Extra Practice 3

Due: 2:00pm on Wednesday, February 10, 2016

You will receive no credit for items you complete after the assignment is due. Grading Policy

Exercise 4.1

Two dogs pull horizontally on ropes attached to a post; the angle between the ropes is 70.0 $^\circ$. Rover exerts a force of 340 N and Fido exerts a force of 250 N .

Part A

Find the magnitude of the resultant force.

Express your answer with the appropriate units.

ANSWER:

F_R = 486 N

Correct

Part B

Find the angle the resultant force makes with Rover's rope.

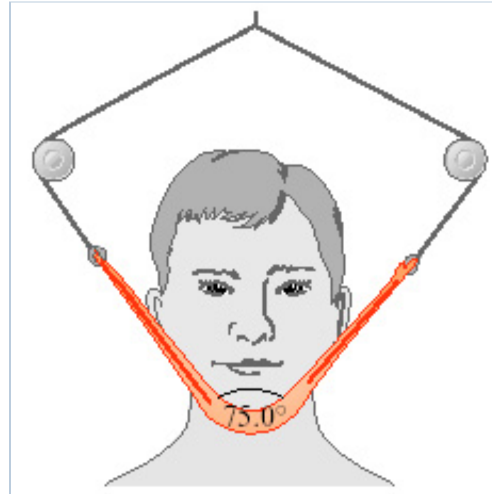
ANSWER:

θ = 28.9 $^\circ$

Correct

Exercise 4.3

Due to a jaw injury, a patient must wear a strap (see the figure) that produces a net upward force of 5.00 N on his chin. The tension is the same throughout the strap.



Part A

To what tension must the strap be adjusted to provide the necessary upward force?

ANSWER:

F = 3.15 N

Correct

Exercise 4.5

Two forces, $\vec{F}_1$ and $\vec{F}_2$, act at a point. The magnitude of $\vec{F}_1$ is 8.60 N, and its direction is an angle 59.0 $^\circ$ above the *x*-axis in the second quadrant. The magnitude of $\vec{F}_2$ is 5.20 N, and its direction is an angle 53.4 $^\circ$ below the *x*-axis in the third quadrant.

Part A

What is the *x*-component of the resultant force?

ANSWER:

F_x = -7.53 N

Correct

Part B

What is the y-component of the resultant force?

ANSWER:

F_y = 3.20 N

Correct

Part C

What is the magnitude of the resultant force?

ANSWER:

F = 8.18 N

Correct

Exercise 4.7

In outer space, a constant net force of magnitude 140 N is exerted on a 31.4 kg probe initially at rest.

Part A

What acceleration does this force produce?

ANSWER:

a = 4.46 $\mathrm{m/s^2}$

Correct

Part B

How far does the probe travel in 10.0 s ?

ANSWER:

l = 223 m

Correct

Exercise 4.11

A hockey puck with mass 0.160 kg is at rest at the origin (x=0) on the horizontal, frictionless surface of the rink. At time t = 0 a player applies a force of 0.250 N to the puck, parallel to the x-axis; he continues to apply this force until t = 2.00 s.

Part A

What is the position of the puck at t = 2.00 s?

ANSWER:

x = 3.13 m

Correct

Part B

In this case what is the speed of the puck?

ANSWER:

v = 3.13 $\mathrm{m/s}$

Correct

Part C

If the same force is again applied at t = 5.00 s, what is the position of the puck at t = 7.00 s?

ANSWER:

x = 21.9 m

All attempts used; correct answer displayed

Part D

In this case what is the speed of the puck?

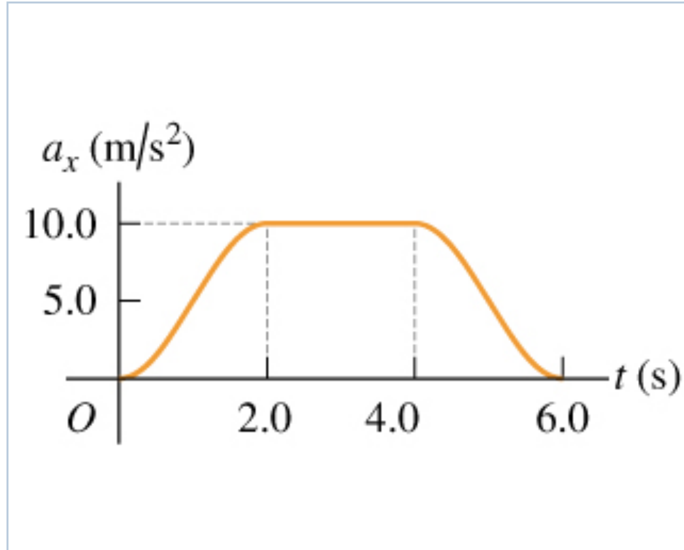
ANSWER:

v = 6.25 $\mathrm{m/s}$

Answer Requested

Exercise 4.13

A 3.50-kg experimental cart undergoes an acceleration in a straight line (the *x*-axis). The graph in shows this acceleration as a function of time.



Part A

Find the maximum net force on this cart.

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

ANSWER:

F_{max} = 35 N

Correct

Part B

When does this maximum force occur?

ANSWER:

- between t = 0 s and t = 2.0 s
- between t = 2.0 s and t = 4.0 s
- between t = 4.0 s and t = 6.0 s
- between t = 0 s and t = 6.0 s

Correct

Part C

During what times is the net force on the cart a constant?

Enter your answers in ascending order separated by a comma. Express your answer using two significant figures.

ANSWER:

t_{min} , t_{max} = 2.0,4.0 s

Correct

Part D

When is the net force equal to zero?

ANSWER:

- at t = 0 s
- at t = 6 s
- at t = 0 s and t = 6 s
- between t = 0 s and t = 6 s

Correct

Exercise 4.15

A small 8.30-kg rocket burns fuel that exerts a time-varying upward force on the rocket. This force obeys the equation $F = A + Bt^2$. Measurements show that at $t = 0$, the force is 102.0 N , and at the end of the first 2.20 s , it is 183.0 N .

Part A

Find the constant A.

ANSWER:

A = 102 N

Correct

Part B

Find the constants B.

ANSWER:

B = 16.7 $\mathrm{N/s^2}$

Correct

Part C

Find the *net* force on this rocket the instant after the fuel ignites.

ANSWER:

F = 20.7 N

Correct

Part D

Find the acceleration of this rocket the instant after the fuel ignites.

ANSWER:

a = 2.49 $\mathrm{m/s^2}$

Correct

Part E

Find the *net* force on this rocket 4.40 s after fuel ignition.

ANSWER:

F = 345 N

Correct

Part F

Find the acceleration of this rocket 4.40 s after fuel ignition.

ANSWER:

a = 41.5 $\mathrm{m/s^2}$

Correct

Part G

Suppose you were using this rocket in outer space, far from all gravity. What would its acceleration be 4.40 s after fuel ignition?

ANSWER:

a = 51.3 $\mathrm{m/s^2}$

Correct

Exercise 4.21

World-class sprinters can accelerate out of the starting blocks with an acceleration that is nearly horizontal and has magnitude 15 $\mathrm{m/s^2}$.

Part A

How much horizontal force must a sprinter of mass 57 kg exert on the starting blocks during a start to produce this acceleration?

Express your answer using two significant figures.

ANSWER:

$F_{horizontal}$ = 860 N

Correct

Part B

Which body exerts the force that propels the sprinter, the blocks or the sprinter herself?

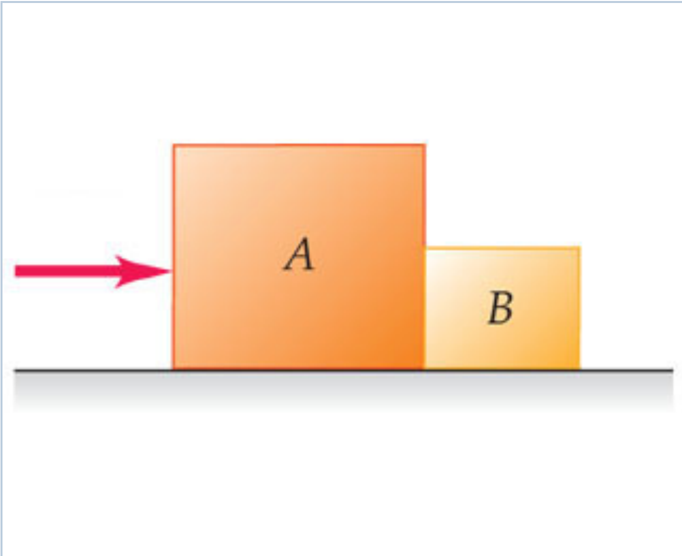
ANSWER:

- (•) The blocks
- ( ) The sprinter herself

Correct

Exercise 4.23

Boxes A and B are in contact on a horizontal, frictionless surface . Box A has mass 16.0 kg and box B has mass 8.0 kg . A horizontal force of 100 N is exerted on box A.



Part A

What is the magnitude of the force that box A exerts on box B?

Express your answer with the appropriate units.

ANSWER:

F = 33 N

Correct

Exercise 4.27

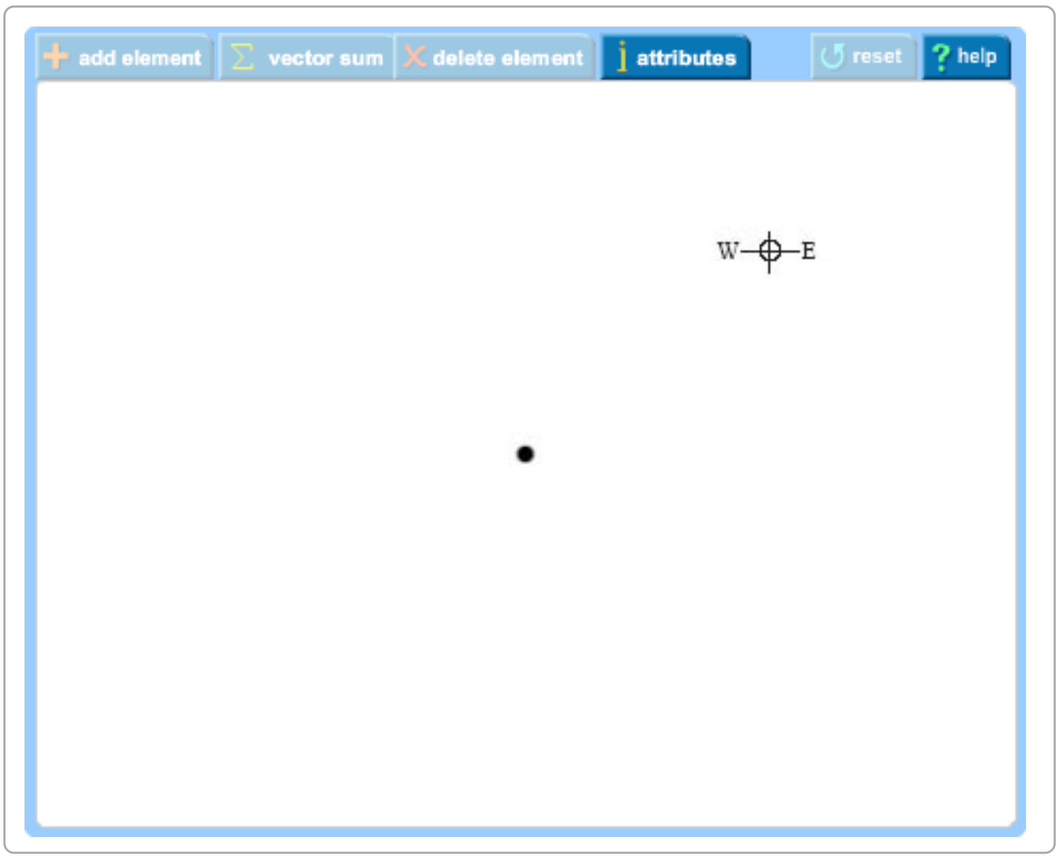
A ball is hanging from a long string that is tied to the ceiling of a train car traveling eastward on horizontal tracks. An observer inside the train car sees the ball hang motionless.

Part A

Draw a clearly labeled free-body diagram for the ball if the train has a uniform velocity.

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

ANSWER:

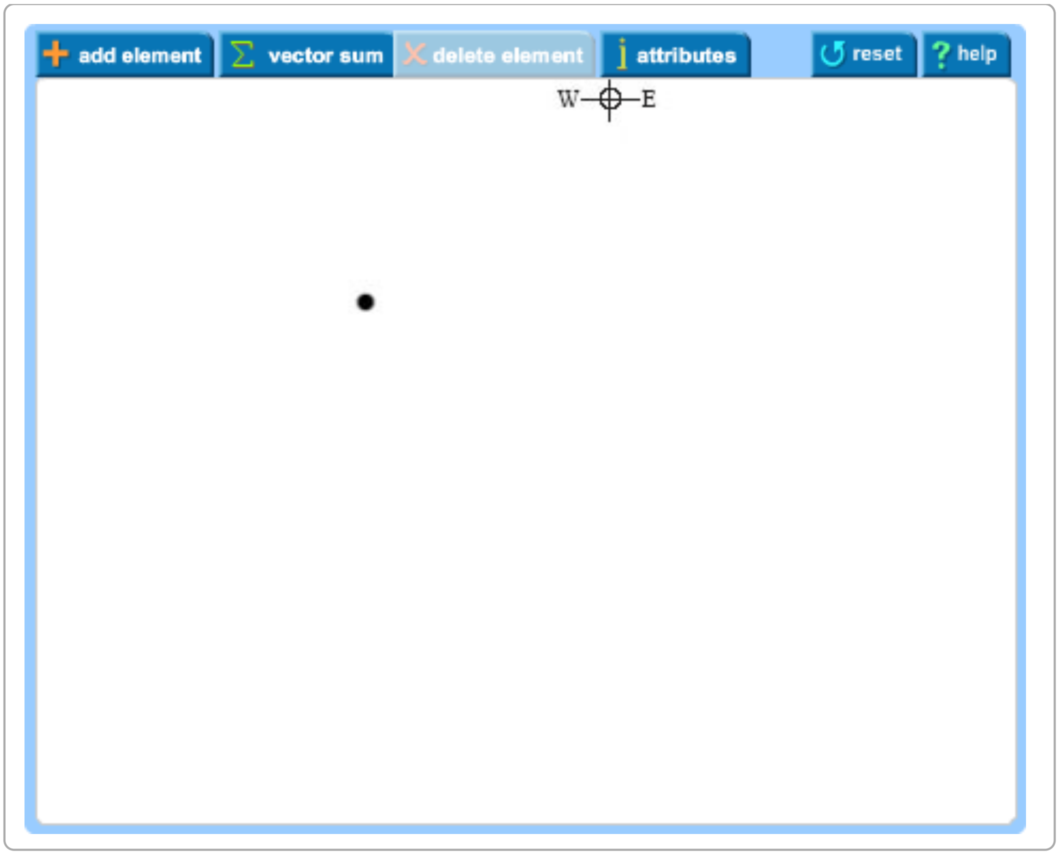


Part B

Draw a clearly labeled free-body diagram for the ball if the train is speeding up uniformly.

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

ANSWER:



Part C

Is the net force on the ball zero in either case?

ANSWER:

- in part A only
- in part B only
- in both parts

Exercise 4.29

A chair of mass 10.5 kg is sitting on the horizontal floor; the floor is not frictionless. You push on the chair with a force F = 44.0 N that is directed at an angle of 40.0 $^{\circ}$ 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 = [ ] N

Problem 4.31

A 4.00 kg bucket of water is accelerated upward by a cord of negligible mass whose breaking strength is 77.0 N .

Part A

If the bucket starts from rest, what is the minimum time required to raise the bucket a vertical distance of 11.5 m without breaking the cord?

Express your answer with the appropriate units.

ANSWER:

t = [ ]

Problem 4.41

To study damage to aircraft that collide with large birds, you design a test gun that will accelerate chicken-sized objects so that their displacement along the gun barrel is given by $x = (9.0 \times 10^3 \mathrm{m/s^2})t^2 - (8.0 \times 10^4 \mathrm{m/s^3})t^3$. The object leaves the end of the barrel at $t = 0.025\ \mathrm{s}$.

Part A

How long must the gun barrel be?

Express your answer using two significant figures.

ANSWER:

L = [ ] m

Part B

What will be the speed of the objects as they leave the end of the barrel?

Express your answer using two significant figures.

ANSWER:

v = [ ] $\mathrm{m/s}$

Part C

What net force must be exerted on a 1.50-kg object at $t = 0$?

Express your answer using two significant figures.

ANSWER:

F = ______ N

Part D

What net force must be exerted on a 1.50-kg object at $t = 0.025\ \mathrm{s}$?

Express your answer using two significant figures.

ANSWER:

F = ______ N

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 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, $\vec{F} = m\vec{a}$ when $\vec{F} = \vec{0}$, 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.
- the net force exerted on it is constant.
- there is only one force exerted on it.

A Gymnast on a Rope

A gymnast of mass 56.0 kg hangs from a vertical rope attached to the ceiling. You can ignore the weight of the rope and assume that the rope does not stretch. Use the value $9.81 \mathrm{m/s^2}$ for the acceleration of gravity.

Part A

Calculate the tension T in the rope if the gymnast hangs motionless on the rope.

Express your answer in newtons.

You did not open hints for this part.

ANSWER:

T = [ ] N

Part B

Calculate the tension T in the rope if the gymnast climbs the rope at a constant rate.

Express your answer in newtons.

You did not open hints for this part.

ANSWER:

T = [ ] N

Part C

Calculate the tension T in the rope if the gymnast climbs up the rope with an upward acceleration of magnitude 1.00 $\mathrm{m/s^2}$.

Express your answer in newtons.

You did not open hints for this part.

ANSWER:

T = [ ] N

Part D

Calculate the tension T in the rope if the gymnast slides down the rope with a downward acceleration of magnitude 1.00 $\mathrm{m/s^2}$.

Express your answer in newtons.

You did not open hints for this part.

ANSWER:

T = [ ] N

Lifting a Bucket

A 6-kg bucket of water is being pulled straight up by a string at a constant speed.

Part A

What is the tension in the rope?

ANSWER:

- about 42 N
- about 60 N
- about 78 N
- 0 N because the bucket has no acceleration.

Part B

This question will be shown after you complete previous question(s).

Part C

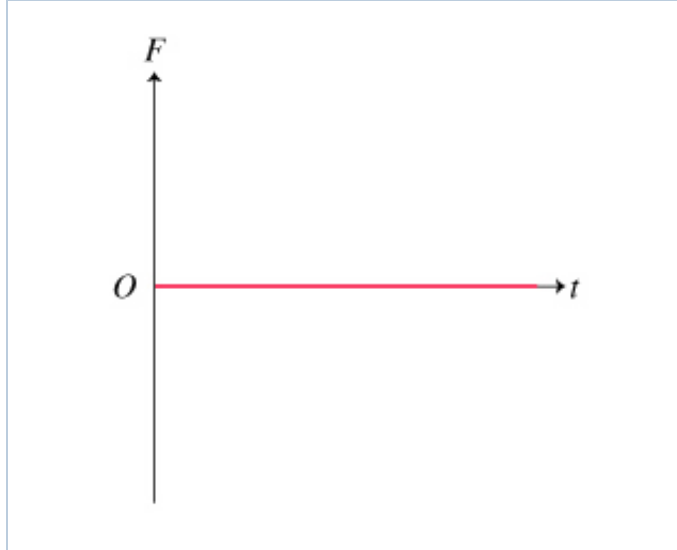
This question will be shown after you complete previous question(s).

Motion from Force Graphing Question

For each of the net force versus time graphs in Parts A, B, and C, construct a *possible* corresponding graph of velocity $v(t)$, or position $x(t)$, versus time. Assume one-dimensional motion.

Part A

Plot velocity versus time.

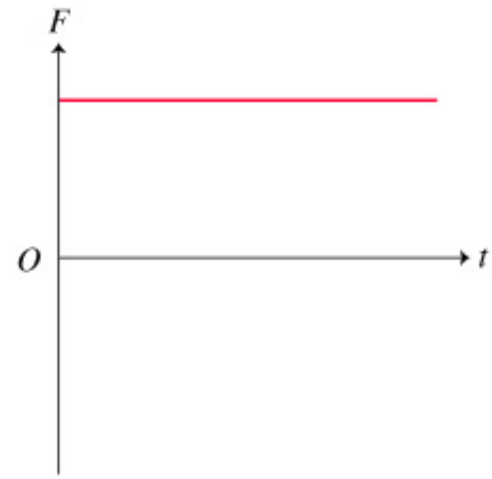


You did not open hints for this part.

ANSWER:

Part B

Plot velocity versus time.

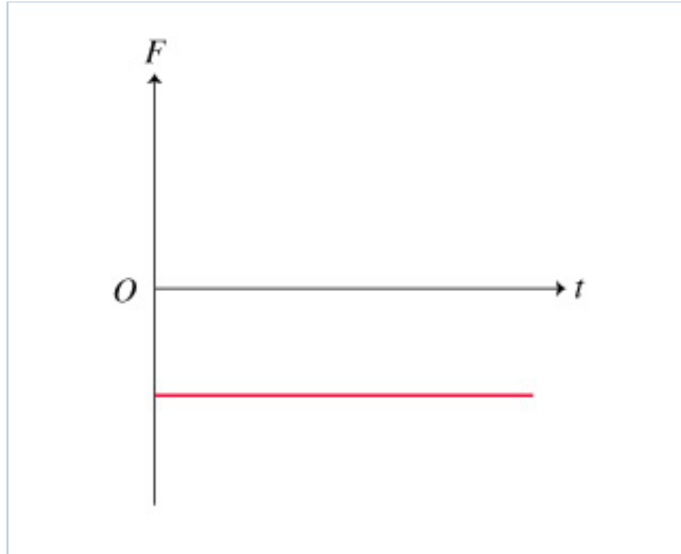


You did not open hints for this part.

ANSWER:

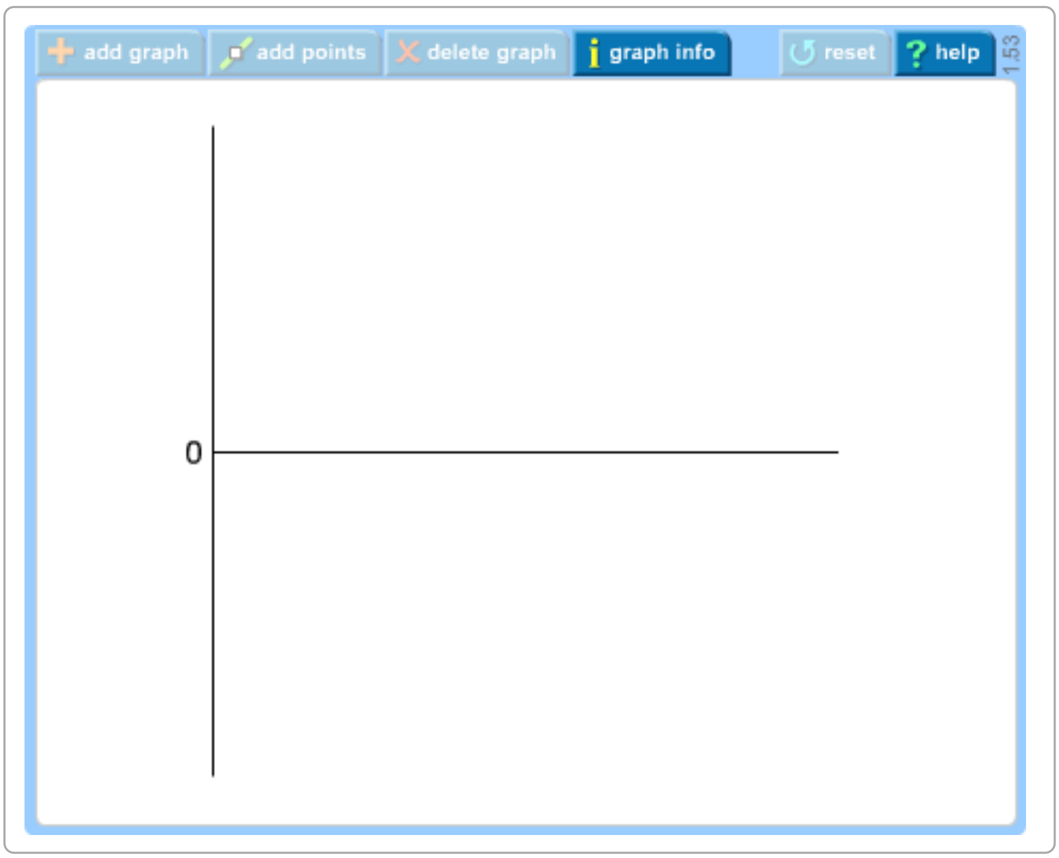
Part C

Plot *position* versus time.



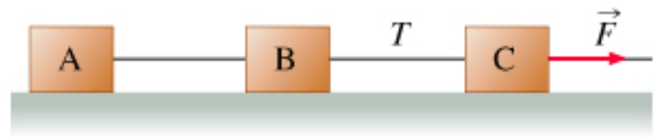
You did not open hints for this part.

ANSWER:



Pulling Three Blocks

Three identical blocks connected by ideal strings are being pulled along a horizontal frictionless surface by a horizontal force $\vec{F}$. The magnitude of the tension in the string between blocks B and C is T = 3.00 N . Assume that each block has mass m = 0.400 kg .



Part A

What is the magnitude F of the force?

Express your answer numerically in newtons.

You did not open hints for this part.

ANSWER:

F = ______ N

Part B

What is the tension T_{AB} in the string between block A and block B?

Express your answer numerically in newtons

You did not open hints for this part.

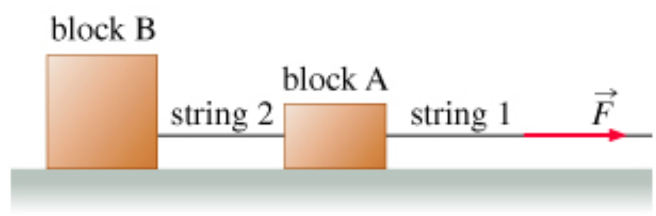
ANSWER:

T_{AB} = ______ N

Pulling Two Blocks

In the situation shown in the figure, a person is pulling with a constant, nonzero force $\vec{F}$ on string 1, which is attached to block A. Block A is also attached to block B via string 2, as shown.

For this problem, assume that neither string stretches and that friction is negligible. Both blocks have finite (nonzero) mass.



Part A

Which one of the following statements correctly descibes the relationship between the accelerations of blocks A and B?

You did not open hints for this part.

ANSWER:

- Block A has a larger acceleration than block B.
- Block B has a larger acceleration than block A.
- Both blocks have the same acceleration.
- More information is needed to determine the relationship between the accelerations.

Part B

How does the magnitude of the tension in string 1, T_1, compare with the tension in string 2, T_2?

You did not open hints for this part.

ANSWER:

- $T_1 > T_2$
- $T_1 = T_2$
- $T_1 < T_2$
- More information is needed to determine the relationship between T_1 and T_2.

Understanding Newton's Laws

Part A

An object cannot remain at rest unless which of the following holds?

You did not open hints for this part.

ANSWER:

- The net force acting on it is zero.
- The net force acting on it is constant and nonzero.
- There are no forces at all acting on it.
- There is only one force acting on it.

Part B

If a block is moving to the left at a constant velocity, what can one conclude?

You did not open hints for this part.

ANSWER:

- There is exactly one force applied to the block.
- The net force applied to the block is directed to the left.
- The net force applied to the block is zero.
- There must be no forces at all applied to the block.

Part C

A block of mass $2\ \mathrm{kg}$ is acted upon by two forces: $3\ \mathrm{N}$ (directed to the left) and $4\ \mathrm{N}$ (directed to the right). What can you say about the block's motion?

You did not open hints for this part.

ANSWER:

- It must be moving to the left.
- It must be moving to the right.
- It must be at rest.
- It could be moving to the left, moving to the right, or be instantaneously at rest.

Part D

A massive block is being pulled along a horizontal frictionless surface by a constant horizontal force. The block must be __________.

You did not open hints for this part.

ANSWER:

- continuously changing direction
- moving at constant velocity
- moving with a constant nonzero acceleration
- moving with continuously increasing acceleration

Part E

Two forces, of magnitude $4\ \mathrm{N}$ and $10\ \mathrm{N}$, are applied to an object. The relative direction of the forces is unknown. The net force acting on the object __________.

Check all that apply.

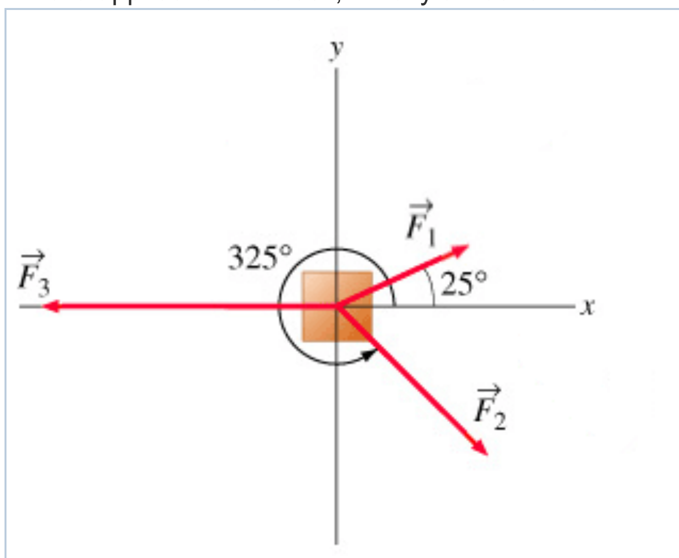
You did not open hints for this part.

ANSWER:

- cannot have a magnitude equal to $5\ \mathrm{N}$
- cannot have a magnitude equal to $10\ \mathrm{N}$
- cannot have the same direction as the force with magnitude $10\ \mathrm{N}$
- must have a magnitude greater than $10\ \mathrm{N}$

± Motion of a Block with Three Forces

The diagram below shows a block of mass $m = 2.00\ \mathrm{kg}$ on a frictionless horizontal surface, as seen from above. Three forces of magnitudes $F_1 = 4.00\ \mathrm{N}$, $F_2 = 6.00\ \mathrm{N}$, and $F_3 = 8.00\ \mathrm{N}$ are applied to the block, initially at rest on the surface, at angles shown on the diagram. In this problem, you will determine the resultant (total) force vector from the combination of the three individual force vectors. All angles should be measured counterclockwise from the positive *x* axis (i.e., all angles are positive).



Part A

Calculate the magnitude of the total resultant force $\vec{F}_r = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$ acting on the mass.

Express your answer in Newtons to three significant figures.

You did not open hints for this part.

ANSWER:

$|\vec{F}_r|$ = N

Part B

What angle does $\vec{F}_r$ make with the positive *x* axis?

Express your answer in degrees to two significant figures.

You did not open hints for this part.

ANSWER:

degrees

Part C

What is the magnitude of the mass's acceleration vector, $\vec{a}$?

Express your answer to two significant figures.

You did not open hints for this part.

ANSWER:

$|\vec{a}|$ = $\mathrm{m/s^2}$

Part D

What is the direction of $\vec{a}$? In other words, what angle does this vector make with respect to the positive *x* axis?

Express your answer in degrees to two significant figures.

You did not open hints for this part.

ANSWER:

degrees

Part E

How far (in meters) will the mass move in 5.0 s?

Express the distance d in meters to two significant figures.

You did not open hints for this part.

ANSWER:

d = [ ] m

Part F

What is the magnitude of the velocity vector of the block at $t = 5.0 \text{ s}$?

Express your answer in meters per second to two significant figures.

You did not open hints for this part.

ANSWER:

$|\vec{v}(5)|$ = [ ] $\mathrm{m/s}$

Part G

In what direction is the mass moving at time $t = 5.0 \text{ s}$? That is, what angle does the velocity vector make with respect to the positive *x* axis?

Express your answer in degrees to two significant figures.

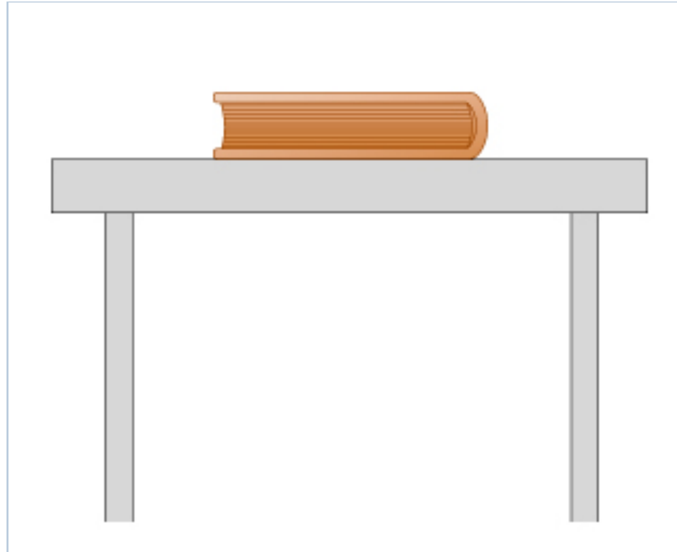
You did not open hints for this part.

ANSWER:

[ ] degrees

A Book on a Table

A book weighing 5 N rests on top of a table.



Part A

A downward force of magnitude 5 N is exerted on the book by the force of

ANSWER:

- the table
- gravity
- inertia

Part B

An upward force of magnitude _____ is exerted on the _____ by the table.

ANSWER:

- 6 N / table
- 5 N / table
- 5 N / book
- 6 N / book

Part C

Do the downward force in Part A and the upward force in Part B constitute a 3rd law pair?

You did not open hints for this part.

ANSWER:

- yes
- no

Part D

The reaction to the force in Part A is a force of magnitude _____, exerted on the _____ by the _____. Its direction is _____ .

You did not open hints for this part.

ANSWER:

- 5 N / earth / book / upward
- 5 N / book / table / upward
- 5 N / book / earth / upward
- 5 N / earth / book / downward

Part E

The reaction to the force in Part B is a force of magnitude _____, exerted on the _____ by the _____. Its direction is _____.

ANSWER:

- 5 N / table / book / upward
- 5 N / table / earth / upward
- 5 N / book / table / upward
- 5 N / table / book / downward
- 5 N / earth / book / downward

Part F

Which of Newton's laws could we have used to predict that the forces in Parts A and B are equal and opposite?

Check all that apply.

ANSWER:

- Newton's 1st law
- Newton's 2nd law
- Newton's 3rd law

Part G

Which of Newton's laws could we have used to predict that the forces in Parts B and E are equal and opposite?

Check all that apply.

ANSWER:

- Newton's 1st law
- Newton's 2nd law
- Newton's 3rd law

A Space Walk

Part A

An astronaut is taking a space walk near the shuttle when her safety tether breaks. What should the astronaut do to get back to the shuttle?

You did not open hints for this part.

ANSWER:

- Attempt to "swim" toward the shuttle.
- Take slow steps toward the shuttle.
- Take a tool from her tool belt and throw it *away* from the shuttle.
- Take the portion of the safety tether still attached to her belt and throw it *toward* the shuttle.

Part B

This question will be shown after you complete previous question(s).

Part C

This question will be shown after you complete previous question(s).

A World-Class Sprinter

World-class sprinters can accelerate out of the starting blocks with an acceleration that is nearly horizontal and has magnitude $15 \mathrm{~m/s^2}$.

Part A

How much horizontal force F must a sprinter of mass 45 kg exert on the starting blocks to produce this acceleration?

Express your answer in newtons using two significant figures.

You did not open hints for this part.

ANSWER:

F = ______ N

Part B

Which body exerts the force that propels the sprinter, the blocks or the sprinter?

You did not open hints for this part.

ANSWER:

- the blocks
- the sprinter

Binary Star System

A binary star system consists of two stars of masses m_1 and m_2. The stars, which gravitationally attract each other, revolve around the center of mass of the system. The star with mass m_1 has a centripetal acceleration of magnitude a_1.

Note that you do not need to understand universal gravitation to solve this problem.

Part A

Find a_2, the magnitude of the centripetal acceleration of the star with mass m_2.

Express the acceleration in terms of quantities given in the problem introduction.

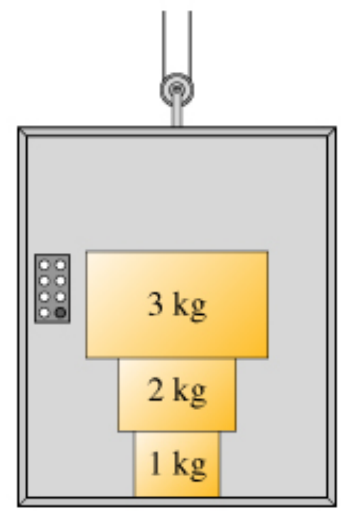
You did not open hints for this part.

ANSWER:

a_2 =

Blocks in an Elevator Ranking Task

Three blocks are stacked on top of each other inside an elevator as shown in .



Answer the following questions with reference to the eight forces defined as follows.

- the force of the 3 kg block on the 2 kg block, $F_{3\ \mathrm{on}\ 2}$,
- the force of the 2 kg block on the 3 kg block, $F_{2\ \mathrm{on}\ 3}$,
- the force of the 3 kg block on the 1 kg block, $F_{3\ \mathrm{on}\ 1}$,
- the force of the 1 kg block on the 3 kg block, $F_{1\ \mathrm{on}\ 3}$,
- the force of the 2 kg block on the 1 kg block, $F_{2\ \mathrm{on}\ 1}$,
- the force of the 1 kg block on the 2 kg block, $F_{1\ \mathrm{on}\ 2}$,
- the force of the 1 kg block on the floor, $F_{1\ \mathrm{on\ floor}}$, and
- the force of the floor on the 1 kg block, $F_{\mathrm{floor\ on}\ 1}$.

Part A

Assume the elevator is at rest. Rank the magnitude of the forces.

Rank from largest to smallest. To rank items as equivalent, overlap them.

You did not open hints for this part.

ANSWER:

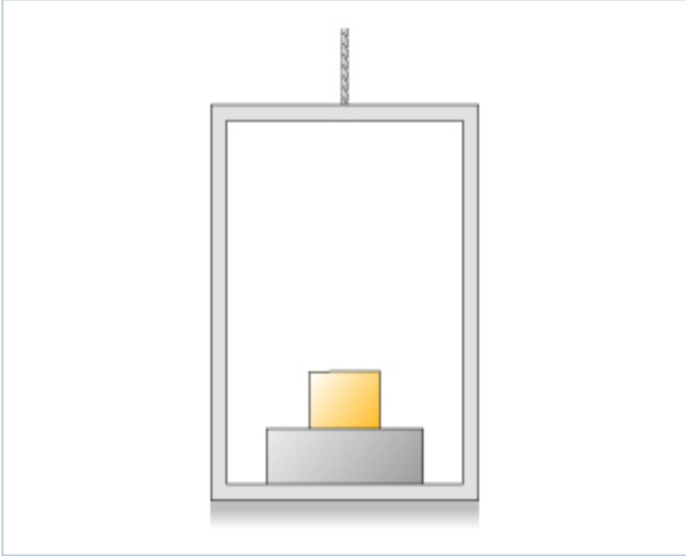
Part B

This question will be shown after you complete previous question(s).

Forces on Blocks in an Elevator Conceptual Question

Two blocks are stacked on top of each other on the floor of an elevator. For each of the following situations, select the correct relationship between the magnitudes of the two forces given.

You will be asked two questions about each of three situations. Each situation is described above the first in the pair of questions. Do not assume anything about a given situation except for what is given in the description for that particular situation.



First situation

The elevator is moving downward at a constant speed.

Part A

You did not open hints for this part.

ANSWER:

The magnitude of the force of the bottom block on the top block is
- greater than
- equal to
- less than
- unknown compared to

the magnitude of the force of the earth on the top block.

Part B

You did not open hints for this part.

ANSWER:

The magnitude of the force of the bottom block on top block is

- greater than
- equal to
- less than
- unknown compared to

the magnitude of the force of the top block on bottom block.

Second situation

The elevator is moving downward at an increasing speed.

Part C

You did not open hints for this part.

ANSWER:

The magnitude of the force of the bottom block on the top block is

- greater than
- equal to
- less than
- unknown compared to

the magnitude of the force of the earth on the top block.

Part D

You did not open hints for this part.

ANSWER:

The magnitude of the force of the bottom block on the top block is

- greater than
- equal to
- less than
- unknown compared to

the magnitude of the force of the top block on the bottom block.

Third situation

The elevator is moving upward.

Part E

You did not open hints for this part.

ANSWER:

The magnitude of the force of the bottom block on the top block is
- greater than
- equal to
- less than
- unknown compared to

the magnitude of the force of the earth on the top block.

Part F

ANSWER:

The magnitude of the force of the bottom block on the top block is
- greater than
- equal to
- less than
- unknown compared to

the magnitude of the force of the top block on the bottom block.

Newton's 3rd Law Discussed

Learning Goal:

To understand Newton's 3rd law, which states that a physical interaction always generates a *pair* of forces on the two interacting bodies.

In *Principia*, Newton wrote:
To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

(translation by Cajori)

The phrase after the colon (often omitted from textbooks) makes it clear that this is a statement about the nature of force. The central idea is that physical interactions (e.g., due to gravity, bodies touching, or electric forces) cause forces to arise between *pairs* of bodies. Each pairwise interaction produces a *pair* of opposite forces, one acting on each body. In summary, each physical interaction between two bodies generates a *pair* of forces. Whatever the physical cause of the interaction, the force on body A from body B is equal in magnitude and opposite in direction to the force on body B from body A.

Incidentally, Newton states that the word "action" denotes both (a) the force due to an interaction and (b) the changes in momentum that it imparts to the two interacting bodies. If you haven't learned about momentum, don't worry; for now this is just a statement about the origin of forces.

Mark each of the following statements as true or false. If a statement refers to "two bodies" interacting via some force, you are *not* to assume that these two bodies have the same mass.

Part A

Every force has one and only one 3rd law pair force.

ANSWER:

- true
- false

Part B

The two forces in each pair act in opposite directions.

ANSWER:

- true
- false

Part C

The two forces in each pair can either both act on the same body or they can act on different bodies.

ANSWER:

- true
- false

Part D

The two forces in each pair may have different physical origins (for instance, one of the forces could be due to gravity, and its pair force could be due to friction or electric charge).

ANSWER:

- true
- false

Part E

The two forces of a 3rd law pair *always* act on different bodies.

ANSWER:

- true
- false

Part F

Given that two bodies interact via some force, the accelerations of these two bodies have the same magnitude but opposite directions. (Assume no other forces act on either body.)

You did not open hints for this part.

ANSWER:

- true
- false

Part G

According to Newton's 3rd law, the force on the (smaller) moon due to the (larger) earth is

ANSWER:

- greater in magnitude and antiparallel to the force on the earth due to the moon.
- greater in magnitude and parallel to the force on the earth due to the moon.
- equal in magnitude but antiparallel to the force on the earth due to the moon.
- equal in magnitude and parallel to the force on the earth due to the moon.
- smaller in magnitude and antiparallel to the force on the earth due to the moon.
- smaller in magnitude and parallel to the force on the earth due to the moon.

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

Part B

This question will be shown after you complete previous question(s).

Part C

This question will be shown after you complete previous question(s).

Part D

Which object exerts an upward force on the book?

ANSWER:

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

Part E

This question will be shown after you complete previous question(s).

Part F

This question will be shown after you complete previous question(s).

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

Part H

This question will be shown after you complete previous question(s).

Part I

This question will be shown after you complete previous question(s).

Part J

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

ANSWER:

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

Part K

This question will be shown after you complete previous question(s).

Part L

This question will be shown after you complete previous question(s).

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

Part N

This question will be shown after you complete previous question(s).

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:

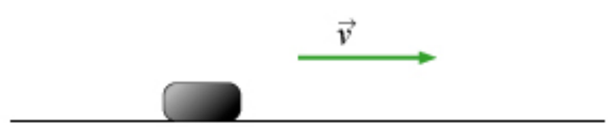
- *Weight, or the force due to gravity.* Weight acts on every object and is directed straight down unless we are considering a problem involving the nonflat earth (e.g., satellites).
- *Normal force.* The normal force exists between two surfaces that are pressed against each other; it is always perpendicular 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:

- force of velocity
- force of push
- weight
- friction
- normal force
- acceleration
- air drag

Part B

This question will be shown after you complete previous question(s).

Part C

This question will be shown after you complete previous question(s).

Part D

This question will be shown after you complete previous question(s).

Part E

This question will be shown after you complete previous question(s).

Part F

This question will be shown after you complete previous question(s).

Part G

This question will be shown after you complete previous question(s).

Part H

This question will be shown after you complete previous question(s).

Part I

This question will be shown after you complete previous question(s).

Free-Body Diagrams and Newton's Laws

When solving problems involving forces and Newton's laws, the following summary of things to do will start your mind thinking about getting involved in the problem at hand.

Problem Solving: Free-Body Diagrams and Newton's Laws

1. Draw a sketch of the situation.
2. Consider only one object (at a time), and draw a free-body diagram for that body, showing all the forces acting on that body. Do not show any forces that the body exerts on other bodies. If several bodies are involved, draw a free-body diagram for each body separately, showing all the forces acting on that body.
3. Newton's second law involves vectors, and it is usually important to resolve vectors into components. Choose an *x* and *y* axis in a way that simplifies the calculation.
4. For each body, Newton's second law can be applied to the x and y components separately. That is the *x* component of the net force on that body will be related to the *x* component of that body's acceleration: $\Sigma F_x = ma_x$, and similarly for the *y* direction.
5. Solve the equation or equations for the unknown(s).

Apply these steps

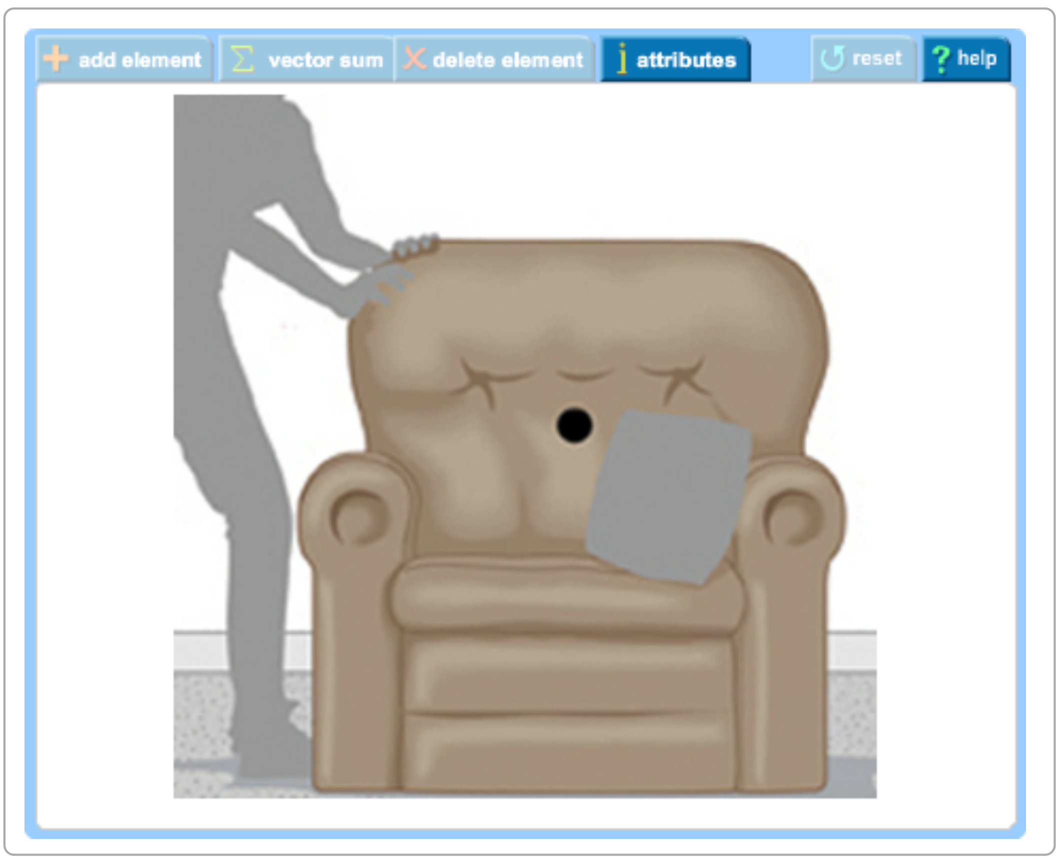
Use the steps outlined above to find the magnitude of the acceleration a of a chair and the magnitude of the normal force F_N acting on the chair: Yusef pushes a chair of mass m = 45.0 kg across a carpeted floor with a force $\vec{F}_\mathrm{p}$ (the subscript 'p' here is lowercase and throughout the question) of magnitude F_p = 160 N directed at θ = 35.0 $\mathrm{degrees}$ below the horizontal. The magnitude of the kinetic frictional force between the carpet and the chair is F_k = 90.6 N.

Part A

Identify and sketch all the external forces acting on the chair. Because the chair can be represented as a point particle of mass m, draw the forces with their tails centered on the black dot in the middle of the chair. Be certain to draw your forces so that they have the correct orientation.

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

ANSWER:



Part B

This question will be shown after you complete previous question(s).

Part C

This question will be shown after you complete previous question(s).

Part D

This question will be shown after you complete previous question(s).

Part E

This question will be shown after you complete previous question(s).

Pushing a Chair along the Floor

A chair of weight 150 N lies atop a horizontal floor; the floor is not frictionless. You push on the chair with a force of F = 39.0 N directed at an angle of 43.0 $^\circ$ below the horizontal and the chair slides along the floor.

Part A

Using Newton's laws, calculate n, the magnitude of the normal force that the floor exerts on the chair.

Express your answer in newtons.

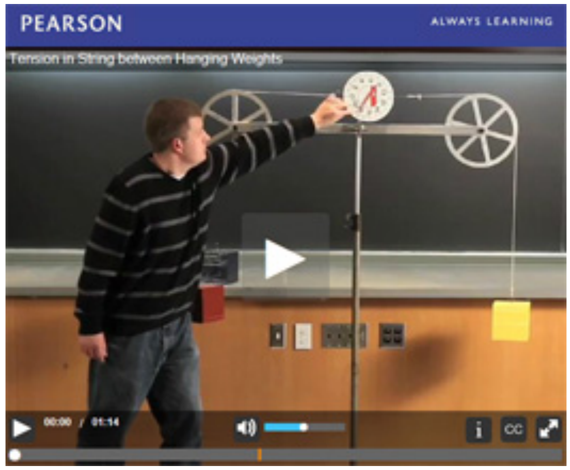
You did not open hints for this part.

ANSWER:

n = N

Video Tutor: Tension in String between Hanging Weights

First, launch the video below. You will be asked to use your knowledge of physics to predict the outcome of an experiment. Then, close the video window and answer the question at right. You can watch the video again at any point.



Part A

Consider the video tutorial you just watched. Suppose that we duplicate this experimental setup in an elevator. What will the spring scale read if the elevator is moving upward at constant speed?

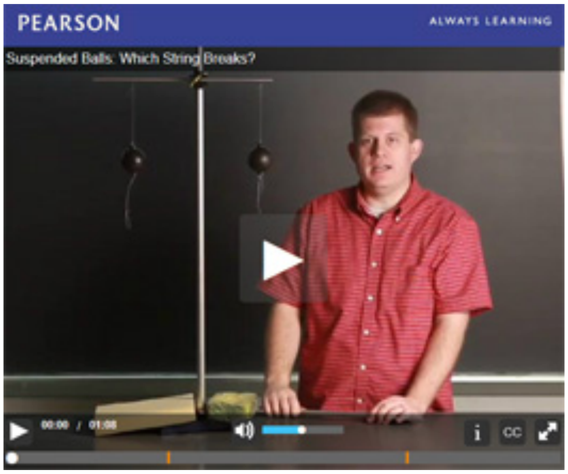
You did not open hints for this part.

ANSWER:

- 0 N
- Less than 18 N but greater than 0 N
- More than 18 N
- 18 N

Video Tutor: Suspended Balls: Which String Breaks?

First, launch the video below. You will be asked to use your knowledge of physics to predict the outcome of an experiment. Then, close the video window and answer the question at right. You can watch the video again at any point.



Part A

A heavy crate is attached to the wall by a light rope, as shown in the figure. Another rope hangs off the opposite edge of the box. If you slowly increase the force on the free rope by pulling on it in a horizontal direction, which rope will break? Ignore friction and the mass of the ropes.

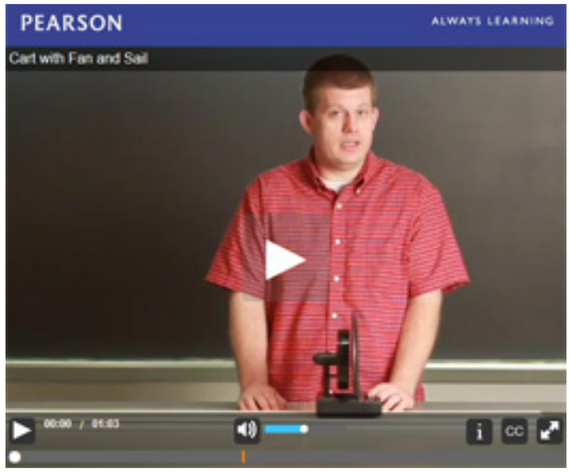
You did not open hints for this part.

ANSWER:

- Both ropes are equally likely to break.
- The rope that you are pulling on will break.
- The rope attached to the wall will break.

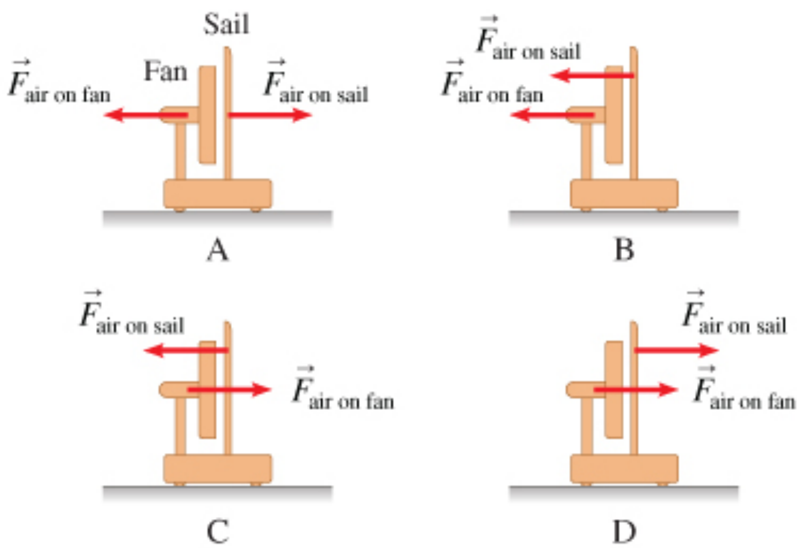
Video Tutor: Cart with Fan and Sail

First, launch the video below. You will be asked to use your knowledge of physics to predict the outcome of an experiment. Then, close the video window and answer the question on the right. You can watch the video again at any point.



Part A

Which of the force diagrams in the figure correctly displays all of the horizontal forces exerted on the cart *by the surrounding air*?



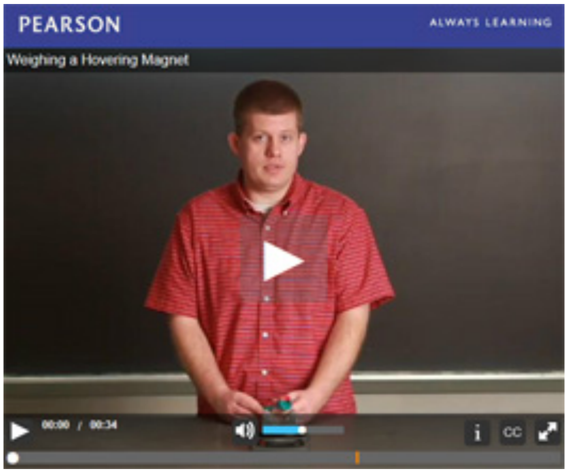
You did not open hints for this part.

ANSWER:

- A
- B
- C
- D

Video Tutor: Weighing a Hovering Magnet

First, launch the video below. You will be asked to use your knowledge of physics to predict the outcome of an experiment. Then, close the video window and answer the questions at right. You can watch the video again at any point.



Part A

Consider the video tutorial you just watched. Suppose that we repeat the experiment, but this time we replace the original 56-g magnet with a more powerful magnet of the same mass.

As you know from experience, the more powerful a magnet is, the more strongly it attracts or repels other magnets or magnetic objects. You have also probably noticed that magnetic forces fall off sharply with distance—two magnets that interact strongly across a distance of millimeters interact more weakly at a distance of a centimeter. (In fact, the strength of the force falls off with the square of the distance.)

With the magnet hovering above the base, what will the scale read? The scale has been zeroed (tared) to subtract the weight of the base.

You did not open hints for this part.

ANSWER:

- –56 g
- Less than 56 g but greater than 0 g
- More than 56 g
- 56 g
- 0 g

Part B

Compared to the magnet in the video, the magnet in Part A will hover at a position

You did not open hints for this part.

ANSWER:

- farther above the base.
- at the same distance above the base.
- closer to the base.

Score Summary:

Your score on this assignment is 22.2%.
You received 40 out of a possible total of 180 points.