< All Assignments

# Chapter 4

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**Chapter 4**

**Due: 11:59pm on Sunday, February 10, 2019**

To understand how points are awarded, read the Grading Policy for this assignment.

## Newton's 1st Law

**Description:** Conceptual. Introduces Newton's first law and follows with questions.

**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 vector 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, $\vec{F}_{\rm net} = m\vec{a}$ when $\vec{F}_{\rm net} = \vec{0}$, 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 may have been acquired from experience 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., vector 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 exerted on the car.
- the net force exerted on the car is directed to the left.
- the net force exerted on the car is zero.
- there is exactly one force exerted on the car.

### Part B

An object cannot remain at rest unless

ANSWER:

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

## Applying Newton's 2nd Law

**Description:** Leads students through the standard prescription for solving Newton's Second Law problems with example of an inclined plane, pulley and two blocks.

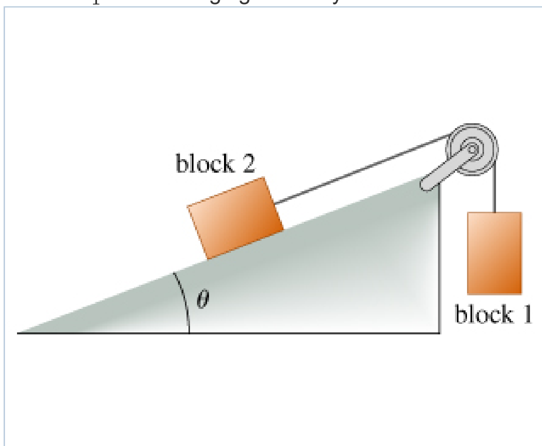
**Learning Goal:**

To learn a systematic approach to solving Newton's 2nd law problems using a simple example.

Once you have decided to solve a problem using Newton's 2nd law, there are steps that will lead you to a solution. One such prescription is the following:

- Visualize the problem and identify special cases.
- Isolate each body and draw the forces acting on it.
- Choose a coordinate system for each body.
- Apply Newton's 2nd law to each body.
- Write equations for the constraints and other given information.
- Solve the resulting equations symbolically.
- Check that your answer has the correct dimensions and satisfies special cases.
- If numbers are given in the problem, plug them in and check that the answer makes sense.
- Think about generalizations or simplfications of the problem.

As an example, we will apply this procedure to find the acceleration of a block of mass $m_2$ that is pulled up a frictionless plane inclined at angle $\theta$ with respect to the horizontal by a perfect string that passes over a perfect pulley to a block of mass $m_1$ that is hanging vertically.




**Visualize the problem and identify special cases**

First examine the problem by drawing a picture and visualizing the motion. Apply Newton's 2nd law, $\sum \vec{F} = m\vec{a}$, to each body in your mind. Don't worry about which quantities are given. Think about the forces on each body: How are these consistent with the direction of the acceleration for that body? Can you think of any special cases that you can solve quickly now and use to test your understanding later?

One special case in this problem is if $m_2 = 0$, in which case block 1 would simply fall freely under the acceleration of gravity: $\vec{a}_1 = -g\hat{j}$.

### Part A

Consider another special case in which the inclined plane is vertical ($\theta = \pi/2$). In this case, for what value of $m_1$ would the acceleration of the two blocks be equal to zero?

**Express your answer in terms of some or all of the variables $m_2$ and $g$.**

ANSWER:

$m_1$ = $m_2$

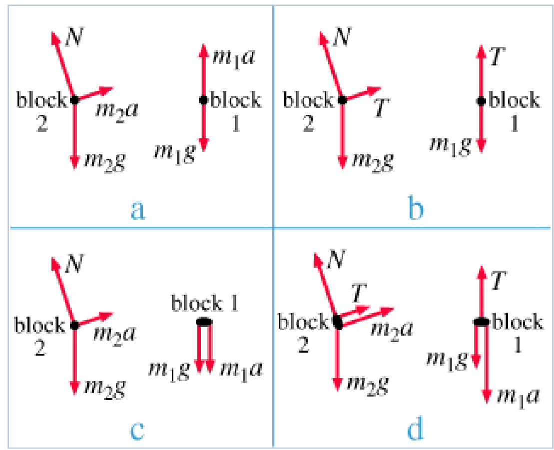
**Isolate each body and draw the forces acting on it**

A force diagram should include only *real* forces that act on the body and satisfy Newton's 3rd law. One way to check if the forces are real is to detrmine whether they are part of a Newton's 3rd law pair, that is, whether they result from a physical interaction that also causes an opposite force on some other body, which may not be part of the problem. Do not decompose the forces into components, and do not include resultant forces that are combinations of other real forces like centripetal force or fictitious forces like the "centrifugal" force.

Assign each force a symbol, but don't start to solve the problem at this point.

## Part B

Which of the four drawings is a correct force diagram for this problem?




ANSWER:

- a
- b (selected)
- c
- d

**Choose a coordinate system for each body**

Newton's 2nd law, $\sum \vec{F} = m\vec{a}$, is a vector equation. To add or subtract vectors it is often easiest to decompose each vector into components. Whereas a particular set of vector components is only valid in a particular coordinate system, the vector equality holds in *any* coordinate system, giving you freedom to pick a coordinate system that most simplifies the equations that result from the component equations.

It's generally best to pick a coordinate system where the acceleration of the system lies directly on one of the coordinate axes. If there is no acceleration, then pick a coordinate system with as many unknowns as possible along the coordinate axes. Vectors that lie along the axes appear in only one of the equations for each component, rather than in two equations with trigonometric prefactors. Note that it is sometimes advantageous to use *different* coordinate systems for each body in the problem.

In this problem, you should use Cartesian coordinates and your axes should be stationary with respect to the inclined plane.

## Part C

Given the criteria just described, what orientation of the coordinate axes would be best to use in this problem?

**In the answer options, "tilted" means with the *x* axis oriented parallel to the plane (i.e., at angle $\theta$ to the horizontal), and "level" means with the *x* axis horizontal.**

ANSWER:

- tilted for both block 1 and block 2
- tilted for block 1 and level for block 2
- (selected) level for block 1 and tilted for block 2
- level for both block 1 and block 2

**Apply Newton's 2nd law to each body**

## Part D

What is $\sum F_{2x}$, the sum of the *x* components of the forces acting on block 2? Take forces acting up the incline to be positive.

**Express your answer in terms of some or all of the variables tension $T$, $m_2$, the magnitude of the acceleration of gravity $g$, and $\theta$.**

**Hint 1.** Decompose the force of gravity on block 2

In this problem, the hardest force vector to express in terms of its coordinates is the force of gravity on block 2. The magnitude of the weight is $m_2g$. Find the force of gravity in terms of its components, using a tilted coordinate system whose *x* axis is parallel to and pointing up the inclined plane.

**Express the force of gravity on block 2, $\vec{F}_{g2}$, in terms of some or all of the variables $m_2$, $g$, and $\theta$. Express your answer as a vector in terms of the unit vectors $\hat{i}$ and $\hat{j}$.**

ANSWER:

$\vec{F}_{g2}$ = $-m_2g\left(\sin(\theta)\,\hat{i}+\cos(\theta)\,\hat{j}\right)$

ANSWER:

$m_2a_{2x} = \sum F_{2x}$ = $T - m_2g\sin(\theta)$

## Part E

Now determine $m_1a_{1y} = \sum F_{1y}$, the sum of the *y* components of the forces acting on block 1. Take forces acting upward as positive.

**Express your answer in terms of some or all of the variables $T$, $m_1$, and $g$.**

ANSWER:

$m_1a_{1y} = \sum F_{1y}$ = $T - m_1g$

## Part F

**Write equations for the constraints and other given information**

In this problem, the fact that the length of the string does not change imposes a constraint on relative accelerations of the two blocks. Find a relationship between the *x* component of the acceleration of block 2, $a_{2\mathrm{x}}$, and the acceleration of block 1. Pay careful attention to signs.

**Express $a_{2\mathrm{x}}$ in terms of $a_{1\mathrm{x}}$ and/or $a_{1\mathrm{y}}$, the components of the acceleration vector of block 1.**

**Hint 1.** Visualize the motion

If block 2 has an acceleration $a_{2\mathrm{x}}$ up the incline, must the acceleration of block 1 be upward or downward to keep the string taut?

ANSWER:

$a_{2x}$ = $-a_{1y}$

## Part G

**Solve and check**
In the previous parts, you obtained the following equations using Newton's 2nd law and the constraint on the motion of the two blocks:

$$m_2 a_{2x} = T - m_2 g \sin(\theta), \quad (1)$$

$$m_1 a_{1y} = T - m_1 g, \quad (2)$$

and

$$a_{2x} = -a_{1y}. \quad (3)$$

Solve these equations to find $a_{1y}$.

Before you enter your answer, make sure it satisfies the special cases you already identified:

- $a_{1y} = -g$ if $m_2 = 0$ and
- $a_{1y} = 0$ if $m_1 = m_2$ and $\theta = \pi/2$.

Also make sure that your answer has dimensions of acceleration.

**Express $a_{1y}$ in terms of some or all of the variables $m_1$, $m_2$, $\theta$, and $g$.**

**Hint 1.** How to solve the equations

Substitute for $T$ from equation (1) into equation (2) and then use $a_{2x}$ from equation (3) in the new equation (2). This will yield a linear equation in $a_{1y}$ that is easy to solve.

ANSWER:

$a_{1y}$ = $\frac{(m_2 \sin(\theta) - m_1) g}{m_1 + m_2}$

Can you see how a simple generalization of the problem could be solved with a little extra work or how you could solve a nontrivial problem that is a subset of this one?
For example, imagine that there is friction in this problem between the plane and block 2. This would lead to an additional force on block 2: $F_{f2} = \mu N$, where the normal force $N$ is given by $N = m_2 g \cos(\theta)$.

This additional force would lead to a new term in the expression for the acceleration of block 1:

$$a_{1y} = \frac{m_2 \sin(\theta) - \mu m_2 \cos(\theta) - m_1}{m_1 + m_2} g.$$

Now, by choosing whether or not $\mu = 0$, you have a result that can be applied whether the plane is frictionless or not!

# Free-Body Diagrams: Introduction

**Description:** Contains several conceptual questions asking the students various questions about free-body diagrams and highlighting their role in the solution process.

**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.

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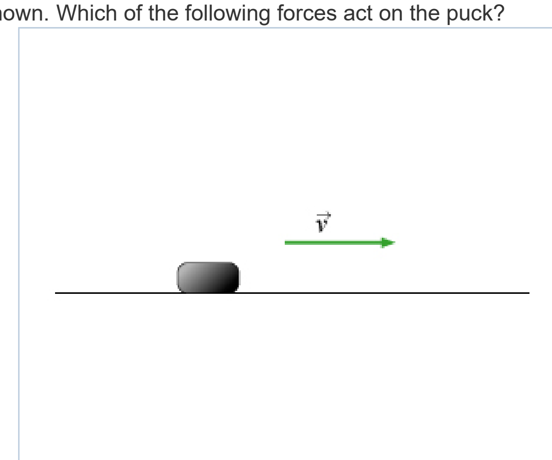
### Part A

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

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

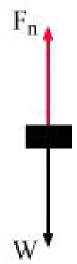
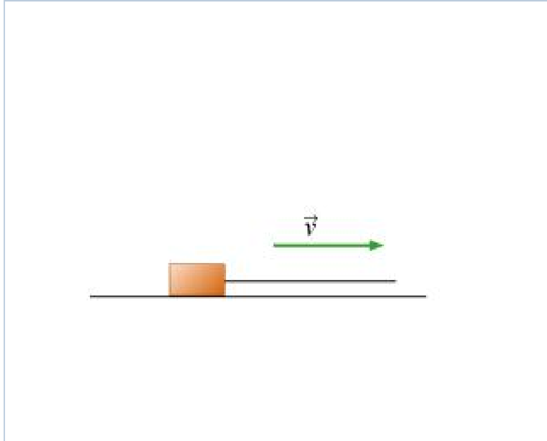



diagram should look like the one shown here.

## 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?

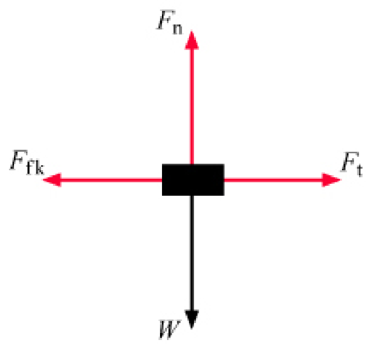
**Check all that apply.**




ANSWER:

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

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*

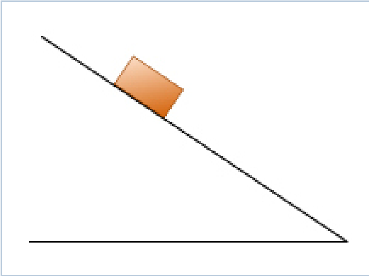



friction. Your free-body diagram should look like that shown here.

## Part C

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

**Check all that apply.**



ANSWER:

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

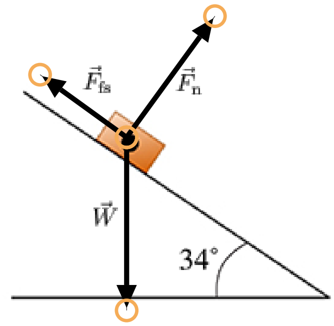
## Part D

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:

No elements selected

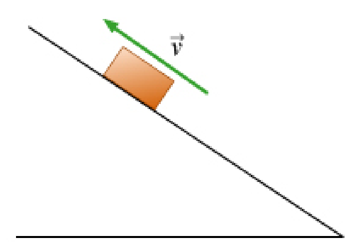



Select the elements from the list and add them to the canvas setting the appropriate attributes.

**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

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.

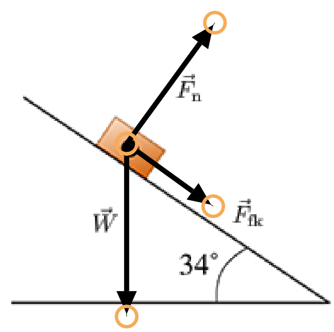
### Part F

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:

No elements selected

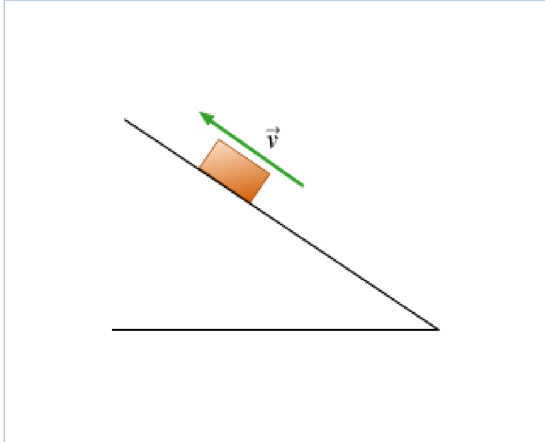



Select the elements from the list and add them to the canvas setting the appropriate attributes.

### Part G

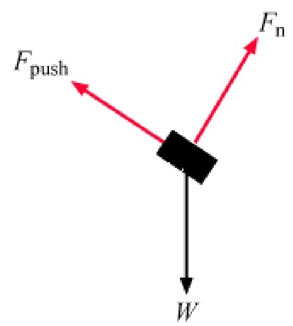
Now consider a block *being pushed* up a *smooth* slope. The force pushing the block is parallel to the slope. Which of the following forces are acting on the block?

**Check all that apply.**




ANSWER:

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




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.

## 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

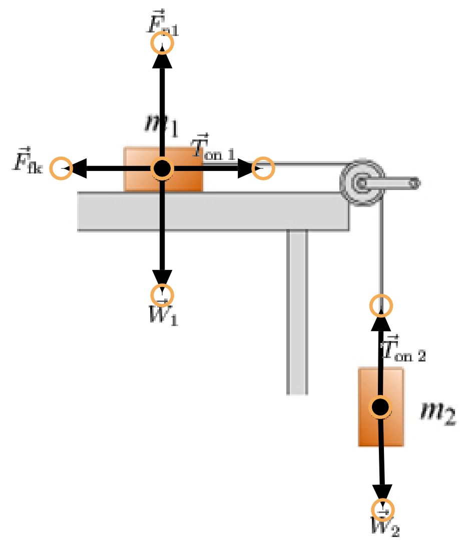
## Part I

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:

No elements selected




Select the elements from the list and add them to the canvas setting the appropriate attributes.

## Free-Body Diagrams

**Description:** Instructions for creating free-body diagrams are provided. Students practice creating diagrams for two different physical situations.

**Learning Goal:**

To gain practice drawing free-body diagrams

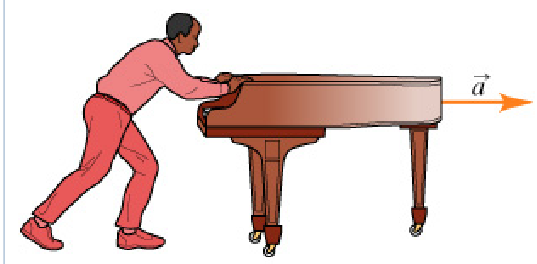
Whenever you face a problem involving forces, always start with a free-body diagram.
To draw a free-body diagram use the following steps:

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.

## 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

## Part C

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

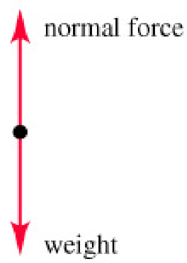
**Hint 1.** Determine the directions and relative magnitudes of the forces

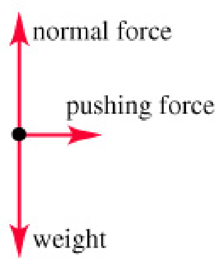
Which of the following statements best describes the correct directions and relative magnitudes of the forces involved?

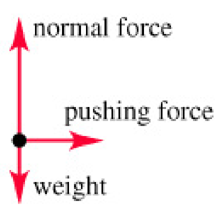
ANSWER:

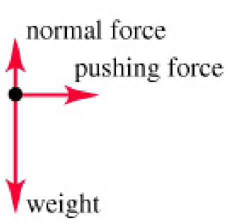
- The normal force and weight are both upward and the pushing force is horizontal.
- The normal force and weight are both downward and the pushing force is horizontal.
- The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force has a greater magnitude than 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:



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.

## Part D

Determine the object of interest for this situation.

ANSWER:

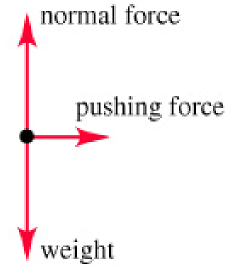
For this situation, you should draw a free-body diagram for

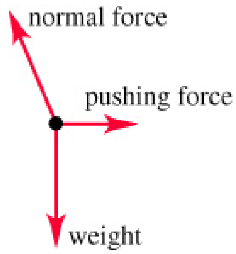
- ○ the ramp.
- ○ Chadwick.
- ◉ the piano.

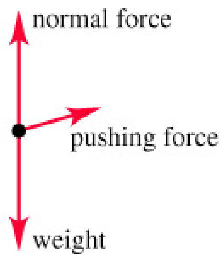
## Part E

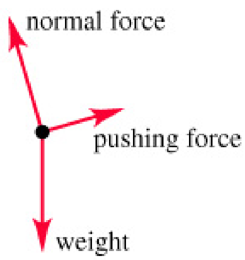
Which diagram accurately represents the free-body diagram for the piano?

ANSWER:




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.

## Tension in a Massless Rope

**Description:** Simple questions about tension and its relationship to the internal forces in a rope. Asks students to make the connection between Newton's Laws and why the tension must be equal everywhere in the rope.

**Learning Goal:**

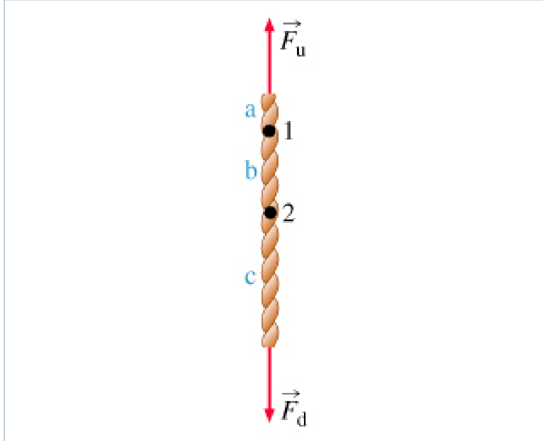
To understand the concept of tension and the relationship between tension and force.

This problem introduces the concept of tension. The example is a rope, oriented vertically, that is being pulled from both ends. Let $F_{\rm u}$ and $F_{\rm d}$ (with u for up and d for down) represent the magnitude of the forces acting on the top and bottom of the rope, respectively. Assume that the rope is massless, so that its weight is negligible compared with the tension. (This is not a ridiculous approximation--modern rope materials such as Kevlar can carry tensions thousands of times greater than the weight of tens of meters of such rope.)

Consider the three sections of rope labeled a, b, and c in the figure.

- At point 1, a downward force of magnitude $F_{\rm ad}$ acts on section a.

- At point 1, an upward force of magnitude $F_{\rm bu}$ acts on section b.
- At point 1, the tension in the rope is $T_1$.
- At point 2, a downward force of magnitude $F_{\rm bd}$ acts on section b.
- At point 2, an upward force of magnitude $F_{\rm cu}$ acts on section c.
- At point 2, the tension in the rope is $T_2$.




Assume, too, that the rope is at equilibrium.

## Part A

What is the magnitude $F_{\rm ad}$ of the downward force on section a?

**Express your answer in terms of the tension $T_1$.**

ANSWER:

$F_{\rm ad}$ = $T_1$

## Part B

What is the magnitude $F_{\rm bu}$ of the upward force on section b?

**Express your answer in terms of the tension $T_1$.**

ANSWER:

$F_{\rm bu}$ = $T_1$

## Part C

The magnitude of the upward force on c, $F_{\rm cu}$, and the magnitude of the downward force on b, $F_{\rm bd}$, are equal because of which of Newton's laws?

ANSWER:

- ○ 1st
- ○ 2nd
- ◉ 3rd

## Part D

The magnitude of the force $F_{\rm bu}$ is _____ $F_{\rm bd}$.

ANSWER:

- ○ less than
- ○ greater than
- ◉ equal to

It is important to realize that $F_{\rm bu}$ and $F_{\rm bd}$ are not a Newton's third law pair of forces. Instead, these forces are equal and opposite due to the fact that the rope is stationary ($a_{\rm b} = 0$) and massless($m_{\rm b} = 0$). By applying Newtons first or second law to this segment of rope you obtain $F_{\rm b\ net} = F_{bu} - F_{bd} = m_{\rm b} a_{\rm b} = 0$, since $m_{\rm b} = 0$ and $a_{\rm b} = 0$. Note that if the rope were accelerating, these forces would still be equal and opposite because $m_{\rm b} = 0$.

## Part E

Now consider the forces on the ends of the rope. What is the relationship between the magnitudes of these two forces?

**Hint 1.** Consider the bigger picture

From Part D, we see that the internal forces of the rope are simply equal to each other. This leaves us with only the external forces to deal with. Since the rope is massless, what must be the relationship between these external forces?

ANSWER:

- ○ $F_u > F_d$
- ◉ $F_u = F_d$
- ○ $F_u < F_d$

The forces on the two ends of an ideal, massless rope are always equal in magnitude. Furthermore, the magnitude of these forces is equal to the tension in the rope.

## Part F

The ends of a massless rope are attached to two stationary objects (e.g., two trees or two cars) so that the rope makes a straight line. For this situation, which of the following statements are true?

**Check all that apply.**

ANSWER:

- [x] The tension in the rope is everywhere the same.
- [x] The magnitudes of the forces exerted on the two objects by the rope are the same.
- [x] The forces exerted on the two objects by the rope must be in opposite directions.
- [x] The forces exerted on the two objects by the rope must be in the direction of the rope.

# Exercise 4.8

**Description:** You walk into an elevator, step onto a scale, and push the "up" button. You recall that your normal weight is ## N. (a) Draw a free-body diagram for you. (b) When the elevator has an upward acceleration of magnitude a, what does the scale...

You walk into an elevator, step onto a scale, and push the "up" button. You recall that your normal weight is 631 $\rm N$ .

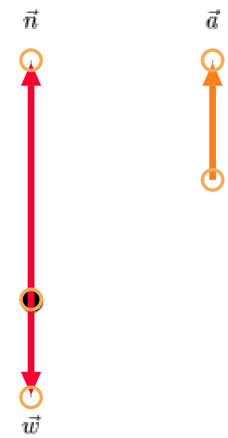
## Part A

Draw a free-body diagram for you.

**Draw the vectors starting at the black dots. The location and orientation of the vectors will be graded. The length of the vectors will not be graded.**

ANSWER:

No elements selected




Select the elements from the list and add them to the canvas setting the appropriate attributes.

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**Part B**

When the elevator has an upward acceleration of magnitude 2.60 $\mathrm{m/s^2}$ , what does the scale read?

**Express your answer with the appropriate units.**

ANSWER:

$F$ = $w + \frac{w}{9.8}a$ = 798$\mathrm{N}$

Also accepted: $w + \frac{w}{9.81}a$ = 798$\mathrm{N}$, $w + \frac{w}{9.8}a$ = 798$\mathrm{N}$

---

**Part C**

If you hold a 3.95-$\mathrm{kg}$ package by a light vertical string, what will be the tension in this string when the elevator accelerates as in the previous part?

**Express your answer with the appropriate units.**

ANSWER:

$T$ = $m\left(9.80 + a\right)$ = 49.0$\mathrm{N}$

Also accepted: $m\left(9.81 + a\right)$ = 49.0$\mathrm{N}$, $m\left(9.80 + a\right)$ = 49.0$\mathrm{N}$

# Exercise 4.12

**Description:** A crate with mass m initially at rest on a warehouse floor is acted on by a net horizontal force of F. (a) What acceleration is produced? (b) How far does the crate travel in t? (c) What is its speed at the end of t?

A crate with mass 25.5 $\mathrm{kg}$ initially at rest on a warehouse floor is acted on by a net horizontal force of 152 $\mathrm{N}$ .

## Part A

What acceleration is produced?

ANSWER:

$a = \frac{F}{m} = 5.96 \quad \mathrm{m/s^2}$

## Part B

How far does the crate travel in 10.5 s ?

ANSWER:

$x = \frac{\frac{F}{m}t^2}{2} = 329 \quad \mathrm{m}$

## Part C

What is its speed at the end of 10.5 s ?

ANSWER:

$v = \frac{F}{m}t = 62.6 \quad \mathrm{m/s}$

# Exercise 4.6

**Description:** An electron of mass m_e leaves one end of a TV picture tube with zero initial speed and travels in a straight line to the accelerating grid, which is a distance s away. It reaches the grid with a speed of v. The accelerating force is constant. (a)...

An electron of mass $9.11\times10^{-31}$ $\mathrm{kg}$ leaves one end of a TV picture tube with zero initial speed and travels in a straight line to the accelerating grid, which is a distance 2.80 $\mathrm{cm}$ away. It reaches the grid with a speed of $3.10\times10^{6}$ $\mathrm{m/s}$ . The accelerating force is constant.

## Part A

Find the acceleration.

ANSWER:

$a = \frac{v^2}{2s} = 1.72\times10^{14} \quad \mathrm{m/s^2}$

## Part B

Find the time to reach the grid.

ANSWER:

$t = \frac{2s}{v}$ = 1.81×10$^{-8}$ s

### Part C

Find the net force. (You can ignore the gravitational force on the electron).

ANSWER:

$F_{net} = \frac{v^2}{2s} m_e$ = 1.56×10$^{-16}$ N

## Exercise 4.16

**Description:** An astronaut's pack weighs w1 when she is on earth but only w2 when she is at the surface of moon. (a) What is the acceleration due to gravity on this moon? (b) What is the mass of the pack on this moon?

An astronaut's pack weighs 19.4 N when she is on earth but only 4.76 N when she is at the surface of moon.

### Part A

What is the acceleration due to gravity on this moon?

**Express your answer with the appropriate units.**

ANSWER:

$g_a = \frac{9.8w2}{w1}$ = 2.40 $\frac{m}{s^2}$

Also accepted: $\frac{9.81w2}{w1}$ = 2.41 $\frac{m}{s^2}$, $\frac{9.8w2}{w1}$ = 2.40 $\frac{m}{s^2}$

### Part B

What is the mass of the pack on this moon?

**Express your answer with the appropriate units.**

ANSWER:

$m = \frac{w1}{9.8}$ = 1.98 kg

Also accepted: $\frac{w1}{9.81}$ = 1.98 kg, $\frac{w1}{9.8}$ = 1.98 kg

## Exercise 4.29

**Description:** A chair of mass m is sitting on the horizontal floor; the floor is not frictionless. You push on the chair with a force F that is directed at an angle of alpha below the horizontal and the chair slides along the floor. (a) Use Newton's laws to...

A chair of mass 13.0 kg is sitting on the horizontal floor; the floor is not frictionless. You push on the chair with a force $F$ = 43.0 N that is directed at an angle of 43.0 $^\circ$ below the horizontal and the chair slides along the floor.

### Part A

Use Newton's laws to calculate the normal force that the floor exerts on the chair.

ANSWER:

$n = mg + F\sin(\alpha)$ = 157 N

## Problem 4.32

**Description:** You have just landed on Planet X. You release a m-g ball from rest from a height of h and measure that it takes t to reach the ground. Ignore any force on the ball from the atmosphere of the planet. (a) How much does the m-g ba...

You have just landed on Planet X. You release a 110-g ball from rest from a height of 16.0 m and measure that it takes 2.60 s to reach the ground. Ignore any force on the ball from the atmosphere of the planet.

### Part A

How much does the 110-g ball weigh on the surface of Planet X?

**Express your answer to three significant figures and include the appropriate units.**

ANSWER:

$W = \frac{2mh}{t^2}$ = 0.521 N

## Alternative Exercise 4.75

**Description:** An astronaut is tethered by a strong cable to a spacecraft. The astronaut and her spacesuit have a total mass of m_1, while the mass of the cable is negligible. The mass of the spacecraft is m_2. The spacecraft is far from any large astronomical...

An astronaut is tethered by a strong cable to a spacecraft. The astronaut and her spacesuit have a total mass of 102 kg , while the mass of the cable is negligible. The mass of the spacecraft is $9.40 \times 10^4$ kg . The spacecraft is far from any large astronomical bodies, so we can ignore the gravitational forces on it and the astronaut. We also assume that both the spacecraft and the astronaut are initially at rest in an inertial reference frame. The astronaut then pulls on the cable with a force of 90.0 N .

### Part A

What force does the cable exert on the astronaut?

ANSWER:

$|F| = F$ = 90.0 N

### Part B

What is the astronaut's acceleration?

ANSWER:

$|a| = \frac{F}{m_1}$ = 0.882 $\mathrm{m/s^2}$

### Part C

What force does the cable exert on the spacecraft?

ANSWER:

$|F| = F$ = 90.0 N

### Part D

What is the acceleration of the spacecraft?

ANSWER:

$|a|$ = $\frac{F}{m_2}$ = $9.57\times10^{-4}$ $\mathrm{m/s^2}$

## Problem 4.43

**Description:** The froghopper (Philaenus spumarius), the champion leaper of the insect world, has a mass of ## mg and leaves the ground (in the most energetic jumps) at ## m/s from a vertical start. The jump itself lasts a mere ## ms before the insect is clear of...

The froghopper (*Philaenus spumarius*), the champion leaper of the insect world, has a mass of 12.3 $\mathrm{mg}$ and leaves the ground (in the most energetic jumps) at 4.00 $\mathrm{m/s}$ from a vertical start. The jump itself lasts a mere 1.00 $\mathrm{ms}$ before the insect is clear of the ground.

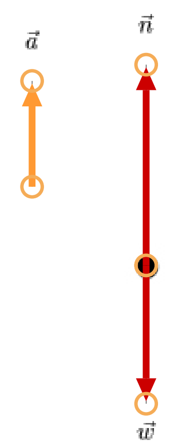
### Part A

Assuming constant acceleration, make a free-body diagram of this mighty leaper while the jump is taking place.

**Draw the force vectors with their tails at the origin of the dot. The orientation of your vectors will be graded. The exact lengths of your vectors will not be graded but the relative length of one to the other will be graded.**

ANSWER:

No elements selected




Select the elements from the list and add them to the canvas setting the appropriate attributes.

### Part B

Find the force that the ground exerts on the froghopper during its jump.

ANSWER:

$F$ = $4.92 \times 10^{-2}$ N

### Part C

Express the force in part B in terms of the froghopper's weight.

ANSWER:

$F$ = 408 $w_{\text{froghopper}}$

## Problem 4.51

**Description:** A mysterious rocket-propelled object of mass m is initially at rest in the middle of the horizontal, frictionless surface of an ice-covered lake. Then a force directed east and with magnitude F(t)= (F_t)t is applied. (a) How far does the object ...

A mysterious rocket-propelled object of mass 48.0 $\mathrm{kg}$ is initially at rest in the middle of the horizontal, frictionless surface of an ice-covered lake. Then a force directed east and with magnitude $F(t) = (15.2\ \mathrm{N/s})t$ is applied.

### Part A

How far does the object travel in the first 6.00 $\mathrm{s}$ after the force is applied?

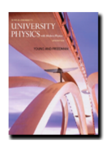
**Express your answer with the appropriate units.**

ANSWER:

$x = \frac{(t^3)(F_t)}{6m}$ = 11.4 $\mathrm{m}$

< All Assignments

**University Physics with Modern Physics, 14e**
Young/Freedman
mahapatra00294
Ends: 05/30/19



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