Question 1

A 0.5 kg hockey puck slides along the surface of the ice with a speed of $10\,\frac{\mathrm{m}}{\mathrm{s}}$. What force must be acting on the puck to keep it moving at constant velocity?

A 0.05 N

B 5 N

C 20 N

D 50 N

E None of these.

Answer

A 0.5 kg hockey puck slides along the surface of the ice with a speed of $10\,\frac{\text{m}}{\text{s}}$. What force must be acting on the puck to keep it moving at constant velocity?

The ice is assumed to be frictionless to a very good approximation, so no force is required to keep the puck moving at a constant velocity. In fact, if any force acts on the puck, it will accelerate, and either spped up or slow down or change direction. Therefore the force required for the puck to just continue as it is, moving with a constant velocity (constant speed in the same direction), is zero.

Question 2

An object is moving with a constant velocity of $(v_x, v_y) = (10, 2)\,\frac{\mathrm{m}}{\mathrm{s}}$. What number of non-zero forces could NOT be acting on this object?

A Zero (No forces at all)

B One

C Two

D Three

Answer

An object is moving with a constant velocity of $(v_x, v_y) = (10, 2)\,\frac{\mathrm{m}}{\mathrm{s}}$. What number of non-zero forces could NOT be acting on this object?

Since the object is moving with constant velocity, the net force acting on it is zero. Therefore whatever forces are acting on the object, they must all cancel out completely. This is not possible if only one non-zero force is acting on the object; in this case, there is a net non-zero force on the object and it *must* accelerate.

Question 3

A train locomotive is moving up a hill heading east. The net force on the locomotive points

A East

B West

C Upwards

D Downwards

E Some combination of A and C

F Some combination of B and D

G None of these

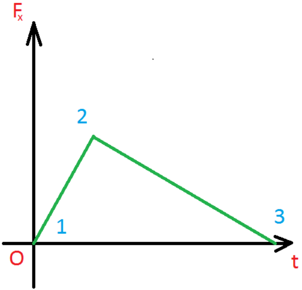
Answer

A train locomotive is moving up a hill heading east. The net force on the locomotive points:

We have no idea! The direction of the velocity of the train at one instant tells us nothing about whether it is accelerating.

Question 4

An object moving in one dimension has $v_x = 0\,\frac{\text{m}}{\text{s}}$ at $t = 0\,\text{s}$. A force acts on it in the x-direction. When is it moving fastest?



A At 1

B At 2

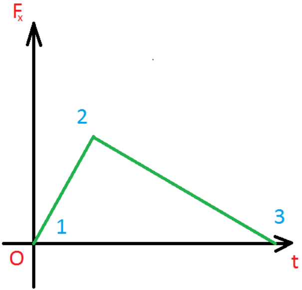
C At 3

D Between 1 and 2

E Between 2 and 3

Answer

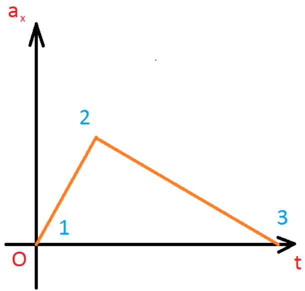
An object moving in one dimension has $v_x = 0\,\frac{\text{m}}{\text{s}}$ at $t = 0\,\text{s}$. A force acts on it in the x-direction. When is it moving fastest?



We know from $\vec{F} = m\vec{a}$, that the direction of acceleration is the same as the direction of the net force, and is proportional to it. Thus, as long as the force is non-zero, the acceleration of the object is non-zero.

Answer

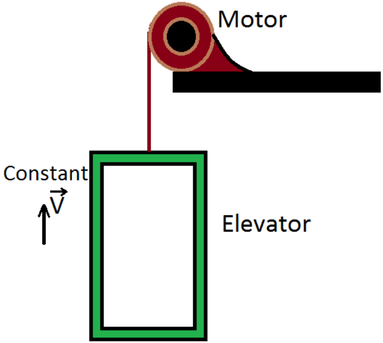
Thus we have the following acceleration vs time graph.



When will this object have its highest velocity? What does the area under this curve represent? Why is it important that we know that $v_x = 0\,\frac{\text{m}}{\text{s}}$ at $t = 0\,\text{s}$?

Question 5

How does the force of gravity (F_g) on the elevator compare to the force of the cable on the elevator (F_T)?



A $F_g < F_T$

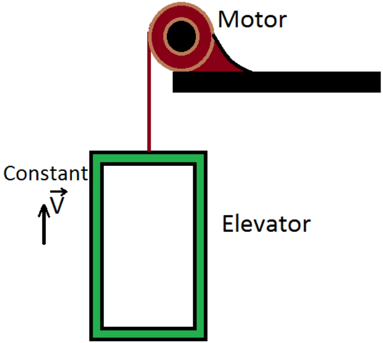
B $F_g > F_T$

C $F_g = F_T$

D Depends on v

Answer

How does the force of gravity (F_g) on the elevator compare to the force of the cable on the elevator (F_T)?



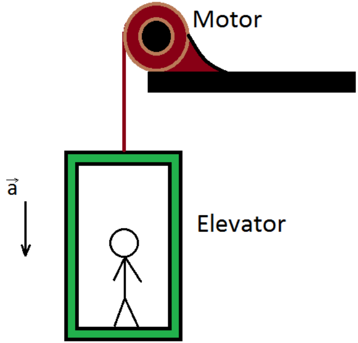
Since the elevator is moving at constant velocity, the net force acting on it must be zero. Thus, we must have

$$\vec{F}_g + \vec{F}_T = 0$$

$$F_g = F_T$$

Question 6

How does the force of gravity (F_g) on the person compare to the normal force of the elevator on the person (F_N)?



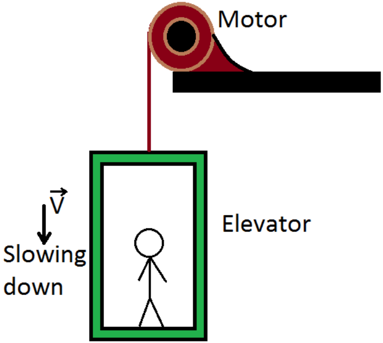
A $F_g < F_N$

B $F_g > F_N$

C $F_g = F_N$

D Depends on a

How does the force of gravity (F_g) on the person compare to the normal force of the elevator on the person (F_N)?



A $F_g < F_N$

B $F_g > F_N$

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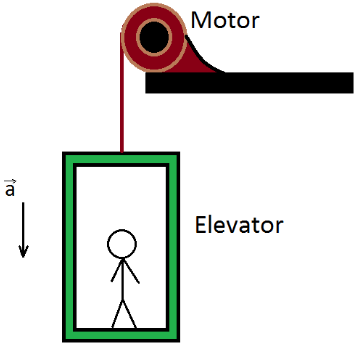
D Depends on a

Answer

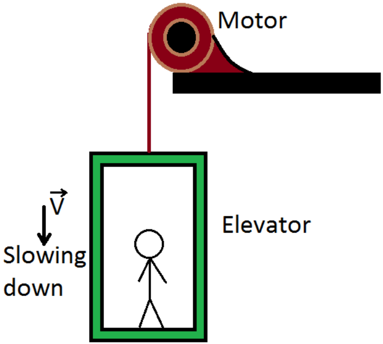
How does the force of gravity (F_g) on the person compare to the normal force of the elevator on the person (F_N)?



If the person is accelerating downwards, the net force on the person must be downwards. Thus the force of gravity on the person must be less than the normal force on the person.

Answer

How does the force of gravity (F_g) on the person compare to the normal force of the elevator on the person (F_N)?



What direction is the acceleration?

We can see that the acceleration must be pointing upwards, so the net force must be upwards, so the normal force on the person must be greater than the gravitational force on the person.

Question 7

The force on a car is given by $\vec{F} = -2\hat{\imath}\,\mathrm{N}$, where $\hat{\imath}$ points to the right. The velocity of the car points

A right

B left

C up

D down

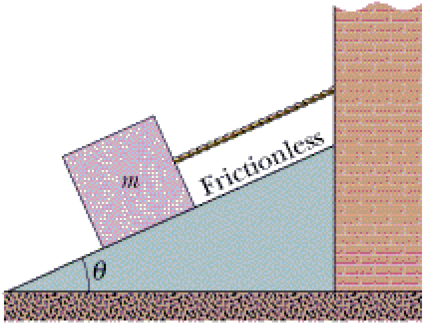
E Don't know

Answer

The force on a car is given by $\vec{F} = -2\hat{\imath}\,\mathrm{N}$, where $\hat{\imath}$ points to the right. The velocity of the car points:

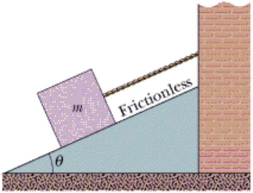
Knowledge of the force acting on an object only tells us about the direction of its acceleration. It does not tell us anything about the direction of the velocity of the object.

The mass of the block is M and the angle θ. Find the tension in the cord and the normal force acting on the block.

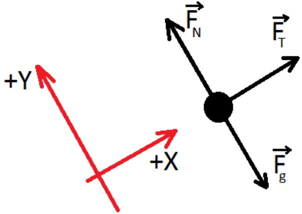


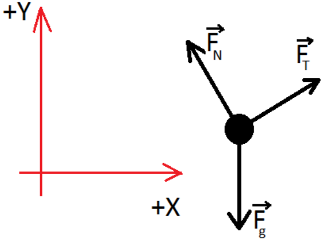
Question 8

Q

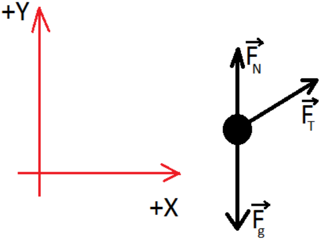


A



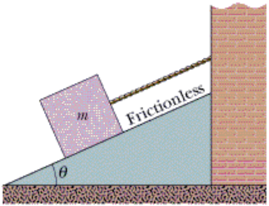


B



C

Q



The force of tension must point along the rope, the force of gravity points towards the centre of the earth (thus, downwards), and the normal force points perpendicular to the surfaces in contact. There is no preferred direction for the axes.

If we use the axes shown in B, we get,

$$\text{(X:)}\ -F_N \sin\theta + F_T \cos\theta = Ma_x = 0\,\mathrm{N}$$

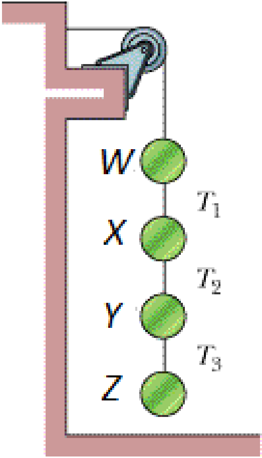
$$\text{(Y:)}\ F_N \cos\theta + F_T \sin\theta - F_g = Ma_y = 0\,\mathrm{N}$$

$$\text{(X:)}\ \Rightarrow F_T = F_N \tan\theta$$

$$\text{(Y:)}\ \Rightarrow F_N \frac{(\cos\theta)^2 + (\sin\theta)^2}{\cos\theta} - Mg = 0$$

$$\Rightarrow F_N = Mg\cos\theta \qquad F_T = Mg\sin\theta$$

How many forces are acting on disk X?



A Two

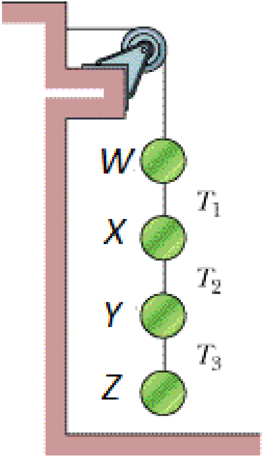
B Three

C Four

D Five

Answer

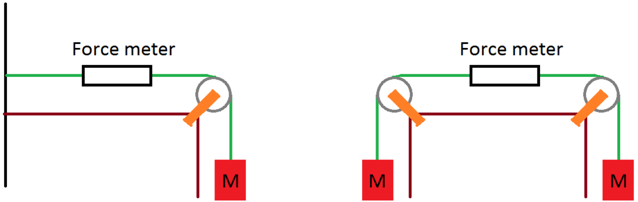
How many forces are acting on disk X?



Disk X only sees the forces acting directly on it; thus it sees the force of gravity, F_{gX}, the force of tension T_1 and the force of tension T_2. It does NOT see the tension T_3, or the weights of disks W, Y or Z, at least not directly.

Question 10

In case 1, the force meter, which reads the tension (T) in the (massless) rope, reads a force of 20 N. What does it read in case 2?



A 0 N

B 10 N

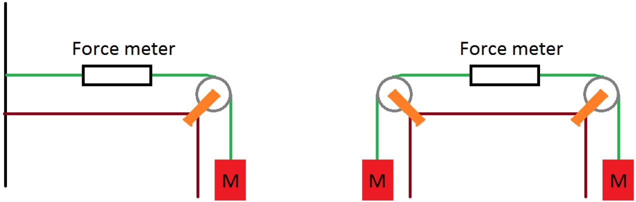
C 20 N

D 40 N

E None of the above.

Answer

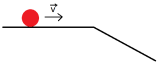
In case 1, the force meter, which reads the tension (T) in the (massless) rope, reads a force of 20 N. What does it read in case 2?



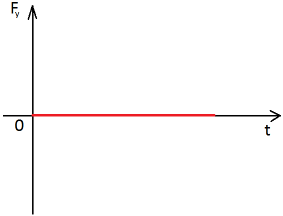
In both cases, the forcemeter is subjected to a pull of T at both ends. Thus, the reading should not change, and should stay at 20 N. After all, the force meter does not know what is on the other side of the rope—it could be a wall, another block, a person, a fish. In all cases, the acceleration of the force meter is zero, so the net force on it is zero, so if there is tension T pointing to the left, there must be tension T pointing to the right as well, and these two tensions are all that the force meter sees.

Question 11

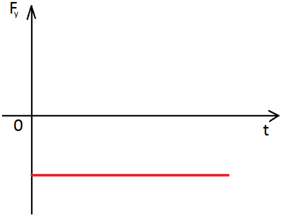
A ball rolls across a road and down a hill as shown. Which of the following graphs of F_y vs t correctly represents the net vertical force on the ball as a function of time? (Assume up is the +y-direction.)



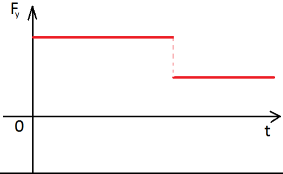
A.



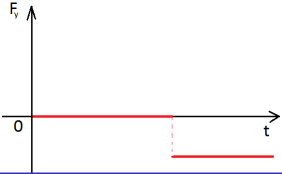
B.



C.

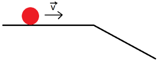


D.



Answer

A ball rolls across a road and down a hill as shown. Which of the following graphs of $F_{\text{net}\,y}$ vs t correctly represents the net vertical force on the ball as a function of time? (Assume up is the $+$y-direction.)



While the ball is rolling along the level surface with constant velocity, the net force on it is zero, and thus $F_{\text{net}\,y} = 0$. As it starts rolling down the slope, it accelerates along the slope (Due to the net force resulting from the gravitational force and the normal force). This acceleration can be broken in to a and y components. The y component is negative (the direction of the net acceleration is down and to the right). The forces acting on the ball are constant, so the acceleration is constant. With these pieces of information we can pick out the right graph.

Not all forces are constant

But not all forces are constant. Some change with

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- time

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But not all forces are constant. Some change with

- time
- position—the gravitational force between two bodies depends on the distance between them. We have:

$$F = G\frac{m_1 m_2}{r^2}.$$

  You can see that as r increases, F decreases.

Not all forces are constant

But not all forces are constant. Some change with

- time
- position
- velocity—the magnitude D of the drag force exerted on a body moving through a fluid can be modelled by

$$D = \frac{1}{2} C \rho A v^2 = B v^2$$

The faster the body moves through the fluid (which could be air, or water, for example), the greater the drag force.

Not all forces are constant

But not all forces are constant. Some change with

- time
- position
- velocity

There are many different kinds of forces, and they can depend on various things. We usually experimentally determine a simple formula which can be used to model their behaviour, and then develop a theory to explain it.

Question 12

Let us consider the case of a skydiver.

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- What are the forces acting on the skydiver? What is the direction of the *net* force?

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- What happens to the y velocity of the skydiver?

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- What happens to the y velocity of the skydiver?
- As a result, what happens to the drag force on the skydiver?

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- As a result, what happens to the drag force on the skydiver?
- Now which way does the net force point?

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- As a result, what happens to the drag force on the skydiver?
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- What happens to the y velocity?

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- As a result, what happens to the drag force on the skydiver?
- Now which way does the net force point?
- What happens to the y velocity?
- What happens to the drag force?

Question 12

Let us consider the case of a skydiver.
At the beginning of his or her jump, the skydiver's vertical velocity is zero.

- What are the forces acting on the skydiver? What is the direction of the *net* force?
- What happens to the y velocity of the skydiver?
- As a result, what happens to the drag force on the skydiver?
- Now which way does the net force point?
- What happens to the y velocity?
- What happens to the drag force?
- Does the drag force keep increasing?

Answer; Drag Force and Terminal Velocity

- The drag force will stop increasing when. . .

Answer; Drag Force and Terminal Velocity

- The drag force will stop increasing when...
- ...the speed of the skydiver stops increasing, which will happen when...

Answer; Drag Force and Terminal Velocity

- The drag force will stop increasing when...
- ...the speed of the skydiver stops increasing, which will happen when...
- ...the acceleration is zero, which will happen when...

Answer; Drag Force and Terminal Velocity

- The drag force will stop increasing when…
- …the speed of the skydiver stops increasing, which will happen when…
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- the net force on the skydiver is zero, which will happen when…

Answer; Drag Force and Terminal Velocity

- The drag force will stop increasing when...
- ...the speed of the skydiver stops increasing, which will happen when...
- ...the acceleration is zero, which will happen when...
- the net force on the skydiver is zero, which will happen when...
- the drag force upwards equals the gravitational force downwards.

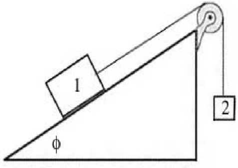
Answer; Drag Force and Terminal Velocity

- The drag force will stop increasing when...
- ...the speed of the skydiver stops increasing, which will happen when...
- ...the acceleration is zero, which will happen when...
- the net force on the skydiver is zero, which will happen when...
- the drag force upwards equals the gravitational force downwards.

So the velocity of a skydiver increases until the drag force is equal and opposite to the gravitational force. The velocity at which this happens is called the *terminal velocity*. Next lecture we will look at some problems involving terminal velocity.

Question 13

In the figure, two blocks are connected by a massless rope. Block 1 of mass M_1 rests on the slope of a frictionless ramp; the rope goes over a frictionless massless pulley, and connects to block 2 of mass M_2. The angle of the slope of the ramp is ϕ. What must M_2 be for the system to be stationary?



A $M_2 = M_1 \cos\phi$

B $M_2 = M_1 \sin\phi$

C $M_2 = M_1 \tan\phi$

D $M_2 = \frac{M_1}{\cos\phi}$

E $M_2 = \frac{M_1}{\sin\phi}$

F $M_2 = \frac{M_1}{\tan\phi}$

Answer

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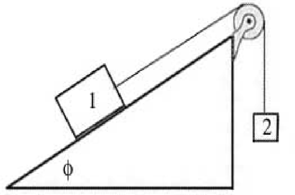
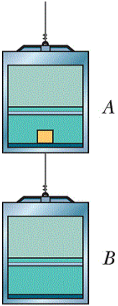


Draw the FBDs for both blocks. Since the rope and pulley are massless and frictionless, the tension at both ends of the rope is the same. For block 2, we get $+T - M_2 g = M_2 a = 0$. For block 1, in the direction parallel to the slope and upwards to the right, we have: $T - M_1 g \sin\theta = 0$, and perpendicular to the slope we have $F_N - M_1 g \cos\theta = 0$. Thus we have: $M_2 g = T = M_1 g \sin\theta$.

Question 14

In the figure, elevator cabs A and B are connected by a short cable and can be pulled upward or lowered by the cable above cab A. Cab A has mass M_A; cab B has mass M_B. A box of catnip of mass M_C lies on the floor of cab A. The tension in the cable connecting the cabs is $T > M_B g$. What is the magnitude of the normal force F_N on the box from the floor?



Answer

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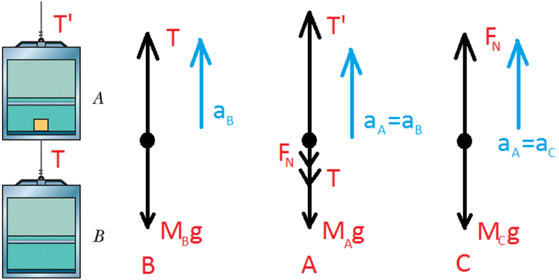
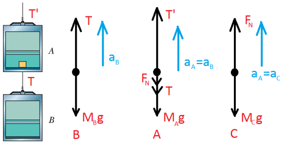
We start by drawing the Free Body Diagrams (FBDs) for all three objects. Note that all three have the same acceleration, which we shall call a.



Answer



We get the following equations:

$$
\begin{aligned}
(\text{B:})\ T - M_B g &= M_B a \\
(\text{A:})\ T' - F_N - M_A g - T &= M_A a \\
(\text{C:})\ F_N - M_C g &= M_C a
\end{aligned}
$$

We know T, M_A, M_B, M_C and g; we do not know T' or F_N or a. To find F_N we can use equation (C:), but to do so we need to know a. This we can find using equation $(B:)$. Thus

$$
\begin{aligned}
a &= \frac{T - M_B g}{M_B} \\
F_N = M_C(a + g) &= M_C\left(g + \frac{T - M_B g}{M_B}\right) \\
&= \frac{M_C * T}{M_B}
\end{aligned}
$$

Reference Frames

So far, I've been ignoring a certain detail. We have seen the first two of Newton's Laws of Motion, but we haven't clarified: are they always true? Are they true for all observers?

It turns out that Newton's laws are only true for observers in an inertial reference frame.

All right, first of all, what is a reference frame?

Reference Frames

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A reference frame is simply a set of coordinates plus an observer who always stays at the origin. This observer could be moving, in which case the origin and the coordinate axes move with him/her.

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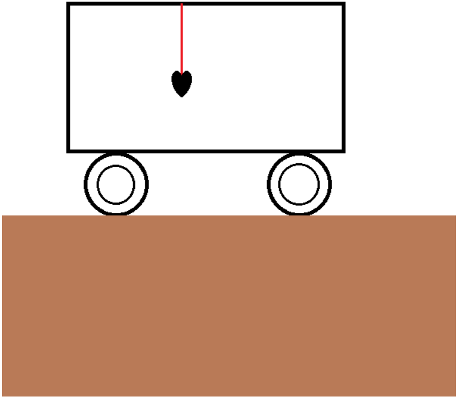
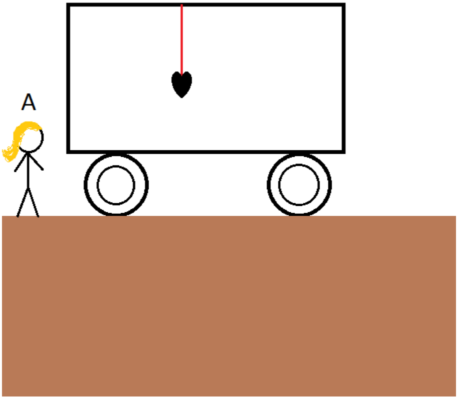
A reference frame is simply a set of coordinates plus an observer who always stays at the origin. This observer could be moving, in which case the origin and the coordinate axes move with him/her.

An inertial reference frame is one in which Newton's Laws hold. That is, no matter what experiments the observer performs, everything he sees can be explained as a result of Newton's Laws.

All right, that seems a little circular. The simplest way to get a feeling for this is to look at a non-inertial reference frame. Let us consider a railcar with a mass hanging from a string inside it.



We consider an observer A on the ground outside the railcar, and look at the Free Body Diagram she draws for the mass.



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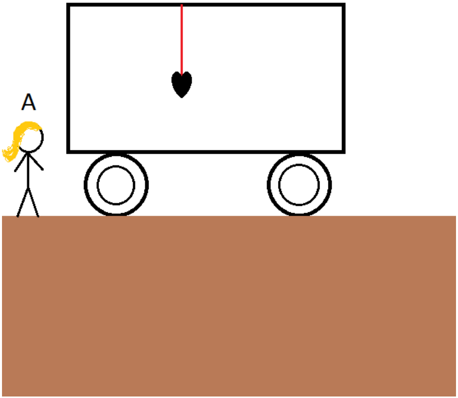
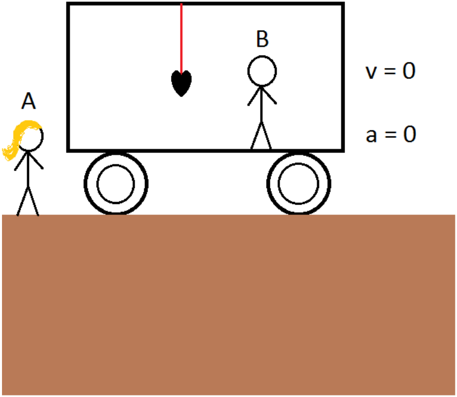
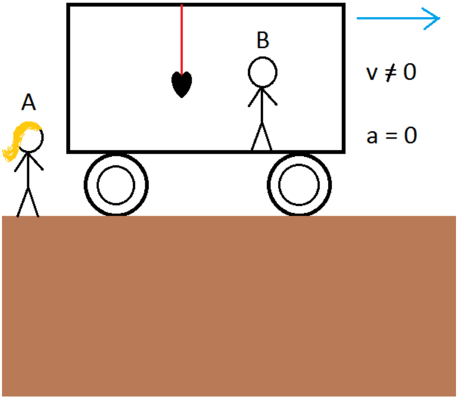


We now consider a second observer B inside the railcar. The railcar is at rest, so the two reference frames are not moving with respect to each other, so they should agree on all the observations they make.

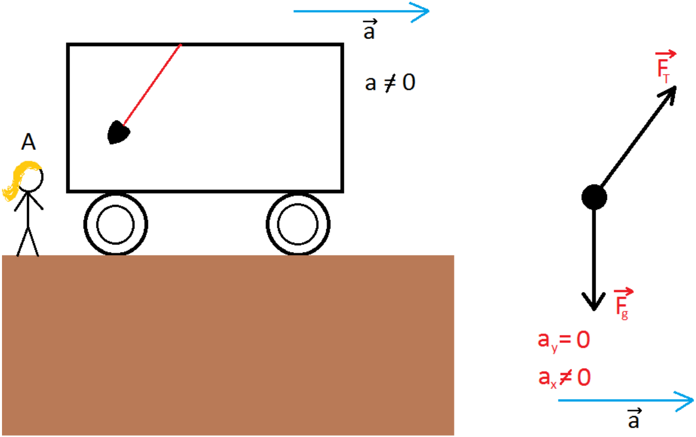


Inertial and Non-inertial Reference Frames

What if the railcar is moving with a constant velocity? Does the Free Body Diagram that B draws change? Do A and B agree on the forces exerted on the mass?



What happens if the railcar is accelerating? Let us look at the Free Body Diagram that A draws.



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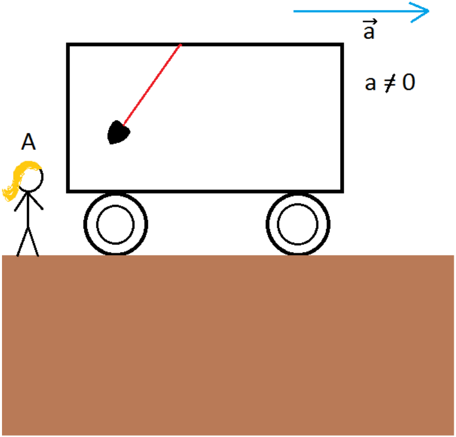
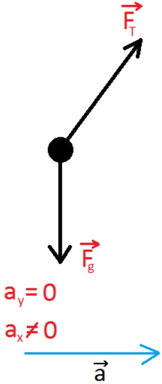
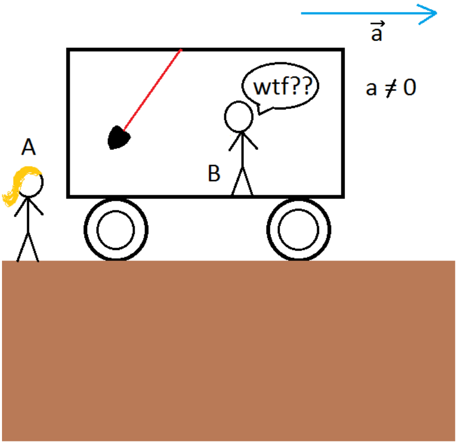
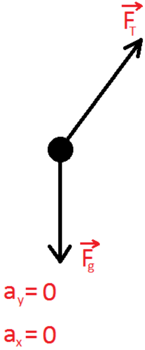




Inertial and Non-inertial Reference Frames

But what about observer B? In his reference frame, *he is stationary*! What does his Free Body Diagram look like?





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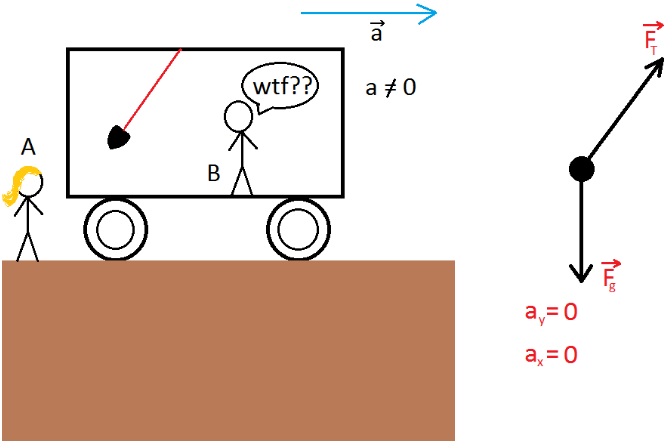
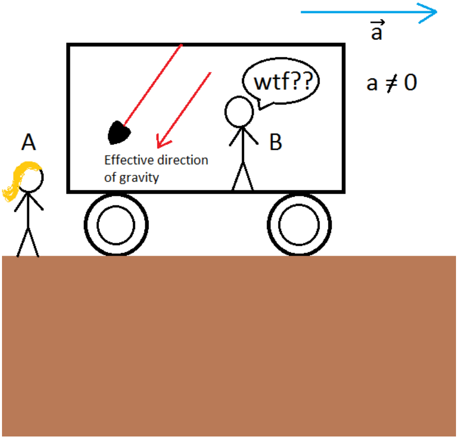


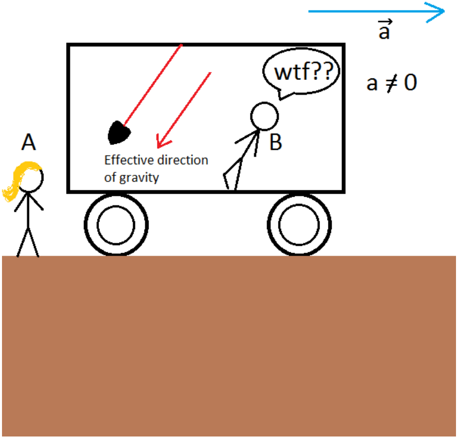
Inertial and Non-inertial Reference Frames

We see that an observer B cannot explain what is happening to the mass with just Newton's Laws. He will have to postulate some new laws of Physics.



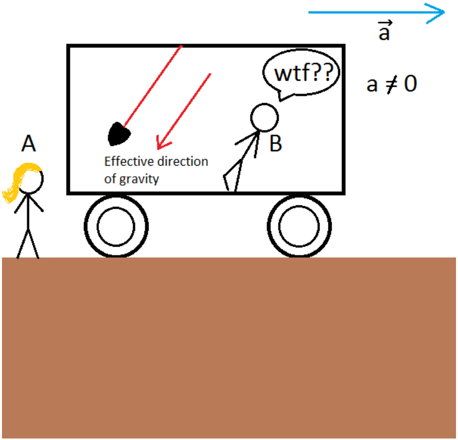
Inertial and Non-inertial Reference Frames

One clue that B will have that something is wrong is that these new forces that he will have to invent, affect everything he sees, in almost the same way. In fact, he will think gravity is acting at a new weird direction.



Inertial and Non-inertial Reference Frames

So, we see here that A is an observer in an inertial frame of reference, and B, when accelerating, is in a noninertial frame of reference.



But if A is in an inertial frame, and B is accelerating with respect to A, then $\vec{a}_{BA} \neq 0$, which means $\vec{a}_{AB} \neq 0$, so we have

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$$m_P\vec{a}_{PB} = m_P\vec{a}_{PA} + m_P\vec{a}_{AB}$$

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$$\vec{F}_{PB} = \vec{F}_{PA} + \vec{F}_{new}$$

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So B will see forces acting on P that he cannot explain by Newton's Laws. And these forces will crop up in every Free Body Diagram he draws, in every experiment he does. And this should be a clue to him that he, B, is in a non-inertial frame.

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Question 15

A car moves horizontally with a constant acceleration of $3\,\frac{\text{m}}{\text{s}^2}$. A ball is suspended by a string from the ceiling of the car. The ball does not swing, being at rest with respect to the car. What angle does the string make with the vertical?

A 17°

B 35°

C 52°

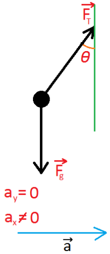
D 73°

E Cannot be found without knowing the length of the string.

Answer

A car moves horizontally with a constant acceleration of $a = 3\,\frac{\text{m}}{\text{s}^2}$. A ball is suspended by a string from the ceiling of the car. The ball does not swing, being at rest with respect to the car. What angle does the string make with the vertical?

Draw the FBD of the ball. We assume it hass mass M.



$$(\text{Y:})F_T \cos\theta - Mg = 0$$

$$(\text{X:})F_T \sin\theta = Ma$$

$$\Rightarrow \tan\theta = \frac{a}{g}$$

Question 16

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\,\frac{\text{m}}{\text{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

1. what is the coin's acceleration relative to the ground (magnitude)?
   A $0.24g$
   B $0.76g$
   C g
   D $1.24g$
   E $2.24g$

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2. what is the coin's acceleration relative to the ground (direction)?
   A Up
   B Down

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1. what is the coin's acceleration relative to the ground (magnitude)?The only force acting on the coin is gravity, so its acceleration should be of magnitude g.

Answer

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\,\frac{\text{m}}{\text{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

2. what is the coin's acceleration relative to the ground (direction)? The only force acting on the coin is gravity, so its acceleration should be in the downwards direction.

Answer

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\,\frac{\mathrm{m}}{\mathrm{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

3. what is the coin's acceleration relative to the customer (magnitude)? We use the relative motion equations, with C: Coin, P: Person, G: Ground.

$$\vec{a}_{CP} = \vec{a}_{CG} + \vec{a}_{GP}$$
$$\vec{a}_{CP} = \vec{a}_{CG} - \vec{a}_{PG}$$
$$\vec{a}_{CP} = -g\hat{\jmath} - (-1.24g\hat{\jmath})$$
$$\vec{a}_{CP} = 0.24g\hat{\jmath}$$

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   - B Down

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2. how long does the coin take to reach the compartment ceiling, a distance d above the knee?

   A $\sqrt{\frac{2d}{0.24g}}$

   B $\sqrt{\frac{2d}{g}}$

   C $\sqrt{\frac{2d}{0.76g}}$

   D $\sqrt{\frac{2d}{1.24g}}$

   E $\sqrt{\frac{2d}{2.24g}}$

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3. in unit-vector notation, what is the actual force on the coin?

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4. in unit-vector notation, what is the apparent force according to the customer's measure of the coin's acceleration?

Answer

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\,\frac{\text{m}}{\text{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

1. what is the coin's acceleration relative to the customer (direction)? From the previous question, we found that the acceleration with respect to the customer is $\vec{a}_{CP} = 0.24g\hat{\jmath}$, thus, in the upwards direction.

Answer

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\,\frac{\text{m}}{\text{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

2. in unit-vector notation, what is the actual force on the coin? The actual force on the coin, as seen from an inertial oserver on the ground, is just $-mg\hat{\jmath}$.

Answer

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\,\frac{\text{m}}{\text{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

3. in unit-vector notation, what is the apparent force according to the customer's measure of the coin's acceleration? As seen from the customer's perspective, the force on the coin is $\vec{F} = m\vec{a}_{CP} = +0.24mg\hat{\jmath}$.

Answer

A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y-axis with an acceleration magnitude of $1.24g$, with $g = 9.80\ \frac{\text{m}}{\text{s}^2}$. A mass m coin rests on the customer's knee. Once the motion begins,

1. how long does the coin take to reach the compartment ceiling, a distance d above the knee? The coin starts from rest. We treat this problem in the frame of the customer. In this frame, the initial position on the knee can be taken to be $y = 0$, the initial velocity $v_{y0} = 0$, and the acceleration $a_y = 0.24g$, with the distance to be covered being d.

$$d = \frac{1}{2} a_y t^2$$

$$\Rightarrow t = \sqrt{\frac{2d}{0.24g}}$$

Question 17

A steel block of mass 1 kg and a wooden block of mass 2 kg are connected by a massless rope. The steel block is held with the rope hanging down and the the wooden block suspended. The steel block is then released and the entire system falls freely under gravity (it is in free-fall). Take $g = 10\,\frac{\text{m}}{\text{s}^2}$. The tension in the rope is:

A 0 N

B 10 N

C 20 N

D 30 N

Answer

A steel block of mass 1 kg and a wooden block of mass 2 kg are connected by a massless rope. The steel block is held with the rope hanging down and the the wooden block suspended. The steel block is then released and the entire system falls freely under gravity (it is in free-fall). Take $g = 10\,\frac{\text{m}}{\text{s}^2}$. The tension in the rope is:

If the blocks are falling freely, then their acceleration is g. Thus the only force acting on them is gravity (F_g). There is no tension in the rope. Here's another way of thinking about it: drop both blocks but without any rope connecting them. Now drop them with a rope connecting them. Is there any difference in their motion? No!

Newton's Third Law

Third Law For every action, there is an equal and opposite reaction.

If object 1 exerts a force $\vec{F}_{21}$ on object 2, then object 2 exerts and equal (in magnitude) and opposite (in direction) force $\vec{F}_{12}$ on object 1. Mathematically,

$$\vec{F}_{21} = -\vec{F}_{12}$$

So forces always come in pairs. However, it is important to note that these forces act on different objects! $\vec{F}_{21}$ acts on object 2, and $\vec{F}_{12}$ acts on object 1.

Newton's Third Law

Let's return to the book on the table.

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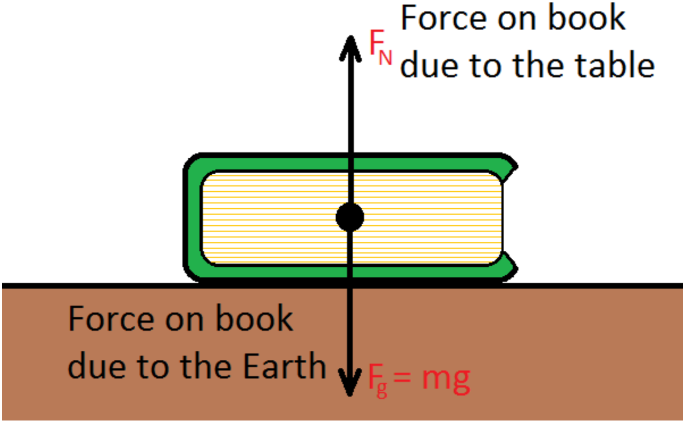
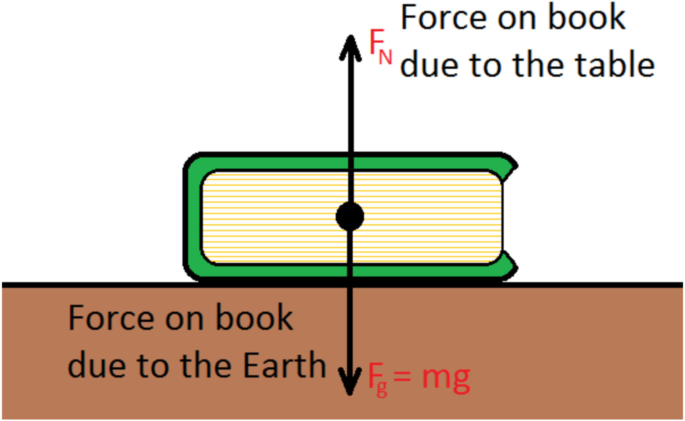
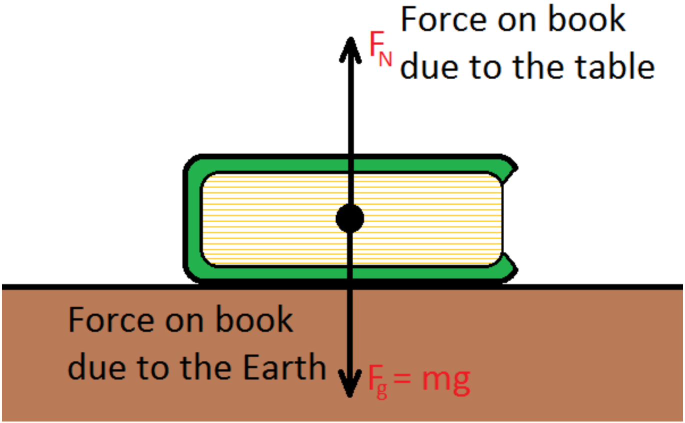


Newton's Third Law

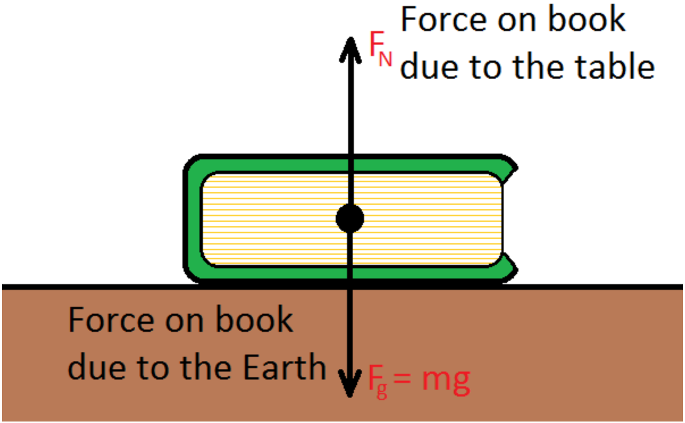


Are these two forces a Third Law 'action-reaction' pair?
(A) Yes, they are equal and opposite. (B) No. (If so, tell me why!)

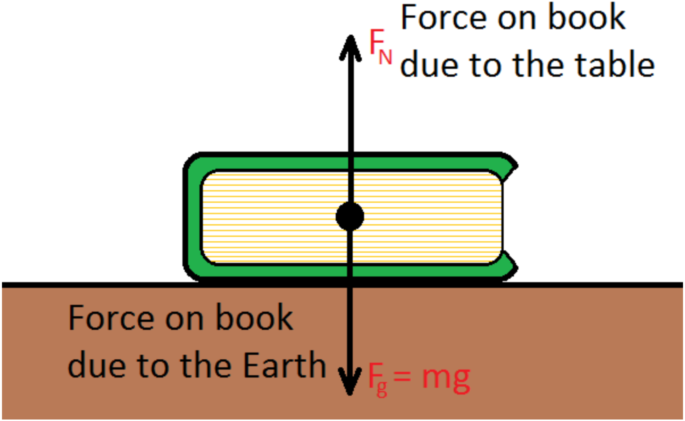


Are these two forces a Third Law 'action-reaction' pair?

(A) Yes, they are equal and opposite. (B) No. (If so, tell me why!)



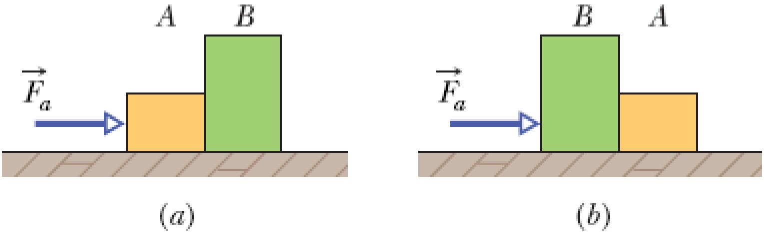
No! An action-reaction pair of forces have to be between the same two objects, and if the action acts on one object of the pair, the reaction has to act on the other object of the pair.



So what are the reactions to these forces acting on the book?

In figure (a), a constant horizontal force $\vec{F}_a$ is applied to block A, which pushes against block B with a 20.0 N force directed horizontally to the right. In figure (b), the same force $\vec{F}_a$ is applied to block B; now block A pushes on block B with a 10.0 N force directed horizontally to the left. The blocks have a combined mass of 12.0 kg. What are the magnitudes of

1. their acceleration in figure (a), and
2. the force $\vec{F}_a$?



Answer

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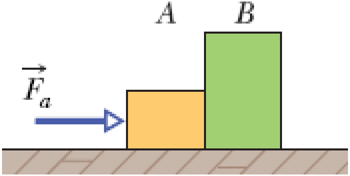
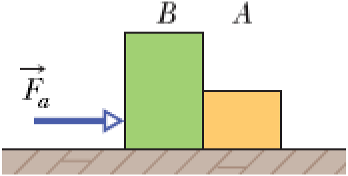


(a)



(b)

Proceed as usual, drawing FBDs for both blocks in both cases. The extra things to keep in mind are: $m_A + m_B = 12\,\text{kg}$, and also the acceleration of both blocks is the same (since they are moving together) and it is the same in both cases (since the total mass and the total external force applied are the same). Besides this, it is necessary to use the Third Law, which tells us that $\vec{F}_{AonB} = -\vec{F}_{BonA}$

Question 19

Team Gryffindor and Team Slytherin are having a tug of war match with a massless rope. Team Slytherin is winning. Which statement is true?

A Team Slytherin is exerting a greater force on the rope than Team Gryffindor.

B Team Slytherin is exerting a greater force on the ground than Team Gryffindor.

C Team Slytherin is exerting the same magnitude of force on the rope as Team Gryffindor.

D Team Slytherin is cheating.

Answer

Team Gryffindor and Team Slytherin are having a tug of war match with a massless rope. Team Slytherin is winning. Which statement is true?

Since the rope is massless, the net force on it must be zero ($\vec{F}_{\text{net}} = m\vec{a}$). Thus both teams are exerting an equal amount of force on the rope. Team Slytherin is exerting a greater force on the ground, so the ground exerts a greater force on them, and thus the net force on them is backward, and they move backward, winning. Thus two (possibly three) of the statements are correct.

Newton's Third Law—where does it come from?

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Let us consider a system with 2 bodies, object 1 and object 2. The system is isolated, so the only thing that 1 can interact with is 2, and vice versa.

Newton's Third Law—where does it come from?

Let us consider a system with 2 bodies, object 1 and object 2. The system is isolated, so the only thing that 1 can interact with is 2, and vice versa.

It turns out that momentum is conserved, so that we have:

$$\vec{p}_1 + \vec{p}_2 = \vec{P}_{total}$$ which will be a constant, since momentum is conserved.

Newton's Third Law—where does it come from?

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$\vec{p}_1 + \vec{p}_2 = \vec{P}_{total}$ which will be a constant, since momentum is conserved.

When we say that momentum is conserved, what we mean is:

$$\vec{P}_{total;initial} = \vec{P}_{total;final}$$

which means $\vec{P}_{total}$ <u>stays constant throughout</u> - thus it is <u>conserved</u>.

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So the only way the momenta of objects 1 and 2 can change is if they act on each other. This interaction will not change the total momentum, which is conserved—it just redistributes the momentum.

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So the only way the momenta of objects 1 and 2 can change is if they act on each other. This interaction will not change the total momentum, which is conserved—it just redistributes the momentum. So we have:

$$\Delta\vec{p}_{12} + \Delta\vec{p}_{21} = 0$$

where $\Delta\vec{p}_{12}$ is the change in $\vec{p}_1$ due to object 2, and $\Delta\vec{p}_{21}$ is the change in $\vec{p}_2$ due to object 1.

Newton's Third Law—where does it come from?

Let us consider a system with 2 bodies, object 1 and object 2. The system is isolated, so the only thing that 1 can interact with is 2, and vice versa.

So we have:

$$\Delta\vec{p}_{12} + \Delta\vec{p}_{21} = 0$$

where $\Delta\vec{p}_{12}$ is the change in $\vec{p}_1$ due to object 2, and $\Delta\vec{p}_{21}$ is the change in $\vec{p}_2$ due to object 1. This interaction takes place over a period of time Δt, so we can write:

$$\frac{\Delta\vec{p}_{12}}{\Delta t} + \frac{\Delta\vec{p}_{21}}{\Delta t} = 0$$

Newton's Third Law—where does it come from?

$$\frac{\Delta \vec{p}_{12}}{\Delta t} + \frac{\Delta \vec{p}_{21}}{\Delta t} = 0$$

In the limit $\Delta t \to 0$, we have:

$$\frac{\mathrm{d}\vec{p}_{12}}{\mathrm{d}t} + \frac{\mathrm{d}\vec{p}_{21}}{\mathrm{d}t} = 0$$

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But this just means that for every force $\vec{F}_{12}$ that object 2 exerts on object 1, object 1 exerts an equal (in magnitude) and opposite (in direction) force $\vec{F}_{21} = -\vec{F}_{12}$ on object 2. That is, for every action, there is an equal and opposite reaction. Note that both the action and the reaction involve the same two bodies, but in this case the action acts on object 1, and the reaction acts on object 2.

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This is Newton's Third Law, and it is a consequence of the Law of Conservation of Momentum.