A Push or a Pull?

Learning Goal:

To understand the concept of force as a push or a pull and to become familiar with everyday forces.

A force can be simply defined as *a push or a pull exerted by one object upon another*.

Although such a definition may not sound too scientific, it does capture three essential properties of forces:

- Each force is created by some object.
- Each force acts upon some *other* object.
- The action of a force can be visualized as a push or a pull.

Since each force is created by one object and acts upon another, *forces must be described as interactions*. The proper words describing the force interaction between objects A and B may be any of the following:

- "Object A acts upon object B with force $\vec{F}$."
- "Object A exerts force $\vec{F}$ upon object B."
- "Force $\vec{F}$ is applied to object B by object A."
- "Force $\vec{F}$ due to object A is acting upon object B."

One of the biggest mistakes you may make is to think of a force as "something an object *has*." In fact, at least two objects are always required for a force to exist.

Each force has a direction: *Forces are vectors.* The main result of such interactions is that the objects involved change their velocities: *Forces cause acceleration*. However, in this problem, we will not concern ourselves with acceleration--not yet.

Some common types of forces that you will be dealing with include the gravitational force (weight), the force of tension, the force of friction, and the normal force.

It is sometimes convenient to classify forces as either *contact forces* between two objects that are touching or as *long-range forces* between two objects that are some distance apart. Contact forces include tension, friction, and the normal force. Long-range forces include gravity and electromagnetic forces. Note that such a distinction is useful but not really fundamental: For instance, on a microscopic scale the force of friction is really an electromagnetic force.

In this problem, you will identify the types of forces acting on objects in various situations.

First, consider a book resting on a horizontal table.

Part A

Which object exerts a downward force on the book?

ANSWER:

- the book itself
- the earth
- the surface of the table

Correct

Part B

The downward force acting on the book is __________.

ANSWER:

- a contact force
- a long-range force

Correct

Part C

What is the downward force acting on the book called?

ANSWER:

- tension
- normal force
- weight
- friction

Correct

Part D

Which object exerts an upward force on the book?

ANSWER:

- the book itself
- the earth
- the surface of the table

Correct

Part E

The upward force acting on the book is ___________.

ANSWER:

- (selected) a contact force
- a long-range force

Correct

Part F

What is the upward force acting on the book called?

ANSWER:

- tension
- (selected) normal force
- weight
- friction

Correct

Now consider a different situation. A string is attached to a heavy block. The string is used to pull the block to the right along a rough horizontal table.

Part G

Which object exerts a force on the block that is directed toward the right?

ANSWER:

- the block itself
- the earth
- the surface of the table
- the string

Correct

Part H

The force acting on the block and directed to the right is ___________.

ANSWER:

- a contact force
- a long-range force

Correct

To exert a tension force, the string must be connected to (i.e., touching) the block.

Part I

What is the force acting on the block and directed to the right called?

ANSWER:

- (selected) tension
- normal force
- weight
- friction

Correct

Part J

Which object exerts a force on the block that is directed toward the left?

ANSWER:

- the block itself
- the earth
- (selected) the surface of the table
- the string

Correct

Part K

The force acting on the block and directed to the left is __________.

ANSWER:

- ◉ a contact force
- ○ a long-range force

Correct

Part L

What is the force acting on the block and directed to the left called?

ANSWER:

- ○ tension
- ○ normal force
- ○ weight
- ◉ friction

Correct

Now consider a slightly different situation. The same block is placed on the same rough table. However, this time, the string is disconnected and the block is given a *quick push* to the right. The block slides to the right and eventually stops. The following questions refer to the motion of the block *after* it is pushed but *before* it stops.

Part M

How many forces are acting on the block in the horizontal direction?

ANSWER:

- ○ 0
- ◉ 1
- ○ 2
- ○ 3

Correct

Once the push has commenced, there is *no force* acting to the right: The block is moving to the right because it was given a velocity in this direction by some force that is no longer applied to the block (probably, the normal force exerted by a student's hand or some spring launcher).

Once the contact with the launching object has been lost, the only horizontal force acting on the block is directed to the left--which is why the block eventually stops.

Part N

What is the force acting on the block that is directed to the *left* called?

ANSWER:

- ○ tension
- ○ normal force
- ○ weight
- ◉ friction

Correct

The force of friction does not disappear as long as the block is moving. Once the block stops, fricion becomes zero (assuming the table is perfectly horizontal).

Score Summary:

Your score on this assignment is 92.7%.
You received 18.54 out of a possible total of 20 points.