Dynamics in-class assignment

Due: 11:59pm on Sunday, July 3, 2022

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

A Gymnast on a Rope

A gymnast of mass 63.0 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.

Hint 1. A body in static equilibrium

The gymnast is hanging at rest. This means that the gymnast is in static equilibrium and, according to Newton's 1st law, the net force acting on the gymnast is zero.

Hint 2. Find what forces act on the gymnast

What are the forces acting on the gymnast?

ANSWER:

- ○ The tension in the rope only.
- ○ The weight of the gymnast only.
- ◉ The tension in the rope and the weight of the gymnast.
- ○ The gymnast is at rest so no forces are acting on her.

ANSWER:

T = 618 N

Correct

Part B

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

Express your answer in newtons.

Hint 1. A body in dynamic equilibrium

The gymnast is moving with a constant velocity. This means that the gymnast is in dynamic equilibrium and, according to Newton's 1st law, the net force acting on the gymnast is zero.

ANSWER:

T = 618 N

Correct

Does it surprise you that the answers to Parts A and B are the same? In both cases, the gymnast is *not* accelerating. Therefore, the net force acting on the gymnast is zero. Since the only two forces acting on the gymnast are tension and weight, the tension in the rope in each case is equal in magnitude (and opposite in direction) to the gymnast's weight.

Part C

Calculate the tension T in the rope if the gymnast climbs up the rope with an upward acceleration of magnitude 1.10 $\mathrm{m/s^2}$.

Express your answer in newtons.

Hint 1. Newton's 2nd law of motion

According to Newton's 2nd law, if a body accelerates, the magnitude of the net force F_{net} acting on it equals the product of the mass m of the body and the acceleration a of the body:

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

Hint 2. Find an expression for the net external force

The only forces acting on the gymnast are the tension in the rope and her own weight. Which of the following relations gives the net force F_{net} acting on the gymnast while accelerating up the rope?

Take the positive direction of the *y* axis to be upward. Here, m and g denote, respectively, the mass of the gymnast and the acceleration due to gravity.

ANSWER:

- ○ $F_{\text{net}} = -T - mg$
- ○ $F_{\text{net}} = -T + mg$
- ◉ $F_{\text{net}} = T - mg$
- ○ $F_{\text{net}} = T + mg$

Hint 3. Find the sign of the acceleration

If you take the positive *y* axis to be upward, then is the acceleration of the gymnast climbing up the rope positive or negative?

ANSWER:

- ◉ positive
- ○ negative

ANSWER:

T = 687 N

Correct

Part D

Calculate the tension T in the rope if the gymnast slides down the rope with a downward acceleration of magnitude 1.10 $\mathrm{m/s^2}$.

Express your answer in newtons.

Hint 1. Newton's 2nd law of motion

According to Newton's 2nd law, if a body accelerates, the magnitude of the net force F_{net} acting on it equals the product of the mass m of the body and the acceleration a of the body:

Hint 2. Find an expression for the net external force

The only forces acting on the gymnast are the tension in the rope and the weight of the gymnast. Which of the following relations gives the net force F_{net} acting on the gymnast while sliding down the rope?

Take the positive *y* axis to be upward, and let m and g denote, respectively, the mass of the gymnast and the acceleration due to gravity.

ANSWER:

- ○ $F_{\mathrm{net}} = -T - mg$
- ○ $F_{\mathrm{net}} = -T + mg$
- ◉ $F_{\mathrm{net}} = T - mg$
- ○ $F_{\mathrm{net}} = T + mg$

Hint 3. Find the sign of the acceleration

If you take the positive *y* axis to be upward, then is the acceleration of the gymnast as she slides down the rope positive or negative?

ANSWER:

- ○ positive
- ◉ negative

ANSWER:

T = 549 N

Correct

In this problem, the directions of velocity and acceleration happened to be the same. If they are different, it is the direction of the *acceleration*, not the direction of velocity, that determines the magnitudes of the forces. Newton's 2nd law has nothing to do with the object's *velocity*.

Free-Body Diagrams

Learning Goal:
To gain practice drawing free-body diagrams

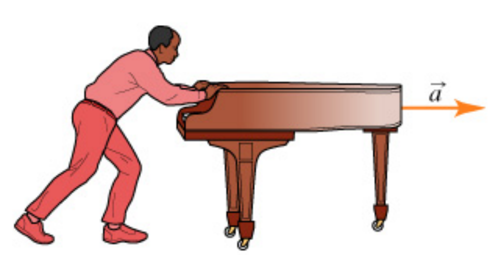
Whenever you face a problem involving forces, always start with a free-body diagram.
To draw a free-body diagram use the following steps:

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
- [x] gravitational force acting on the piano (piano's weight)
- [ ] speed of the piano
- [ ] gravitational force acting on Chadwick (Chadwick's weight)
- [x] force of the floor on the piano (normal force)
- [ ] force of the piano on the floor
- [x] 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.

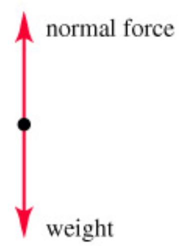
Hint 1. Determine the directions and relative magnitudes of the forces

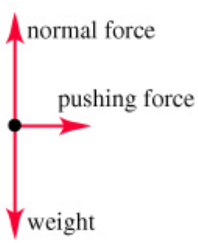
Which of the following statements best describes the correct directions and relative magnitudes of the forces involved?

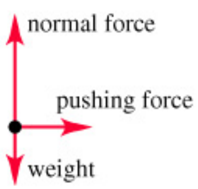
ANSWER:

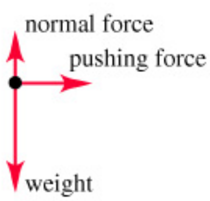
- The normal force and weight are both upward and the pushing force is horizontal.
- The normal force and weight are both downward and the pushing force is horizontal.
- The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force has a greater magnitude than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







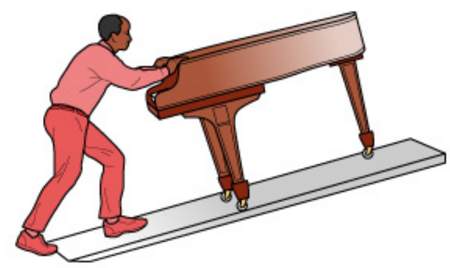


Correct

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. The ramp is frictionless. Is

Chadwick strong enough to push the piano up the ramp alone or must he get help? To solve this problem you should start by drawing a free-body diagram.



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.

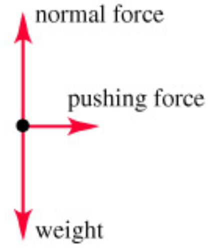
Correct

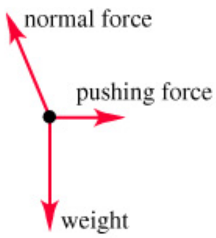
Now draw the free-body diagram of the piano in this new situation. Follow the same sequence of steps that you followed for the first situation. Again draw your diagram before you look at the choices below.

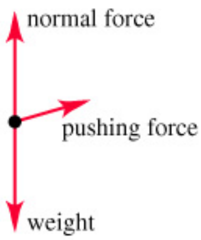
Part E

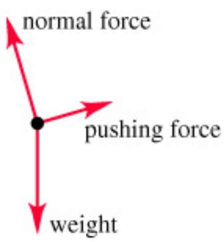
Which diagram accurately represents the free-body diagram for the piano?

ANSWER:









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.

Velocity from Force Diagram Ranking Task

Below are birds-eye views of six identical toy cars moving to the right at 2 $\mathrm{m/s}$. Various forces act on the cars with magnitudes and directions indicated below. All forces act in the horizontal plane and are either parallel or at 45 or 90 degrees to the car's motion.

Part A

Rank these cars on the basis of their speed a short time (ie. before any car's speed can reach zero) after the forces are applied.

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

Hint 1. How to approach the problem

First, added up the force vectors to find the net force acting on the car. Since you are asked about the speed a short time after the forces are applied, the speeds of all cars will be close to 2 $\mathrm{m/s}$. For each car, the small difference from 2 $\mathrm{m/s}$ will be due to the acceleration caused by the net force acting on the car. A net force acting to the right will result in a speed greater than 2 $\mathrm{m/s}$, while a net force acting to the left will result in a speed less than 2 $\mathrm{m/s}$. Recall that the acceleration may be found from the net force by using Newton's 2nd law, $\Sigma\vec{F} = m\vec{a}$.

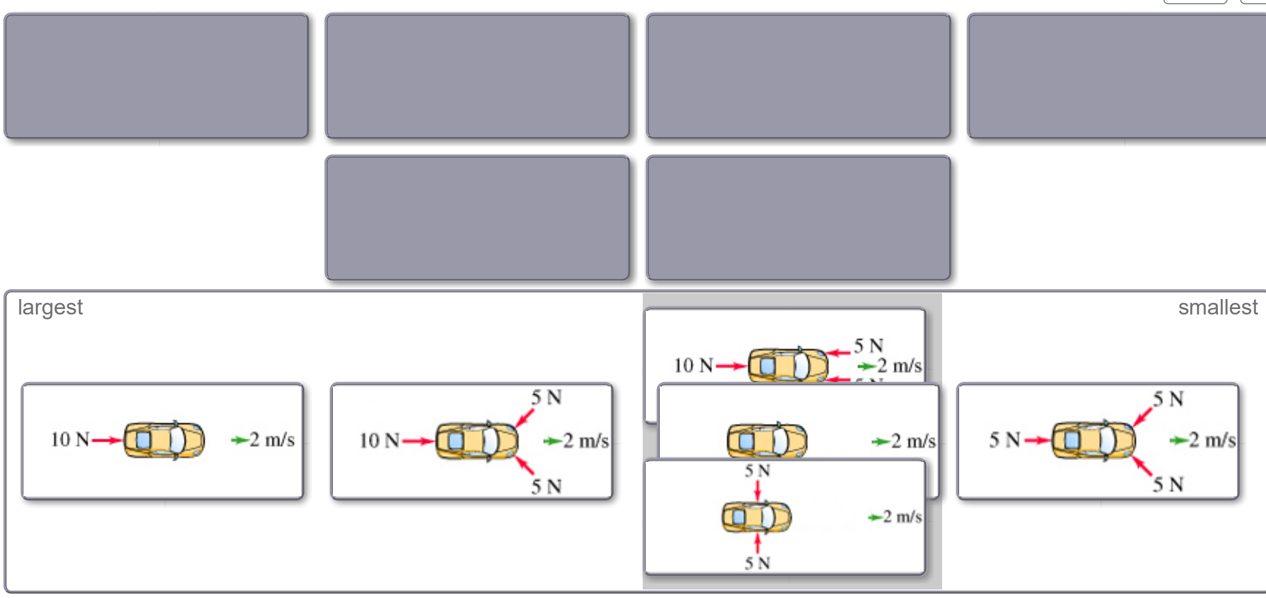
Hint 2. Summing force vectors

Forces are vectors and sum in the same way that velocity or acceleration vectors sum. Be careful when resolving vectors into components, if you need to. Once the force vectors are summed into a single total, or net force $\Sigma\vec{F}$, the acceleration $\vec{a}$ of the car of mass m can be determined by Newton's 2nd law:

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

ANSWER:

Reset Help



The correct ranking cannot be determined.

Correct

± Two Forces Acting at a Point

Two forces, $\vec{F}_1$ and $\vec{F}_2$, act at a point. $\vec{F}_1$ has a magnitude of 8.40 N and is directed at an angle of 62.0 $^\circ$ above the negative *x* axis in the second quadrant. $\vec{F}_2$ has a magnitude of 5.40 N and is directed at an angle of 53.2 $^\circ$ below the negative *x* axis in the third quadrant.

Part A

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

Express your answer in newtons.

Hint 1. How to approach the problem

The resultant force is defined as the vector sum of all forces. Thus, its *x* component is the sum of the *x* components of the forces, and its *y* component is the sum of the *y* components of the forces.

Hint 2. Find the *x* component of $\vec{F}_1$

Find the *x* component of $\vec{F}_1$.

Express your answer in newtons.

Hint 1. Components of a vector

Consider a vector $\vec{A}$ that forms an angle θ with the positive *x* axis. The *x* and *y* components of $\vec{A}$ are, respectively,

$$A_x = A\cos\theta \text{ and } A_y = A\sin\theta,$$

where A is the magnitude of the vector. Note that

$$A_x < 0 \text{ and } A_y > 0 \text{ if } \frac{\pi}{2} < \theta < \pi,$$

$$A_x < 0 \text{ and } A_y < 0 \text{ if } \pi < \theta < \frac{3\pi}{2}.$$

Hint 2. Find the direction of $\vec{F}_1$

$\vec{F}_1$ is directed at an angle of 62.0 $^\circ$ above the *x* axis in the second quadrant. When you calculate the components of $\vec{F}_1$, however, the direction of the force is commonly expressed in terms of the angle that the vector representing the force forms with the *positive x* axis. What is the angle that $\vec{F}_1$ forms with the positive *x* axis? Select an answer from the following list, where $\theta = 62.0\ ^\circ$.

ANSWER:

- ○ θ
- ◉ $180^\circ - \theta$
- ○ $180^\circ + \theta$
- ○ $90^\circ + \theta$

ANSWER:

-3.94 N

Hint 3. Find the *x* component of $\vec{F}_2$

Find the *x* component of $\vec{F}_2$.

Express your answer in newtons.

Hint 1. Components of a vector

Consider a vector $\vec{A}$ that forms an angle θ with the positive *x* axis. The *x* and *y* components of $\vec{A}$ are, respectively,

$$A_x = A\cos\theta \text{ and } A_y = A\sin\theta,$$

where A is the magnitude of the vector. Note that

$$A_x < 0 \text{ and } A_y > 0 \text{ if } \frac{\pi}{2} < \theta < \pi,$$

$$A_x < 0 \text{ and } A_y < \text{ if } \pi < \theta < \frac{3\pi}{2}.$$

Hint 2. Find the direction of $\vec{F}_2$

$\vec{F}_2$ is directed at an angle of 53.2 $^\circ$ below the *x* axis in the third quadrant. When you calculate the components of $\vec{F}_2$, however, the direction of the force is commonly expressed in terms of the angle that the vector representing the force forms with the *positive* *x* axis. What is the angle that $\vec{F}_2$ forms with the positive *x* axis? Select an answer from the following list, where $\theta = 53.2$ $^\circ$.

ANSWER:

- θ
- $180^\circ - \theta$
- $\theta - 180^\circ$
- $-90^\circ - \theta$

ANSWER:

-3.23 N

ANSWER:

-7.18 N

Correct

Part B

What is the *y* component of the resultant force?

Express your answer in newtons.

Hint 1. How to approach the problem

Follow the same procedure that you used in Part A to find the *x* component of the resultant force, though now calculate the *y* components of the two forces.

Hint 2. Find the *y* component of $\vec{F}_1$

Find the *y* component of $\vec{F}_1$.

Express your answer in newtons.

Hint 1. Components of a vector

Consider a vector $\vec{A}$ that forms an angle θ with the positive *x* axis. The *x* and *y* components of $\vec{A}$ are, respectively,

$$A_x = A\cos\theta \text{ and } A_y = A\sin\theta,$$

where A is the magnitude of the vector. Note that

$$A_x < 0 \text{ and } A_y > 0 \text{ if } \frac{\pi}{2} < \theta < \pi,$$

$$A_x < 0 \text{ and } A_y < 0 \text{ if } \pi < \theta < \frac{3\pi}{2}.$$

ANSWER:

7.42 N

Hint 3. Find the *y* component of $\vec{F}_2$

Find the *y* component of $\vec{F}_2$.

Express your answer in newtons.

Hint 1. Components of a vector

Consider a vector $\vec{A}$ that forms an angle θ with the positive *x* axis. The *x* and *y* components of $\vec{A}$ are, respectively,

$$A_x = A\cos\theta \text{ and } A_y = A\sin\theta,$$

where A is the magnitude of the vector. Note that

$$A_x < 0 \text{ and } A_y > 0 \text{ if } \frac{\pi}{2} < \theta < \pi,$$

$$A_x < 0 \text{ and } A_y < 0 \text{ if } \pi < \theta < \frac{3\pi}{2}.$$

ANSWER:

-4.32 N

ANSWER:

3.09 N

Correct

Part C

What is the magnitude of the resultant force?

Express your answer in newtons.

Hint 1. Magnitude of a vector

Consider a vector $\vec{A}$, whose components are A_x and A_y. The magnitude of $\vec{A}$ is

$$A = \sqrt{A_x^2 + A_y^2}.$$

ANSWER:

7.82 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 9.20 N , and its direction is an angle 61.0 $^\circ$ above the *x*-axis in the second quadrant. The magnitude of $\vec{F}_2$ is 6.60 N , and its direction is an angle 54.1 $^\circ$ below the *x*-axis in the third quadrant.

Part A

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

ANSWER:

F_x = -8.33 N

Correct

Part B

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

ANSWER:

F_y = 2.70 N

Correct

Part C

What is the magnitude of the resultant force?

ANSWER:

F = 8.76 N

Correct

Chapter 4, Conceptual Question 2

Part A

Which of the following statements is not true?

Hint 1. The usefulness of Newton's laws:

Newton's laws of motion comprise the foundation of classical mechanics and every familiar kind of motion can be analyzed using them.

ANSWER:

- (selected) Newton's laws always apply to specific body and its motion and free body diagram helps us to identify the relevant forces.
- When a passenger bus suddenly starts or stops, passengers seem to lunge backward or forward.
- When in free fall, in the absence of air resistance or any other force, a heavy object does not have greater acceleration than light object does.
- It gets progressively easier for a rocket to accelerate as it travels through outer space.

Correct

The answer is correct. The statement is false. Although Newton's first and second laws apply to specific body, the third law relates the forces that two different bodies exert on each other. So Newton's third law does not apply to a specific body.

Exercise 4.6

An electron of mass 9.11×10^{-31} 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 1.60 cm away. It reaches the grid with a speed of 2.60×10^{6} $\mathrm{m/s}$. The accelerating force is constant.

Part A

Find the acceleration.

ANSWER:

a = 2.11×10^{14} $\mathrm{m/s^2}$

Correct

Part B

Find the time to reach the grid.

ANSWER:

t = 1.23×10^{-8} s

Correct

Part C

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

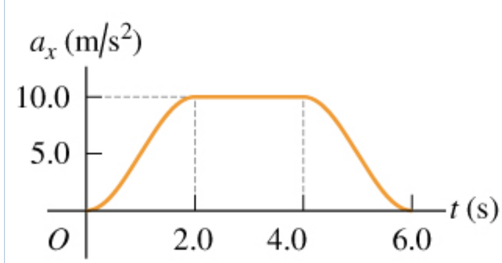
ANSWER:

F_{net} = 1.92×10^{-16} N

Correct

Exercise 4.13

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



Part A

Find the maximum net force on this cart.

ANSWER:

F_{max} = 35.0 N

Correct

Part B

During what time interval is the net force on the cart a constant?

Express your answer using two significant figures. Enter your answers numerically separated by a comma.

ANSWER:

$t_{\mathrm{min}}, t_{\mathrm{max}}$ = 2.0,4.0 s

Correct

Part C

When is the net force equal to zero?

Express your answer numerically. If there is more than one point, enter each point separated by a comma. Express your answer using two significant figures.

ANSWER:

t = 0,6.0 s

Correct

Exercise 5.9

A man pushes on a piano with mass 170 kg; it slides at constant velocity down a ramp that is inclined at 17.0 $^\circ$ above the horizontal floor. Neglect any friction acting on the piano.

Part A

Calculate the magnitude of the force applied by the man if he pushes parallel to the incline.

Express your answer with the appropriate units.

ANSWER:

F = 490 N

Correct

Part B

Calculate the magnitude of the force applied by the man if he pushes parallel to the floor.

Express your answer with the appropriate units.

ANSWER:

F = 510 N

Correct

Exercise 5.11

An astronaut is inside a 2.25×10^6 kg rocket that is blasting off vertically from the launch pad. You want this rocket to reach the speed of sound (331 $\mathrm{m/s}$) as quickly as possible, but you also do not want the astronaut to black out. Medical tests have shown that astronauts are in danger of blacking out for an acceleration greater than $4g$.

Part A

What is the maximum thrust the engines of the rocket can have to just barely avoid blackout? Start with a free-body diagram of the rocket.

ANSWER:

F_{thrust} = 1.10×10^8 N

Correct

Part B

What force, in terms of her weight W, does the rocket exert on the astronaut? Start with a free-body diagram of the astronaut.

ANSWER:

F = $5W$

Correct

Part C

What is the shortest time it can take the rocket to reach the speed of sound?

ANSWER:

t = 8.44 s

Correct

Exercise 5.28

A box of bananas weighing 40.0 N rests on a horizontal surface. The coefficient of static friction between the box and the surface is 0.40 and the coefficient of kinetic friction is 0.20.

Part A

If no horizontal force is applied to the box and the box is at rest, how large is the friction force exerted on the box?

ANSWER:

0 N

Correct

Part B

What is the magnitude of the friction force if a monkey applies a horizontal force of 6.0 N to the box and the box is initially at rest?

Express your answer using two significant figures.

ANSWER:

6.0 N

Correct

Part C

What minimum horizontal force must the monkey apply to start the box in motion?

Express your answer using two significant figures.

ANSWER:

16 N

Correct

Part D

What minimum horizontal force must the monkey apply to keep the box moving at constant velocity once it has been started?

Express your answer using two significant figures.

ANSWER:

8 N

Correct

Part E

If the monkey applies a horizontal force of 18.0 N, what is the magnitude of the friction force ?

Express your answer using two significant figures.

ANSWER:

8 N

Correct

Part F

If the monkey applies a horizontal force of 18.0 N, what is the box's acceleration?

ANSWER:

2.45 $\mathrm{m/s^2}$

Correct

Exercise 5.43

A stone with a mass of 0.600 kg is attached to one end of a string 0.800 m long. The string will break if its tension exceeds 65.0 N . The stone is whirled in a horizontal circle on a frictionless tabletop; the other end of the string remains fixed.

Part A

Find the maximum speed the stone can attain without breaking the string.

ANSWER:

v_{max} = 9.31 $\mathrm{m/s}$

Correct

Score Summary:

Your score on this assignment is 100%.
You received 100 out of a possible total of 100 points.