Chapter 6
Force and Motion - I

6-1 Force

Force

What is force?

A force is either a push or a pull that acts on an object.

Force is an effect which can,

a) Start motion,

b) Stop motion,

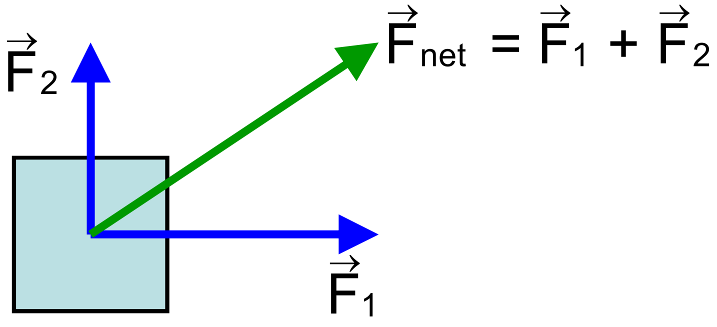
c) Change the speed or direction of motion,

d) Change the shape or size of a body.

6-1 Force

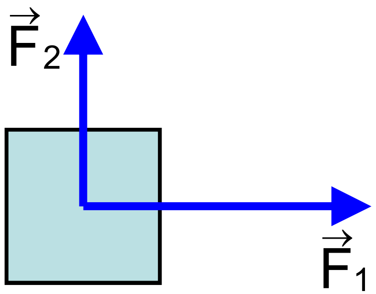
Force is a vector quantity

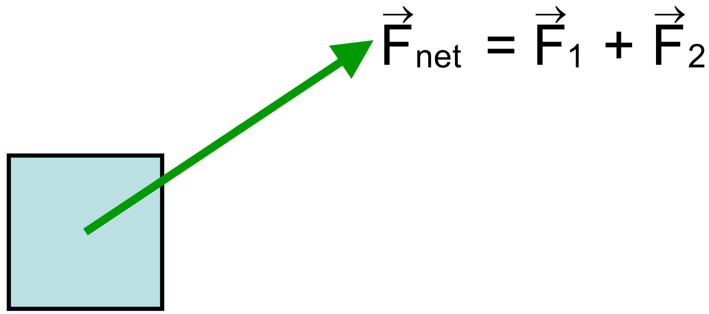
Force is a vector quantity. It has a direction and magnitude.



Add $\vec{F}_1$ and $\vec{F}_2$ vectorially to find their net force $\vec{F}_{net}$.
$\vec{F}_{net}$ is also called the resultant force.

You can use either $\vec{F}_1$ and $\vec{F}_2$ or the net force $\vec{F}_{net}$.



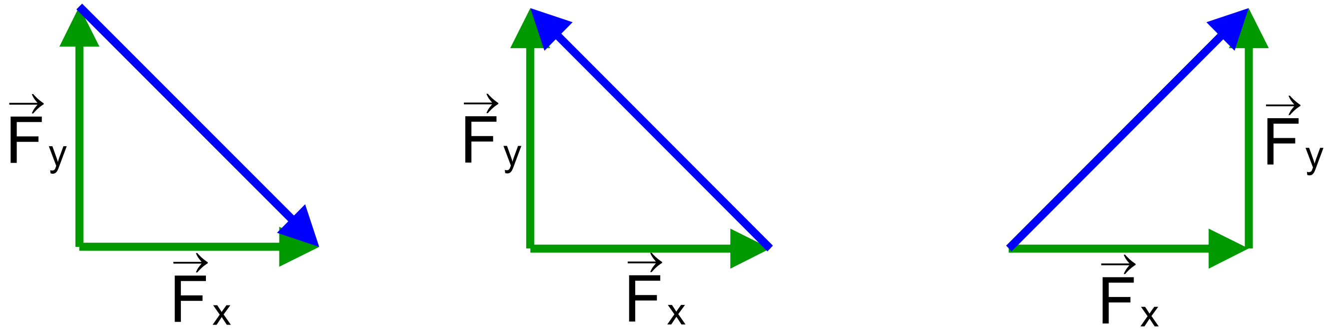


Principle of superposition: A force that has the magnitude and direction of the net force has the same effect on the body as all the individual forces together.

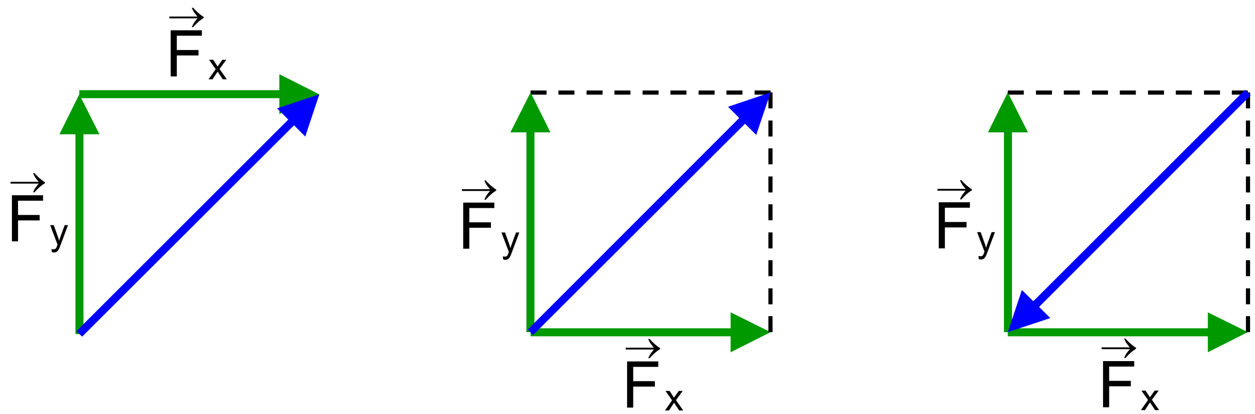
6-1 Force

Checkpoint 1

Indicate the correct net force direction.



Solution	Wrong	Wrong	Correct



Solution	Correct	Correct	Wrong

6-2 Some Particular Forces
Gravitational force

Earth exerts a gravitational force $\vec{F}_g$ on any object near its surface. The gravitational force pulls the object directly down toward the ground.

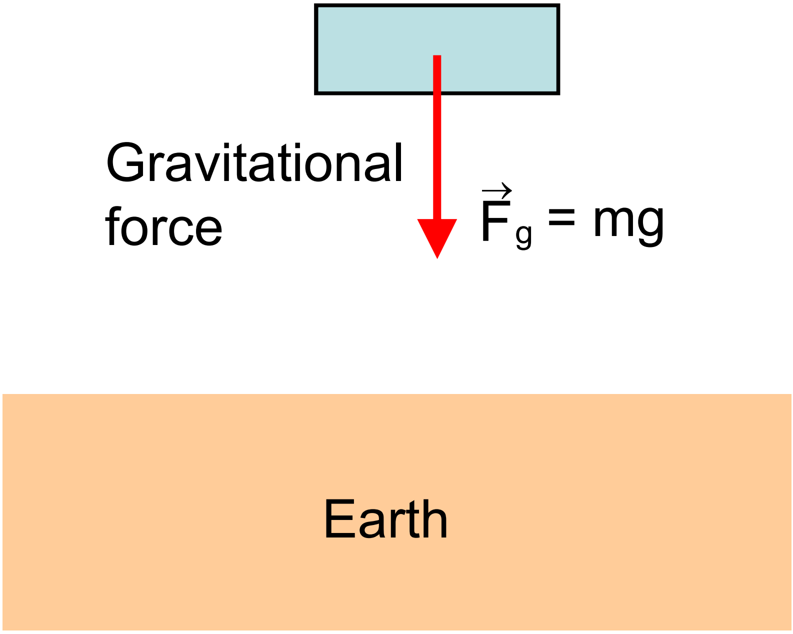
Magnitude of the gravitational force

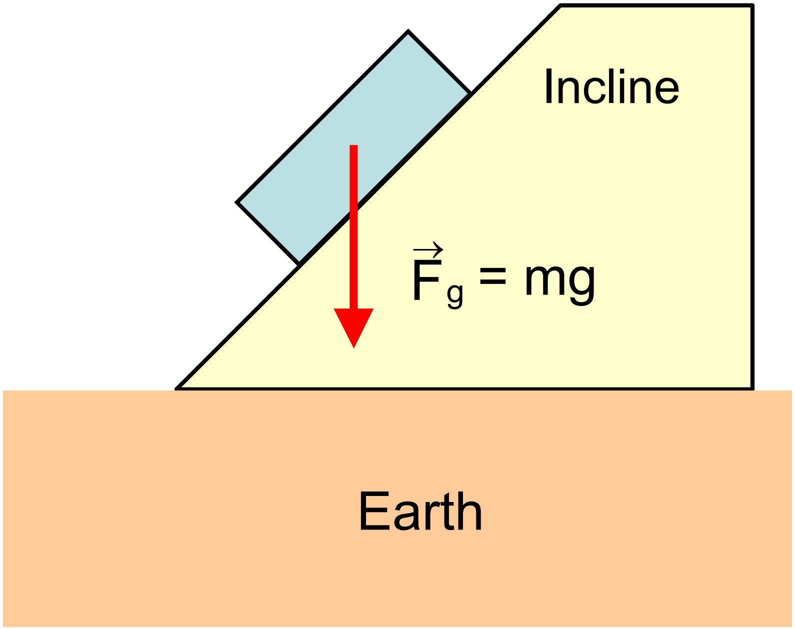
Mass of the object

Free fall acceleration

$$F_g = m\,g$$

In SI units, $g = 9.8\ m/s^2$

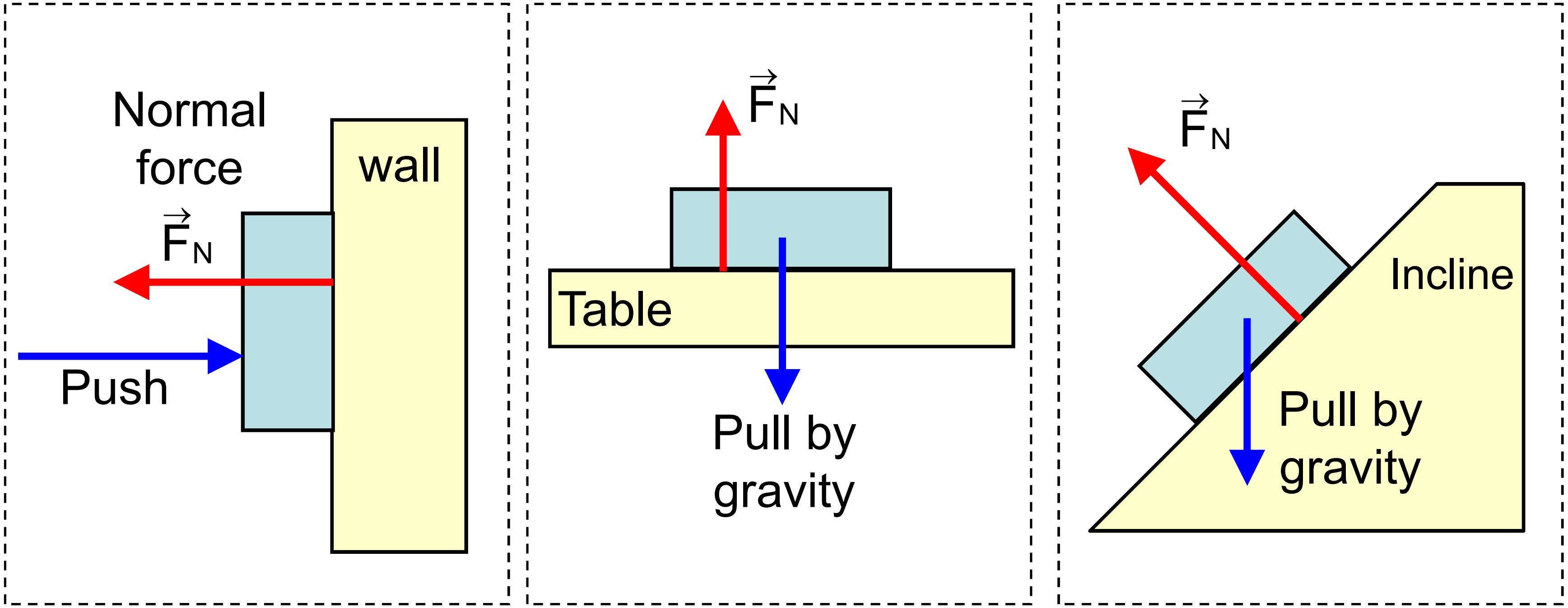




Directly down toward the ground.

6-2 Some Particular Forces
Normal force

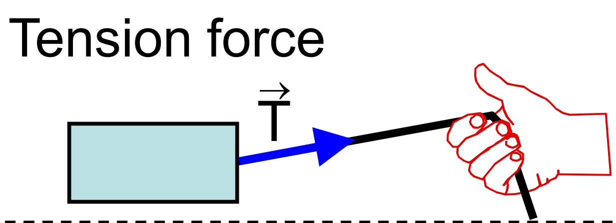
When an object presses against a surface, the surface deforms and pushes the object with a normal force $\vec{F}_N$ that is perpendicular to the surface.



Normal force is always perpendicular to the surface.

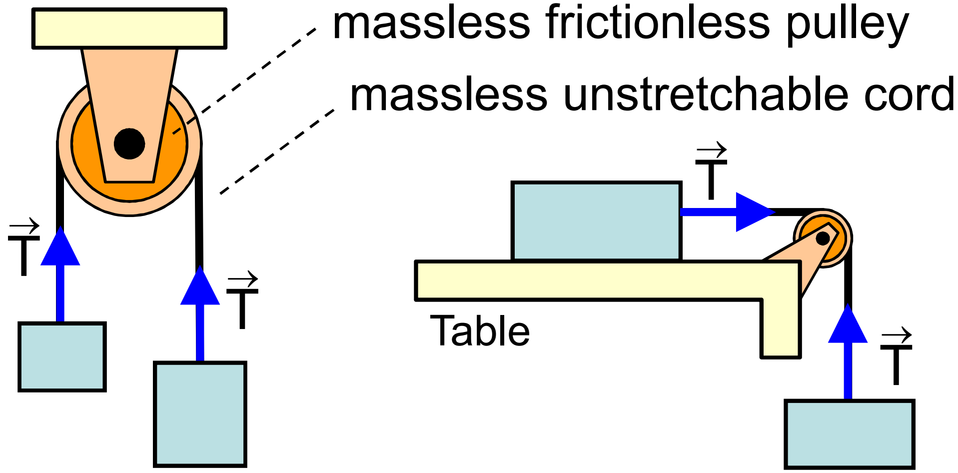
6-2 Some Particular Forces
Tension

When a rope attached to an object is pulled tight, the rope pulls the object with a tension force $\vec{T}$ directed away from the object and along the rope. The magnitude of the tension force is called tension.



The tension force is directed away from the object and is along the rope.

The rope is massless and unstretchable so that the rope is only used as a connection between two objects and pulls both objects with the same tension even if the objects and the rope are accelerating and even if the rope runs around a massless frictionless pulley.

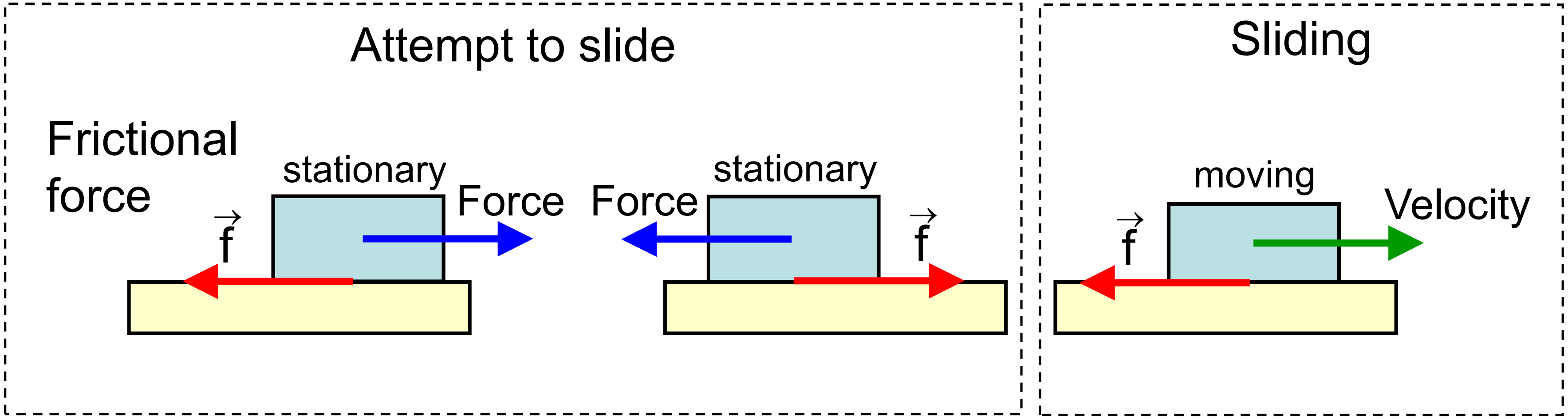


The cord pulls both objects with the same tension

massless ≡ mass is negligible compared to the object's mass

6-2 Some Particular Forces
Friction

When we slide or attempt to slide an object over a surface, the motion is resisted by a frictional force $\vec{f}$ which is directed parallel to the surface and opposite to the direction of the intended motion.



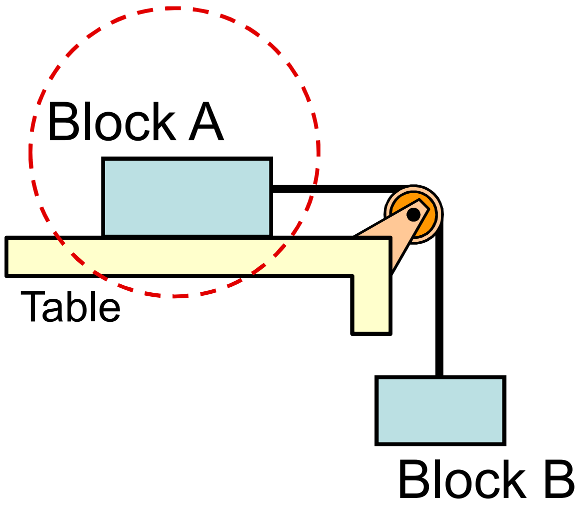
Frictional forces is directed along the surface and opposite to the direction of the motion or intended motion

In this chapter, we ignore frictional forces and assume that all surfaces are frictionless.
We will consider frictional forces in more detail in the next chapter.

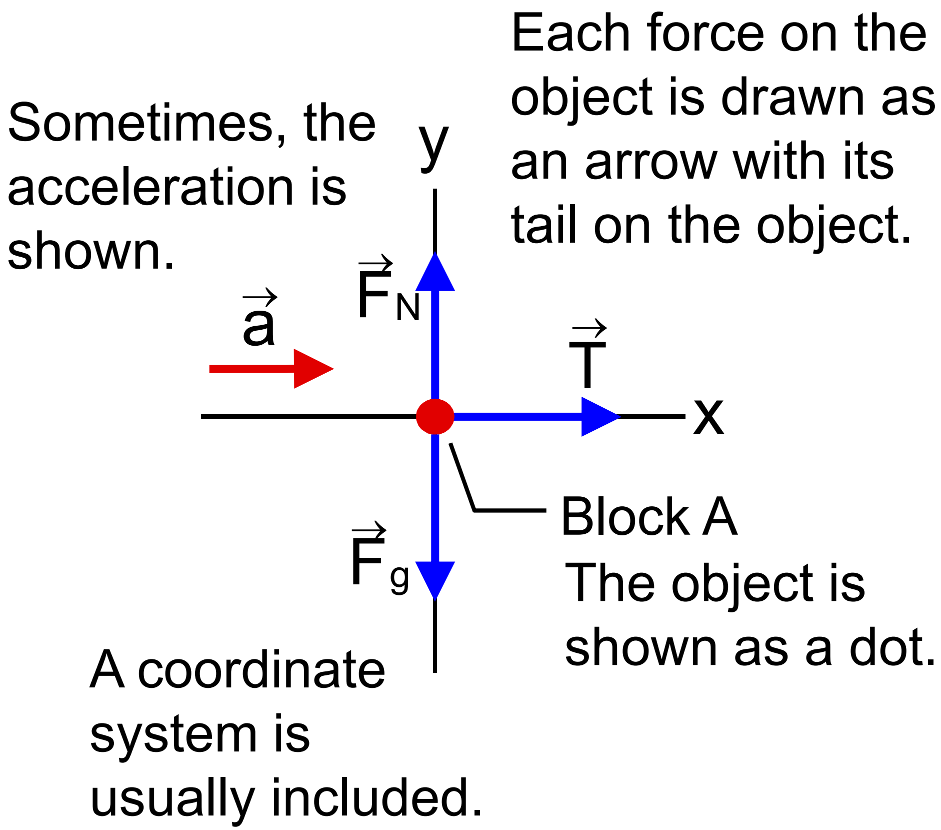
6-2 Some Particular Forces

Free-body diagram

The free-body diagram is
a diagram used to show all external forces acting on the object.



Free-body diagram for block A



6-2 Some Particular Forces

Free-body diagram

The free-body diagram is
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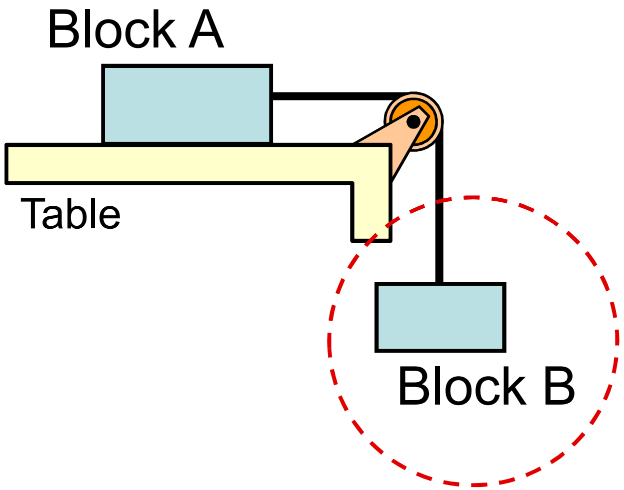
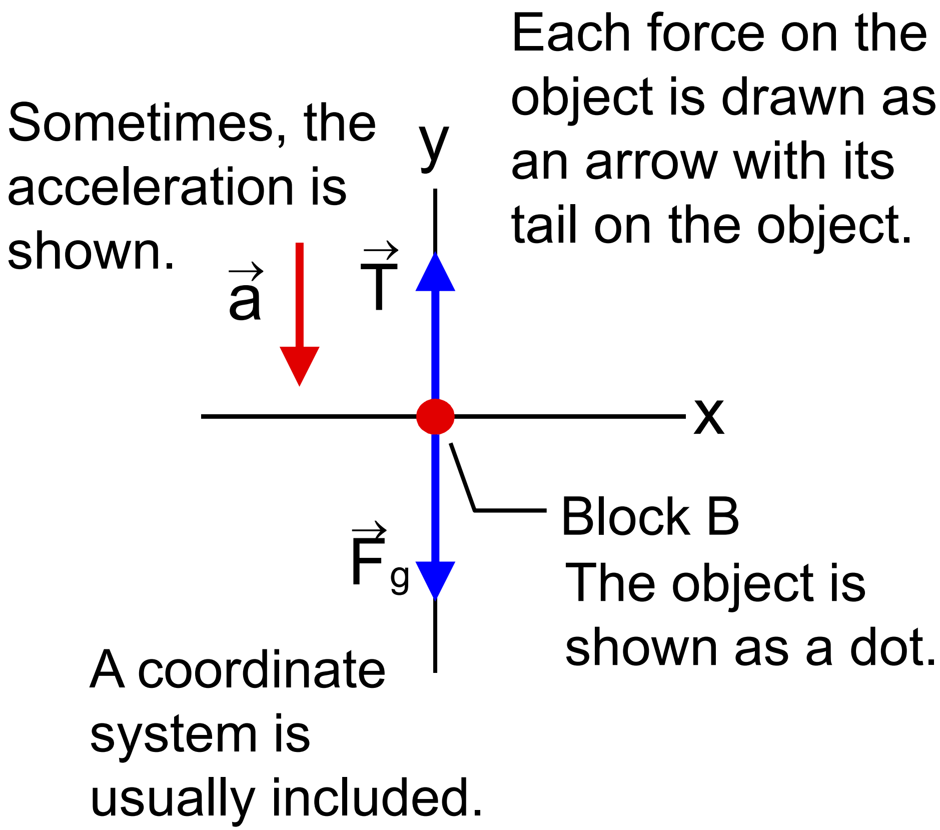
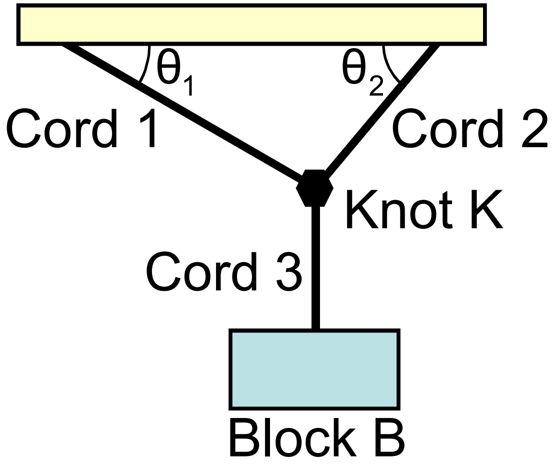


Free-body diagram for block B



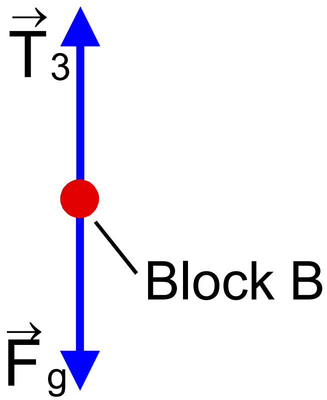
6-2 Some Particular Forces
Free-body diagram

The free-body diagram is
a diagram used to show all external forces acting on the object.

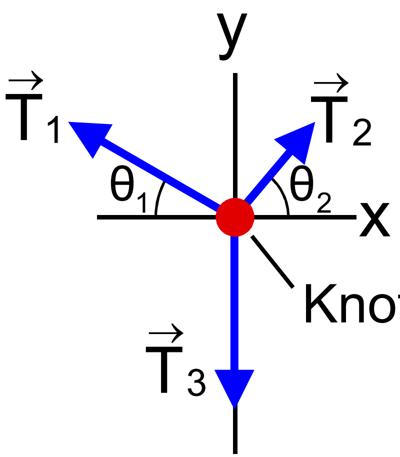


Knot K is massless

Free-body diagram
for block B



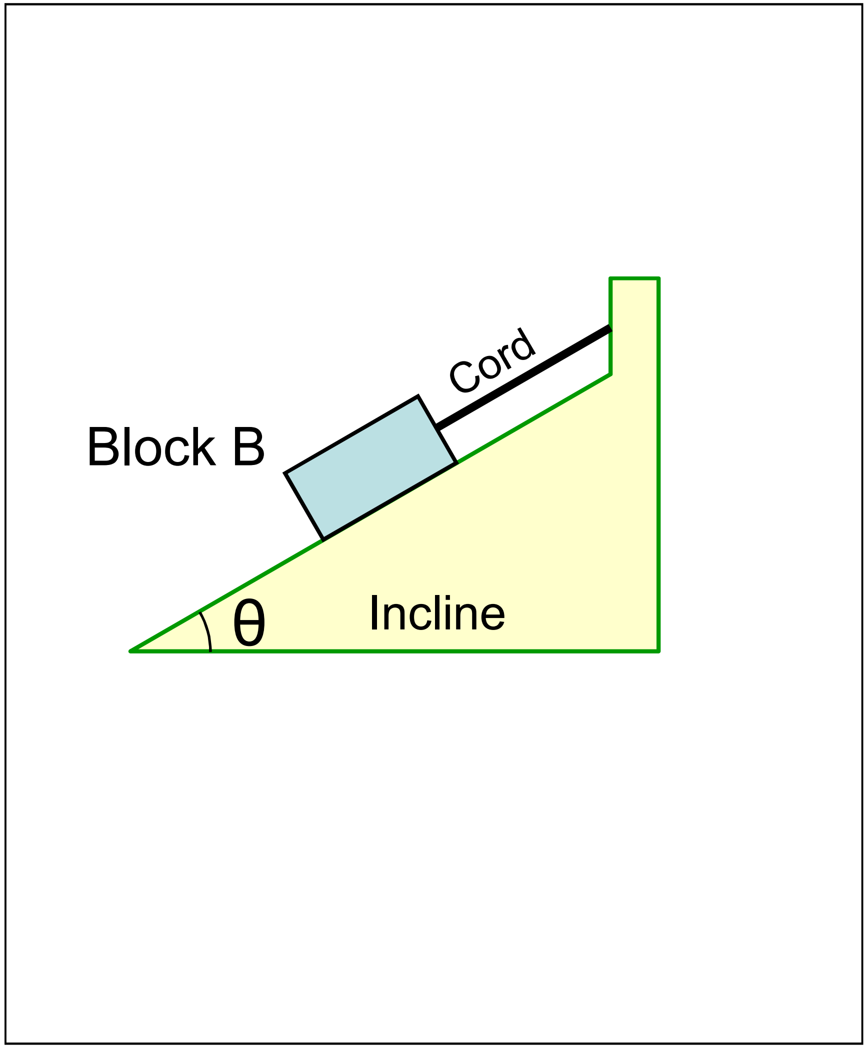
Free-body diagram
for knot K

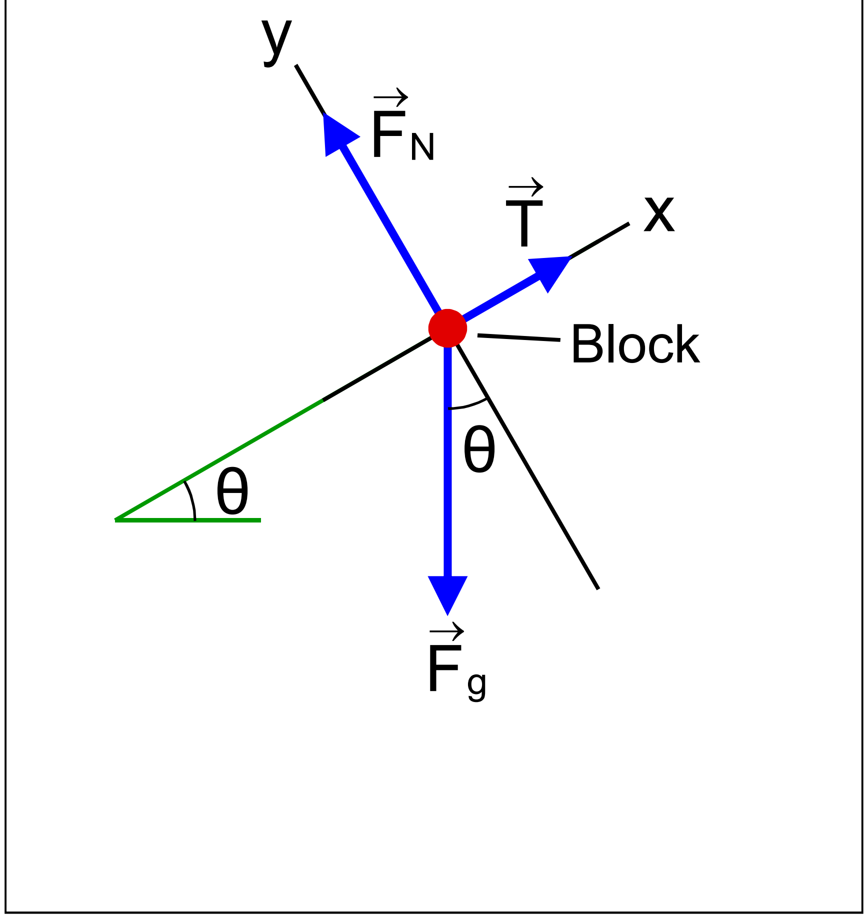


Since knot K is massless,
the gravitational force on
it is zero.

6-2 Some Particular Forces
Free-body diagram

The free-body diagram is
a diagram used to show all external forces acting on the object.

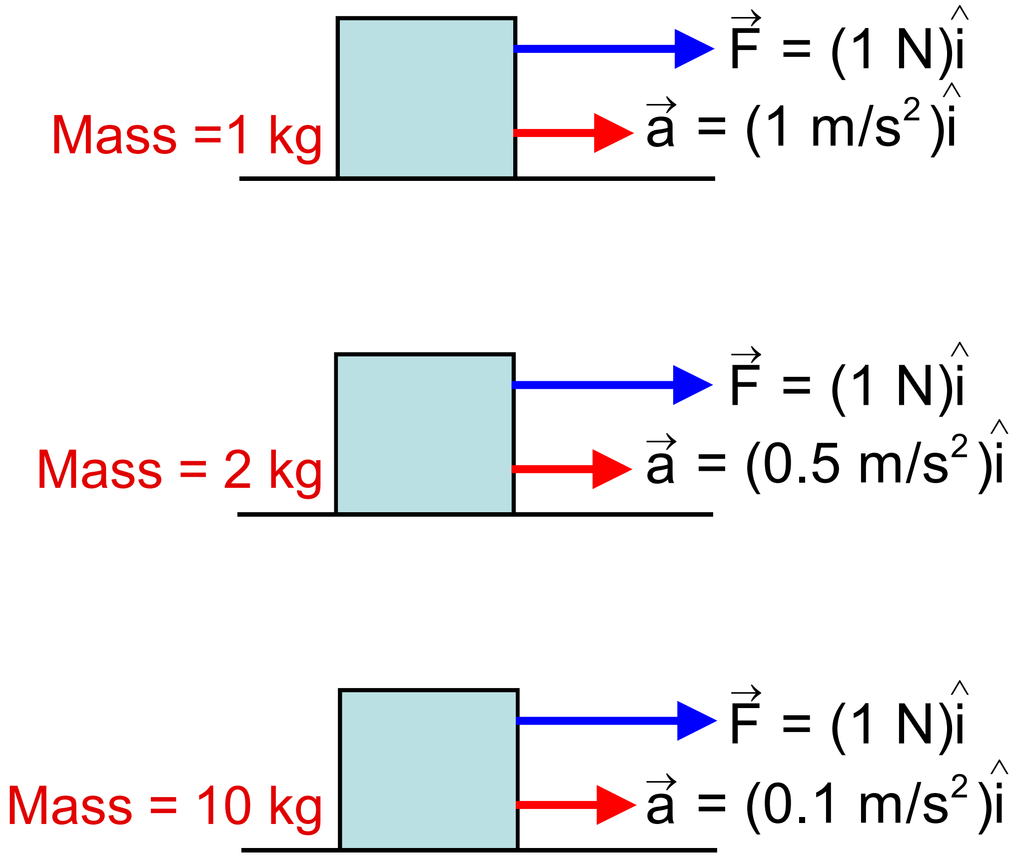




6-3 Mass
Mass relates force to acceleration

The mass of an object is the property of the object that relates a force on the object to the resultant acceleration.

Mass is a scalar quantity



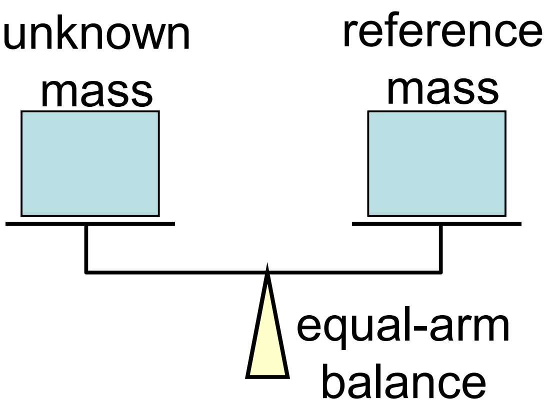
The greater the mass of an object, the less that object accelerates under the action of an applied force.

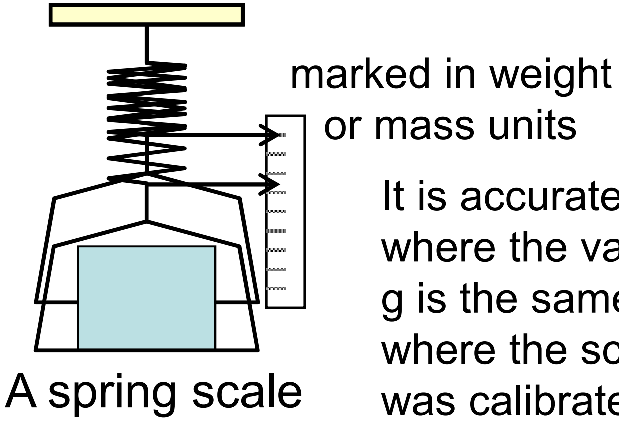
6-3 Mass
Weight

The weight W of an object is equal to the magnitude F_g of the gravitational force on the object.

$$W = m\,g$$

Weight of an object (W); Its mass (m); Free fall acceleration (g)





It is accurate only where the value of g is the same as where the scale was calibrated.

Weight and mass are different quantities.

On Earth

mass = 0.30 kg

$g = 9.8\ m/s^2$

weight = $(0.30\ kg)(9.8\ m/s^2) = 2.9\ N$

On the Moon

mass = 0.30 kg

$g = 1.6\ m/s^2$

weight = $(0.30\ kg)(1.6\ m/s^2) = 0.49\ N$

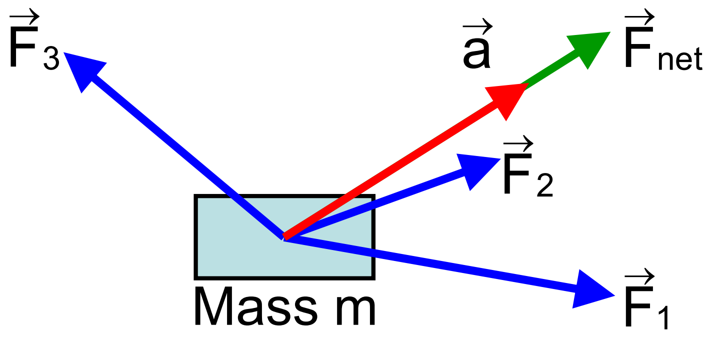
Mass is a property of an object.
It does not change with location.

The SI unit for weight is Newton.
The SI unit for mass is kg

6-4 Newton's Second Law
Force, mass, and acceleration

Newton's second law: The net force on an object is equal to the product of the object's mass and its acceleration.

$$\vec{F}_{net} = m\,\vec{a}$$

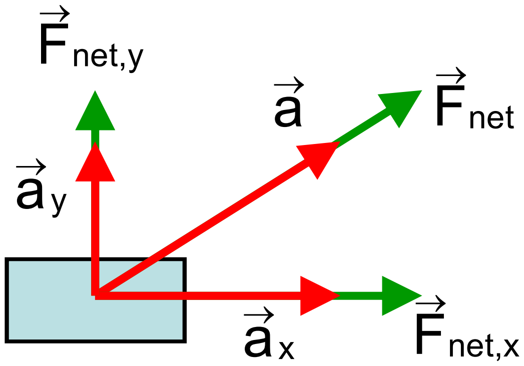


The vector sum of all forces that act on the object.

6-4 Newton's Second Law
By components

Newton's second law: The net force on an object is equal to the product of the object's mass and its acceleration.

$$\vec{F}_{net} = m\,\vec{a} \quad \Rightarrow \quad \begin{cases} F_{net,x} = m\,a_x \\ F_{net,y} = m\,a_y \\ F_{net,z} = m\,a_z \end{cases}$$



The acceleration component along a given axis is caused only by the sum of the force components along that same axis.

6-4 Newton's Second Law
Units in Newton's second law

Newton's second law: The net force on an object is equal to the product of the object's mass and its acceleration.

$$\vec{F}_{net} = m\,\vec{a}$$

System	Length	Mass	Acceleration	Force	
SI (MKS)	meter (m)	kilogram (kg)	m/s^2	Newton (N)	1N = 1 kg m/s^2
CGS	centimeter (cm)	gram (g)	cm/s^2	dyne	1 dyne = 1 g.cm/s^2
British	foot (ft)	slug	ft/s^2	pound (lb)	1 lb = 1 slug. ft/s^2

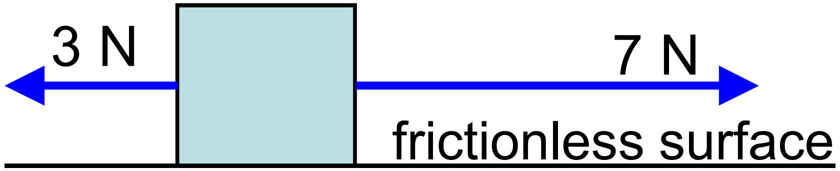
SI system = The international system of units
MKS = meter-kilogram-second system
CGS = centimeter-gram-second system

6-4 Newton's Second Law
Checkpoint 2

What are the magnitude and direction of a third force so that the block is

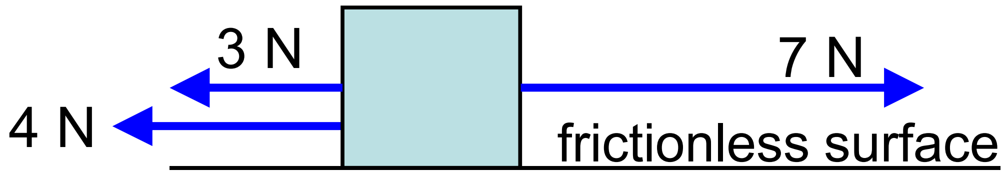
(a) stationary,

(b) moving to the right with constant speed 10 m/s.



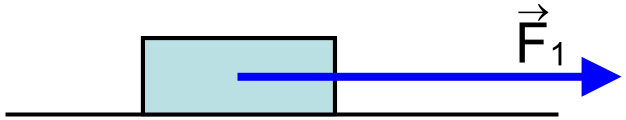
Solution

For both cases the block is not accelerating.
According to Newton's second law, the net force acting on it must be zero.
The third force should have a magnitude of 4 N and directed to the left.



6-4 Newton's Second Law
Example 1

A puck moves in one dimension over a frictionless surface. The puck's mass is m = 0.40 kg. What is the acceleration of the puck, if F_1 = 8.0 N?



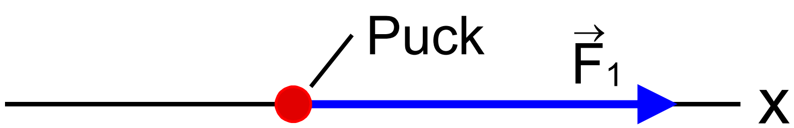
Solution

Newton's second law along the x axis

$$F_{net,x} = m\,a_x$$

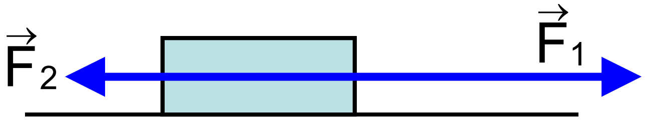
$$F_1 = m\,a_x$$

$$a_x = \frac{F_1}{m} = \frac{8.0\text{ N}}{0.40\text{ kg}} = 20\text{ m/s}^2$$



6-4 Newton's Second Law
Example 2

A puck moves in one dimension over a frictionless surface. The puck's mass is m = 0.40 kg. What is the acceleration of the puck, if F_1 = 8.0 N, and F_2 = 4.0 N?



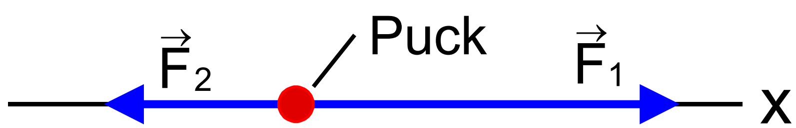
Solution

Newton's second law along the x axis

$$F_{net,x} = m\, a_x$$

$$F_1 - F_2 = m\, a_x$$

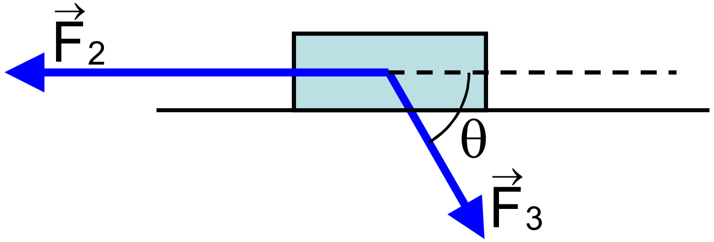
$$a_x = \frac{F_1 - F_2}{m} = \frac{4.0\ \text{N}}{0.40\ \text{kg}} = 10\ \text{m/s}^2$$



6-4 Newton's Second Law

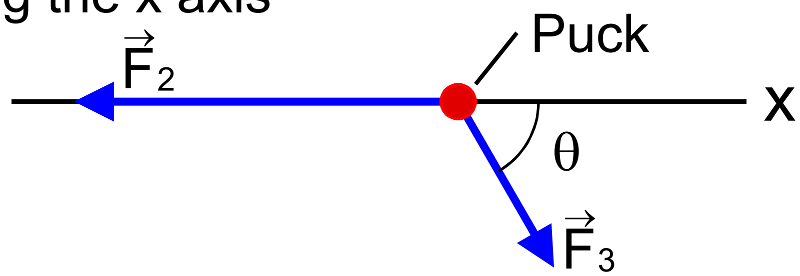
Example 3

A puck moves in one dimension over a frictionless surface. The puck's mass is m = 0.40 kg. What is the acceleration of the puck, if F_2 = 4.0 N, F_3 = 2.0 N, and $\theta = 60^0$?



Solution

Newton's second law along the x axis



$$F_{net,x} = m\,a_x$$

$$F_{3,x} - F_2 = m\,a_x$$

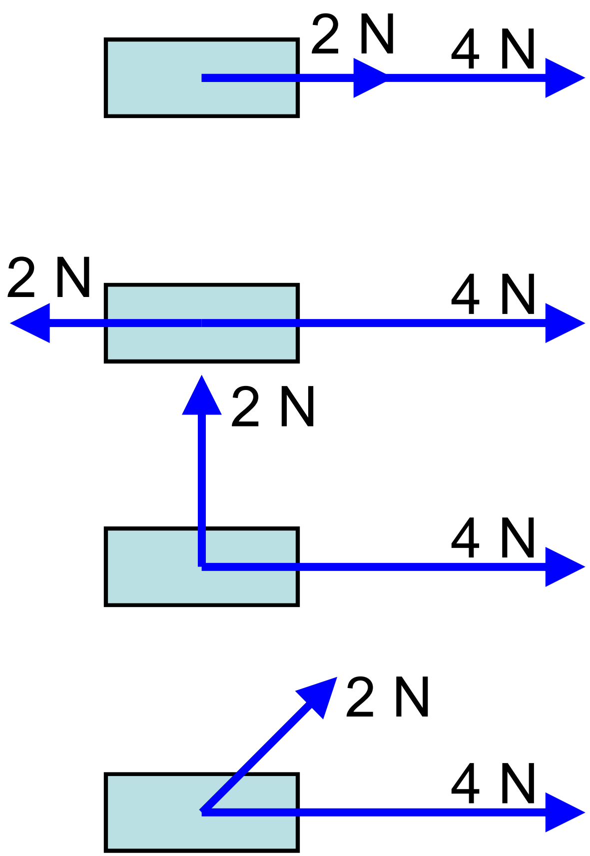
$$F_3 \cos\theta - F_2 = m\,a_x$$

$$a_x = \frac{F_3 \cos\theta - F_2}{m} = \frac{(2.0\text{ N})\cos 60^\circ - 4.0\text{N}}{0.40\text{ kg}} = -7.5\text{ m/s}^2$$

The net force accelerates the puck in the negative direction.

6-4 Newton's Second Law
Checkpoint 3

The figure shows overhead views of four situations for the same block. Rank the situations according the magnitudes of
(a) the net force on the block
(b) the acceleration of the block,
greatest first.



Solution

1

4

3

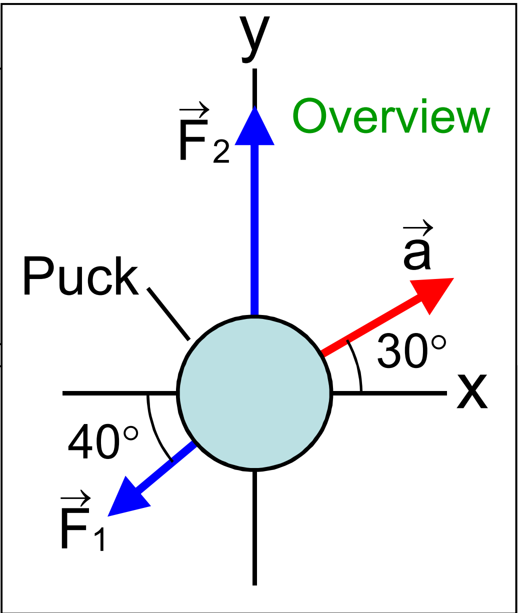
2

$$\vec{F}_{net} = m\,\vec{a}$$

The ranking of the magnitudes of the net force and acceleration are the same.

6-4 Newton's Second Law
Example 4

Three forces accelerates a 0.2 kg puck at 4.0 m/s^2 over a frictionless surface. F_1 = 10 N, and F_2 = 15 N. What is the third force in unit-vector notation and magnitude-angle notation ?



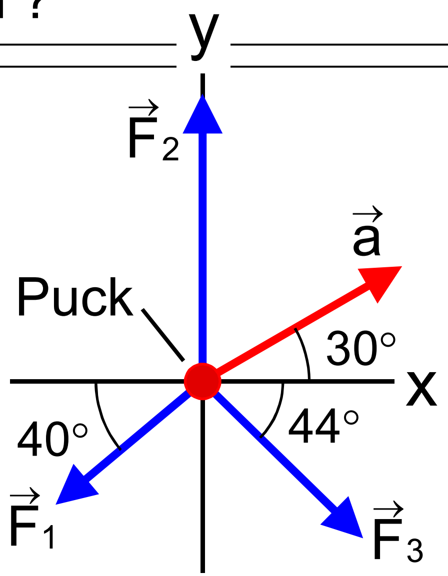
Solution

Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = m\,\vec{a}$$

$$\vec{F}_3 = m\,\vec{a} - \vec{F}_1 - \vec{F}_2$$



Along the x axis

$$F_{3,x} = m\,a_x - F_{1,x} - F_{2,x}$$
$$= m\,a\cos 30^\circ - F_1\cos 220^\circ - F_2\cos 90^\circ$$
$$= 8.4\text{ N}$$

Along the y axis

$$F_{3,y} = m\,a_y - F_{1,y} - F_{2,y}$$
$$= m\,a\sin 30^\circ - F_1\sin 220^\circ - F_2\sin 90^\circ$$
$$= -8.2\text{ N}$$

$$\vec{F}_3 = F_{3,x}\,\hat{i} + F_{3,y}\,\hat{j}$$

$$\vec{F}_3 = (8.4\text{ N})\hat{i} - (8.2\text{N})\hat{j}$$

$$F_3 = \sqrt{F_{3,x}^2 + F_{3,y}^2} = 12\text{ N}$$

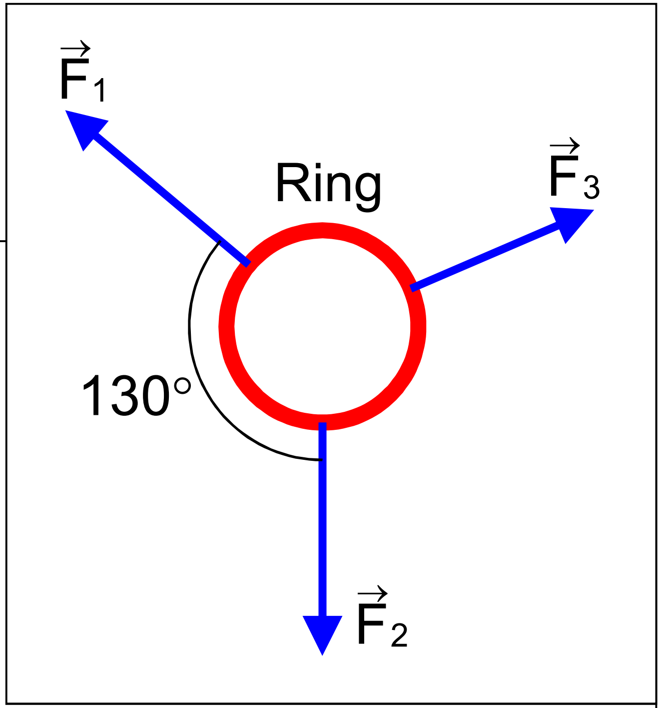
The angle from the positive direction of the x axis

$$\theta = \tan^{-1}\frac{F_{3,y}}{F_{3,x}} = -44^\circ$$

6-4 Newton's Second Law

Example 5

Three forces are exerted on a ring. The ring remains stationary. F_1 = 180 N, and F_3 = 150 N. What is the magnitude of the third force?



Solution

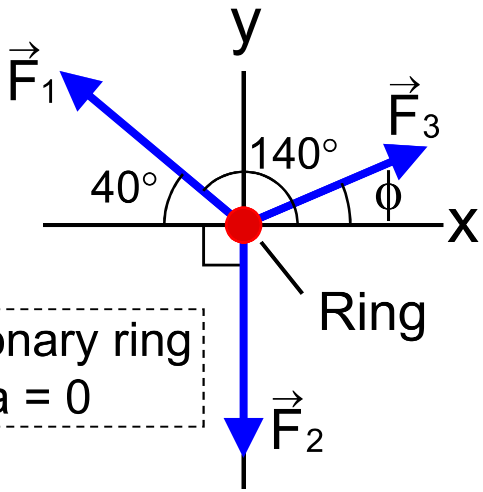
Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$$

Stationary ring
$a = 0$

$$\vec{F}_2 = -\vec{F}_1 - \vec{F}_3$$



Along the x axis

$$F_{2,x} = -F_{1,x} - F_{3,x}$$

$$F_2\cos(-90°) = -F_1\cos(140°) - F_3\cos\phi$$

$$0 = -(180\text{ N})\cos(140°) - (150\text{ N})\cos\phi$$

$$\phi = \cos^{-1}\left(\frac{-(180\text{ N})\cos(140°)}{150\text{ N}}\right)$$

$$= 23°$$

Along the y axis

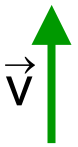
$$F_{2,y} = -F_{1,y} - F_{3,y}$$

$$F_2\sin(-90°) = -F_1\sin(140°) - F_3\sin\phi$$

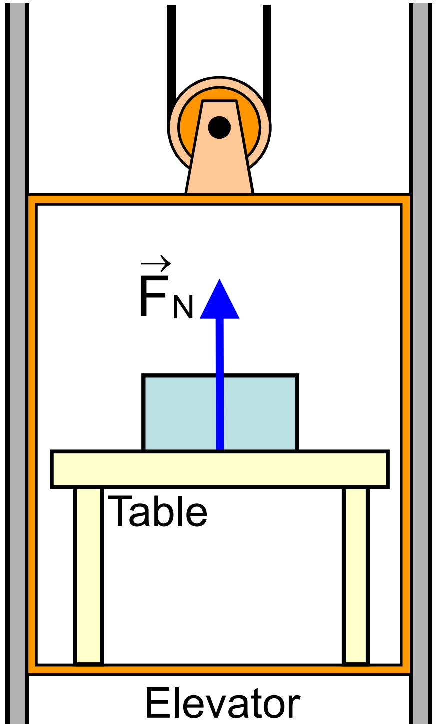
$$-F_2 = -(180\text{ N})\sin(140°) - (150\text{ N})\sin\phi$$

$$F_2 = 175\text{ N}$$

6-4 Newton's Second Law
Checkpoint 4



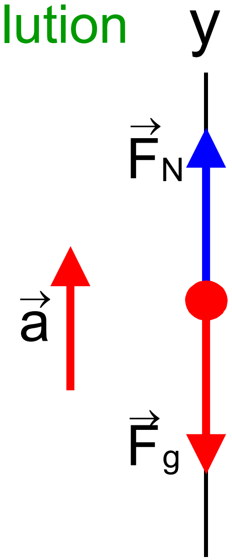
Elevator cab moving upward



Is the magnitude of the normal force $\vec{F}_N$ greater than, less than, or equal to m g if the elevator moving upward
(a) at a constant speed and

(b) at increasing speed?

Solution



Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{F}_N + \vec{F}_g = m\,\vec{a}$$

<u>Along the y axis</u>

$$F_N - F_g = m\,a$$

$$F_N = m\,a + F_g$$

$$F_N = m\,a + m\,g$$

For constant speed,
$a = 0$ and $F_N = m\,g$

For upward increasing speed,
$a > 0$ and $F_N > mg$

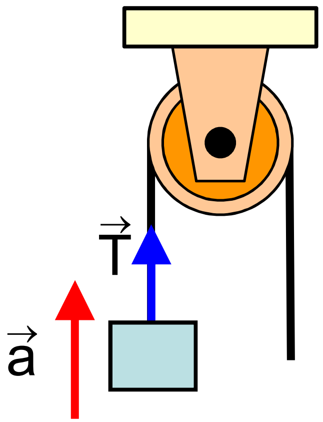
6-4 Newton's Second Law
Checkpoint 5

If the suspended object weighs 50 N. Is T equal to, greater than, or less than 50 N when the object is moving upward

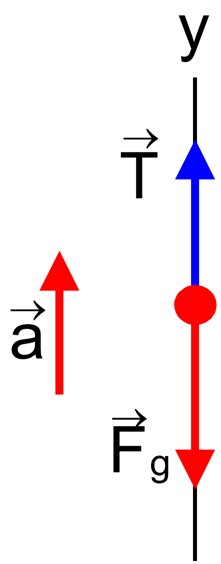
(a) at constant speed,

(b) increasing speed, and

(c) at decreasing speed



Solution



Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{T} + \vec{F}_g = m\,\vec{a}$$

Along the y axis

$$T - F_g = m\,a$$

$$T = m\,a + F_g$$

W

For constant speed,
$a = 0$ and $T = 50$ N.

For upward increasing speed,
$a > 0$ and $T > 50$ N.

For upward decreasing speed,
$a < 0$ and $T < 50$ N.

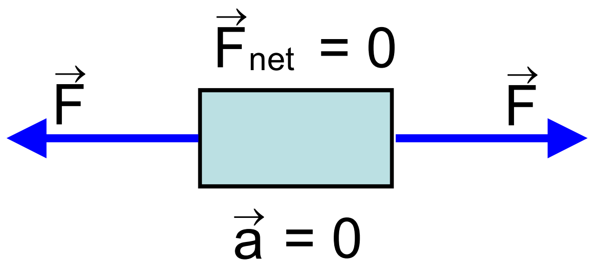
6-5 Newton's First Law
Special case of Newton's Second Law

Newton's first law: If no net force acts on an object ($F_{net} = 0$), the object cannot accelerate, that is, the object's velocity cannot change.

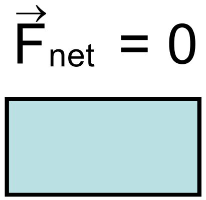
Newton's first law is a special case of Newton's second law.

$$\vec{F}_{net} = m\,\vec{a}$$

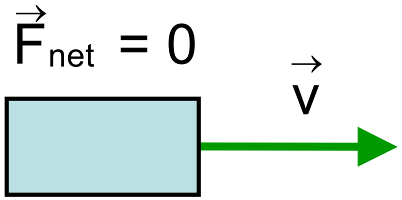
$$\vec{F}_{net} = 0 \;\rightarrow\; \vec{a} = 0.$$



There may be multiple forces on an object, but if their net force is zero, the object cannot accelerate.



If the object at rest, it stays at rest.

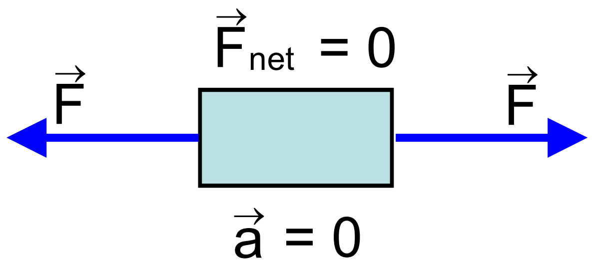


If the object is moving, it continues to move with the same velocity (same magnitude and same direction).

6-5 Newton's First Law
Equilibrium

$$\vec{F}_{net} = 0 \rightarrow \vec{a} = 0.$$

Newton's first law: If no net force acts on an object ($F_{net} = 0$), the object cannot accelerate, that is, the object's velocity cannot change.

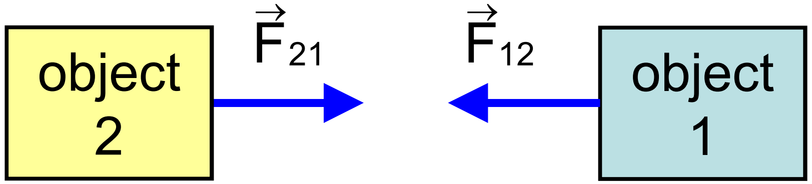


When the sum of the forces on an object is zero, we say that the object is in equilibrium,
or
the forces on the object balance one another,
or
the forces on the object cancel one another.

6-6 Newton's Third Law
Third-law force pair

Two objects interact when they exert forces on each other.

Newton's third law: When two objects interact, the forces on the objects from each other are always equal in magnitude and opposite in direction.



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

$$F_{21} = F_{12}$$

Notation

$\vec{F}_{12}$

on from

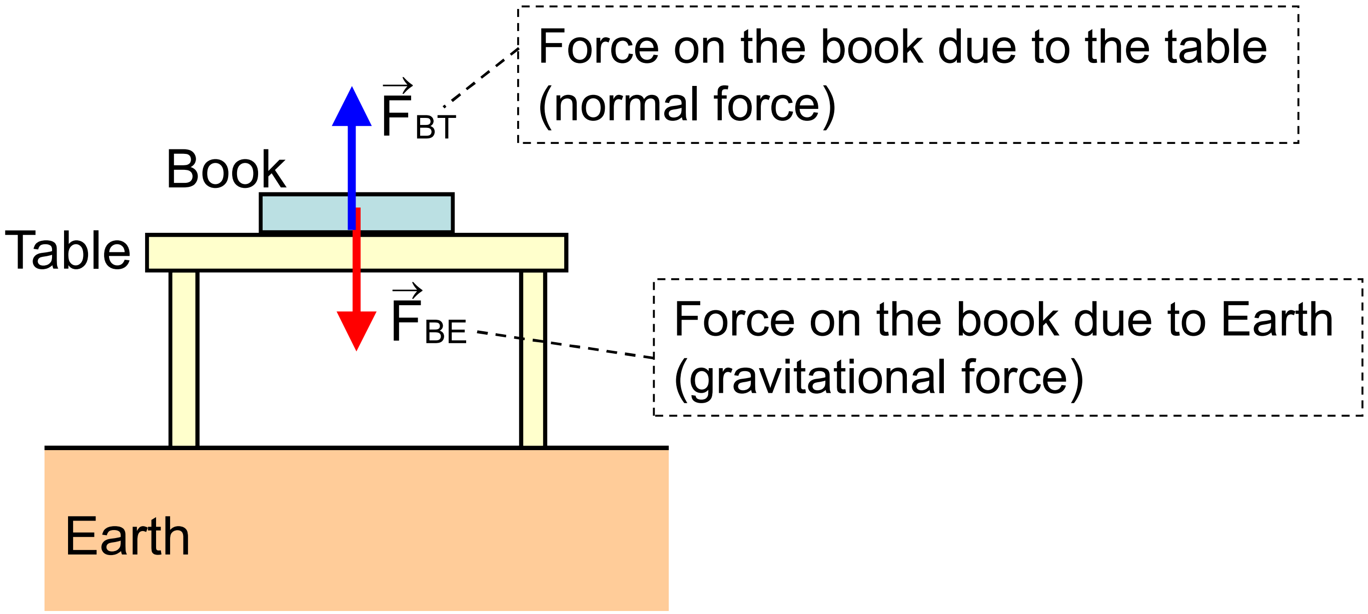
The force on object 1 from object 2

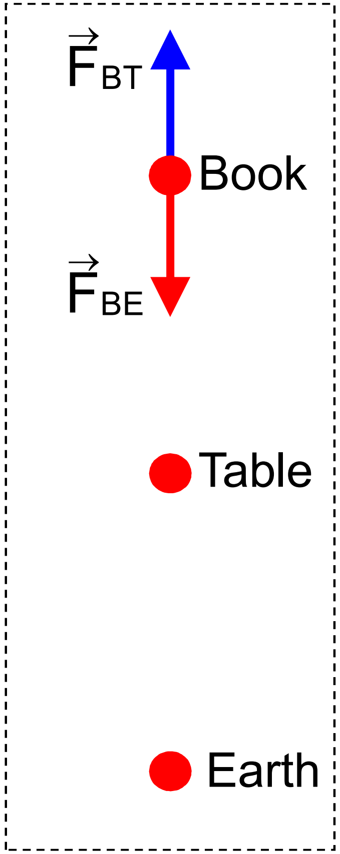
If object 2 exerts a force on object 1,
then object 1 exerts an equal and opposite force on object 2.
Forces occur in pairs.
A single force cannot exist.

The two forces between two interacting objects are called a **third-law force pair** or **action-reaction pair**.

6-6 Newton's Third Law
Interaction between two objects

Newton's second law applies to a single object, whereas Newton's third law applies to an interaction between two objects.

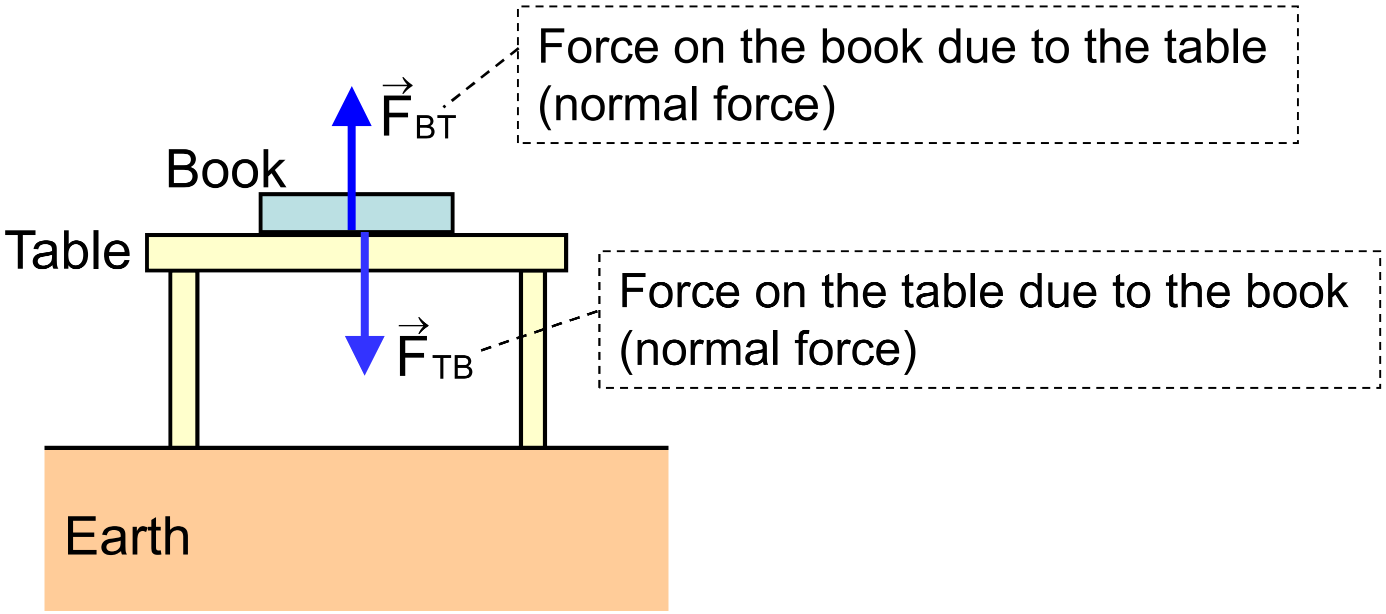


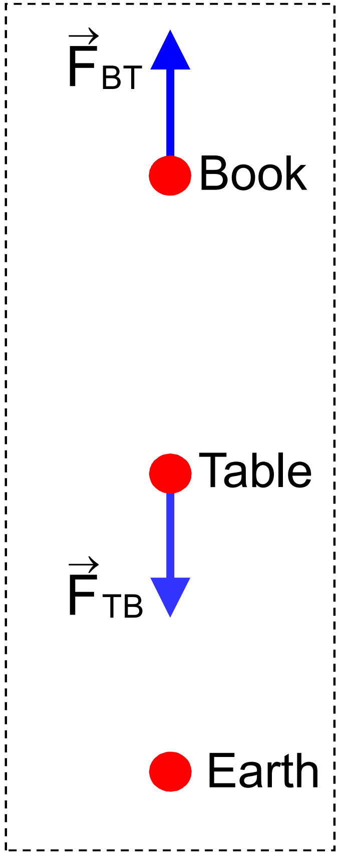


$\vec{F}_{BT}$ and $\vec{F}_{BE}$ are **not** a third-law pair because they are forces on a single object, whereas a third-law pair is two forces between two interacting objects.

6-6 Newton's Third Law
Interaction between two objects

Newton's second law applies to a single object, whereas Newton's third law applies to an interaction between two objects.

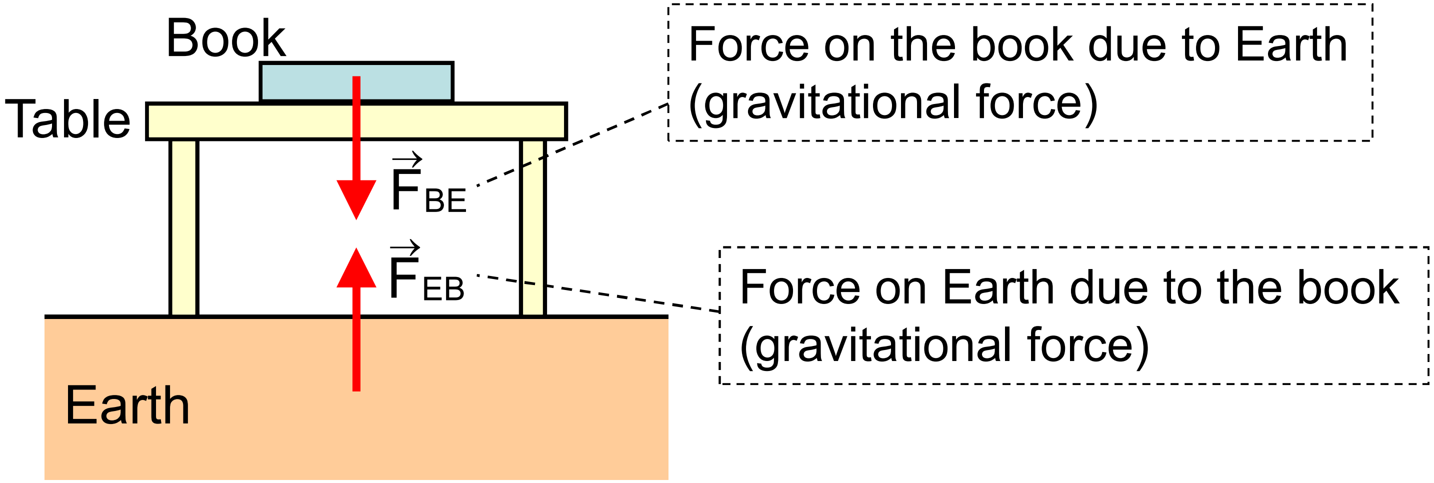


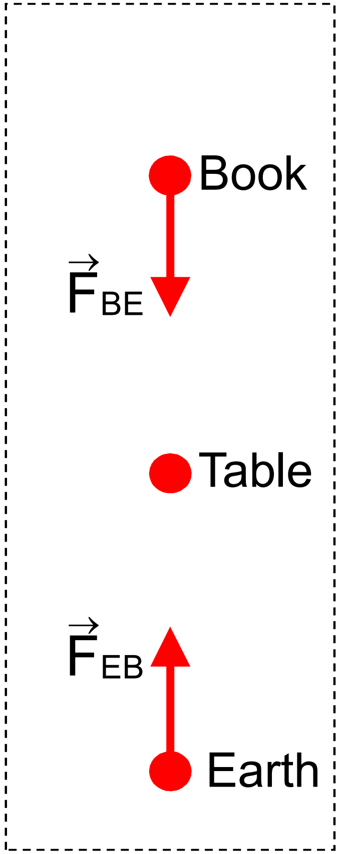


$\vec{F}_{BT}$ and $\vec{F}_{TB}$ are a third-law pair because they are forces on two interacting objects.
The book pushes the table with a force which is equal in magnitude and opposite in direction to the force that the table pushes the book with.

6-6 Newton's Third Law
Interaction between two objects

Newton's second law applies to a single object, whereas Newton's third law applies to an interaction between two objects.

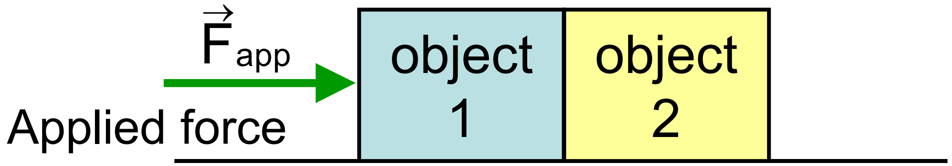




$\vec{F}_{BE}$ and $\vec{F}_{EB}$ are a third-law pair because they are forces on two interacting objects.
Earth pulls the book with a force which is equal in magnitude and opposite in direction to the force that the book pulls Earth with.

6-6 Newton's Third Law
Accelerating objects

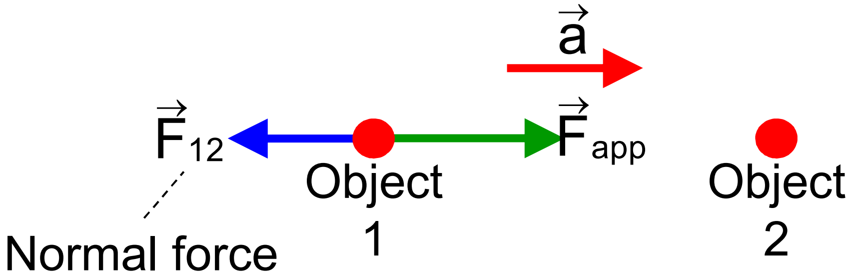
Newton's third law holds for stationary and accelerating objects.



Forces on object 1

Newton's second law

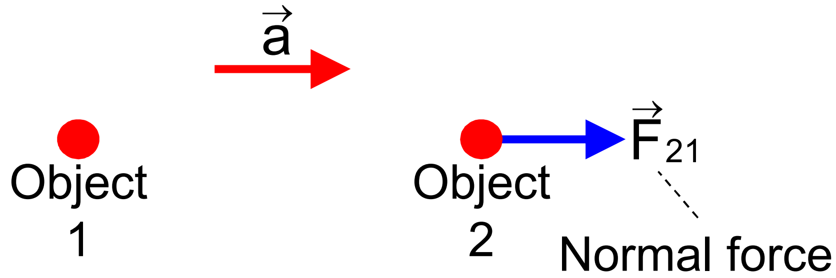
$$\vec{F}_{app} + \vec{F}_{12} = m_1 \vec{a}$$



Forces on object 2

Newton's second law

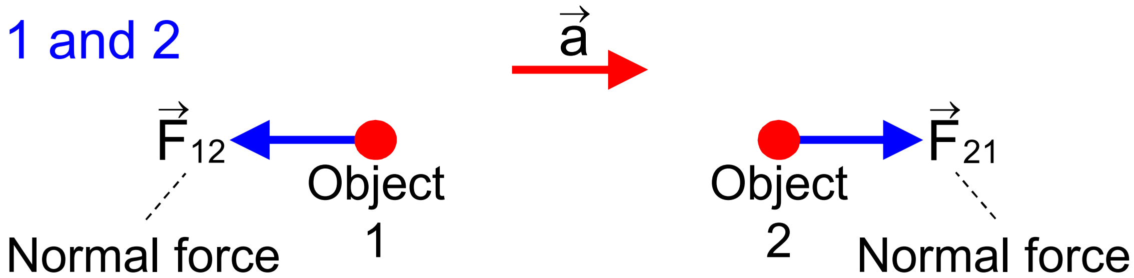
$$\vec{F}_{21} = m_2 \vec{a}$$



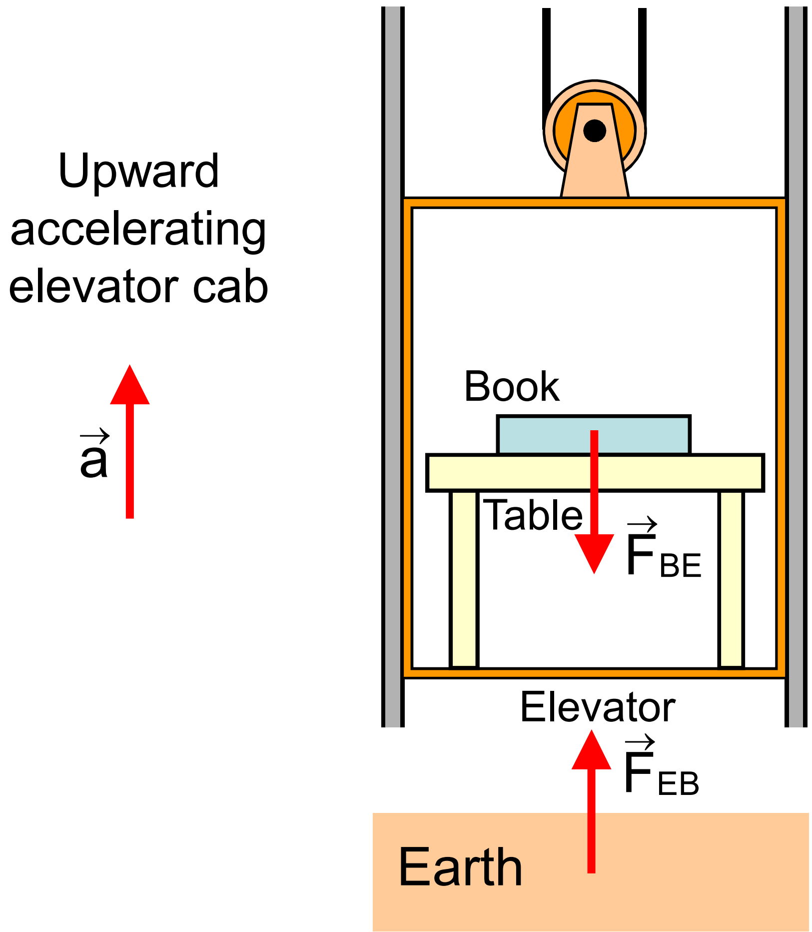
Forces between object 1 and 2

Newton's third law

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



6-6 Newton's Third Law
Checkpoint 6



Does the magnitude of $\vec{F}_{BE}$ and $\vec{F}_{EB}$ increase, decrease or stay the same?
Are they still equal in magnitude and opposite in direction?

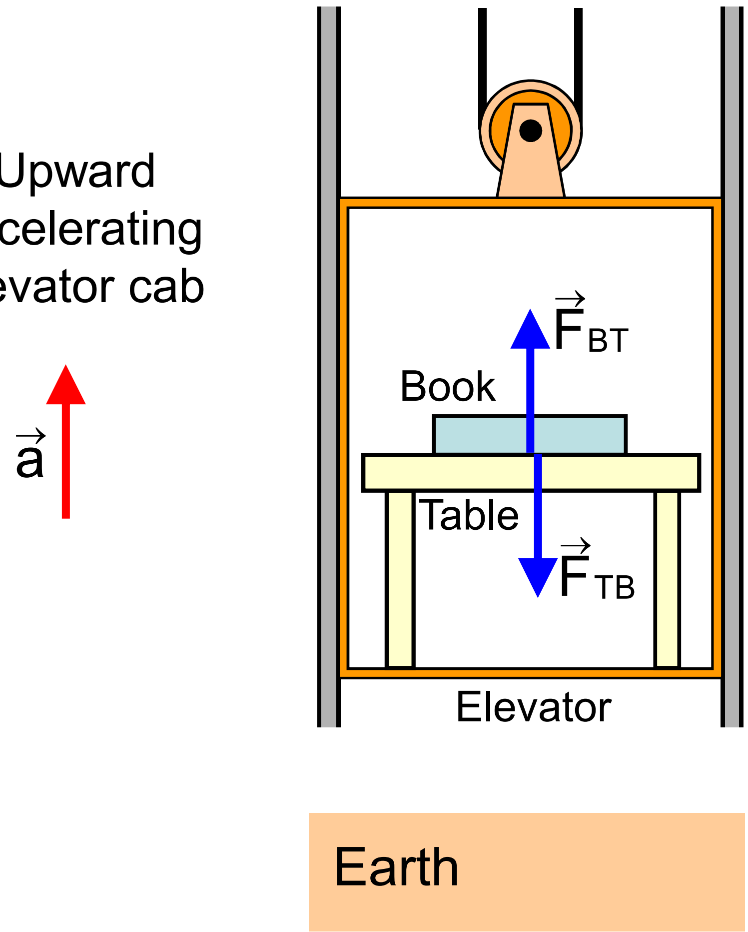
Solution

The magnitude of the gravitational force $\vec{F}_{BE}$ is equal to m g and it depends only on the mass of the book m and the free fall acceleration $g = 9.8 \text{ m/s}^2$. So its magnitude does not change

According to Newton's third law, the two forces are still equal in magnitude and opposite in direction.

6-6 Newton's Third Law
Checkpoint 7

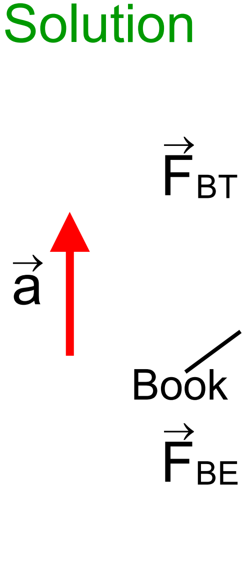
Upward accelerating elevator cab



Does the magnitude of $\vec{F}_{BT}$ and $\vec{F}_{TB}$ increase, decrease or stay the same?

Are they still equal in magnitude and opposite in direction?

Solution



Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{F}_{BT} + \vec{F}_{BE} = m\,\vec{a}$$

Along the y axis

$$F_{BT} - F_{BE} = m\,a$$

$$F_{BT} = F_{BE} + m\,a$$

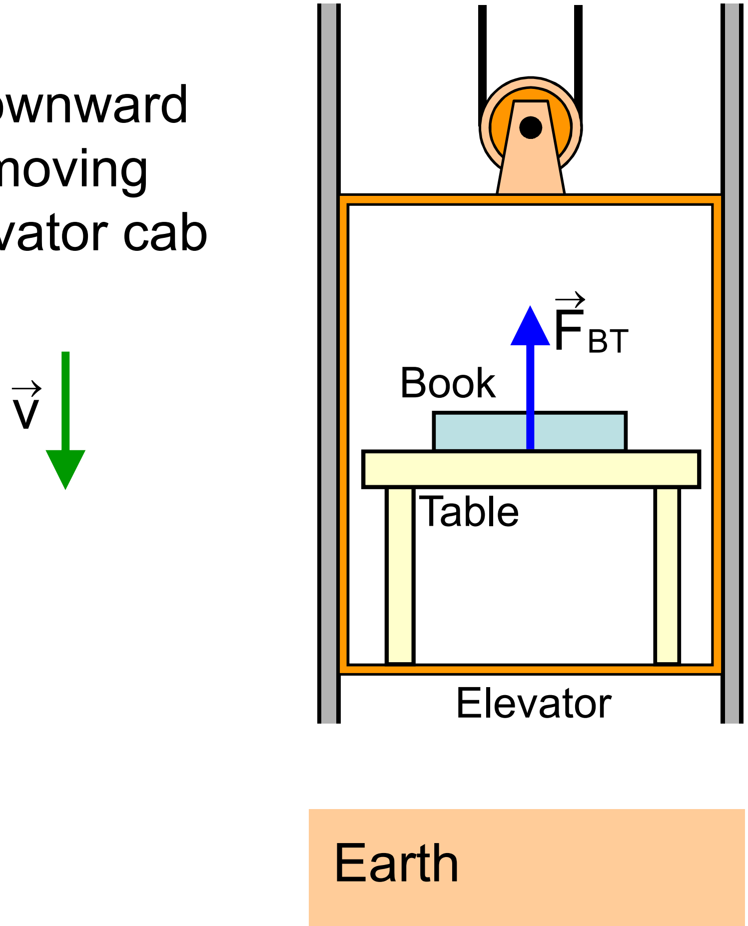
$$F_{BT} = m\,g + m\,a$$

Since $a > 0$, the magnitude of $\vec{F}_{BT}$ increases.

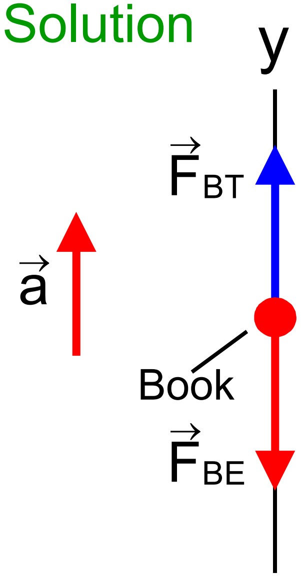
According to Newton's third law, $\vec{F}_{BT}$ and $\vec{F}_{TB}$ are still equal in magnitude and opposite in direction.

6-6 Newton's Third Law
Checkpoint 8

Downward moving elevator cab



Solution



Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{F}_{BT} + \vec{F}_{BE} = m\,\vec{a}$$

Along the y axis

$$F_{BT} - F_{BE} = m\,a$$

$$F_{BT} = F_{BE} + m\,a$$

$$F_{BT} = m\,g + m\,a$$

(a) For constant speed, $a = 0$. So

$$F_{BT} = m\,g$$

(b) For increasing speed downward, $a < 0$.

$$F_{BT} < m\,g$$

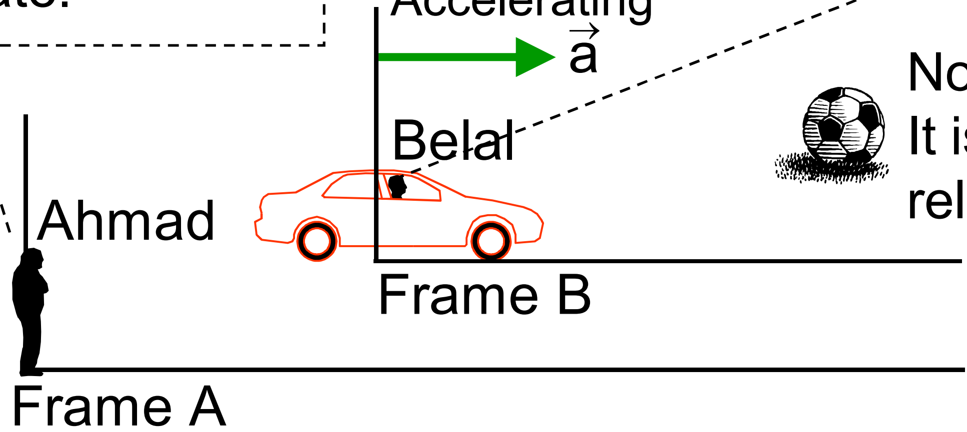
Is the magnitude of the normal force $\vec{F}_{BT}$, greater than, less than, or equal to mg if the elevator moving downward
(a) at constant speed, and
(b) at increasing speed?

6-7 Applying Newton's Laws
Inertial reference frames

Newton's laws are not true in any reference frame.
They are valid only in a reference frame that is **not accelerating**.
A reference frame in which Newton's laws hold is called an **inertial reference frame**.

Frame A is not accelerating.
Ahmad can apply Newton's first law.
Since there is no net force exerted on the ball, the ball cannot accelerate.

Frame B is accelerating.
Belal cannot apply Newton's first law.
He sees the ball accelerating toward left even when there is no net force exerted on the ball.



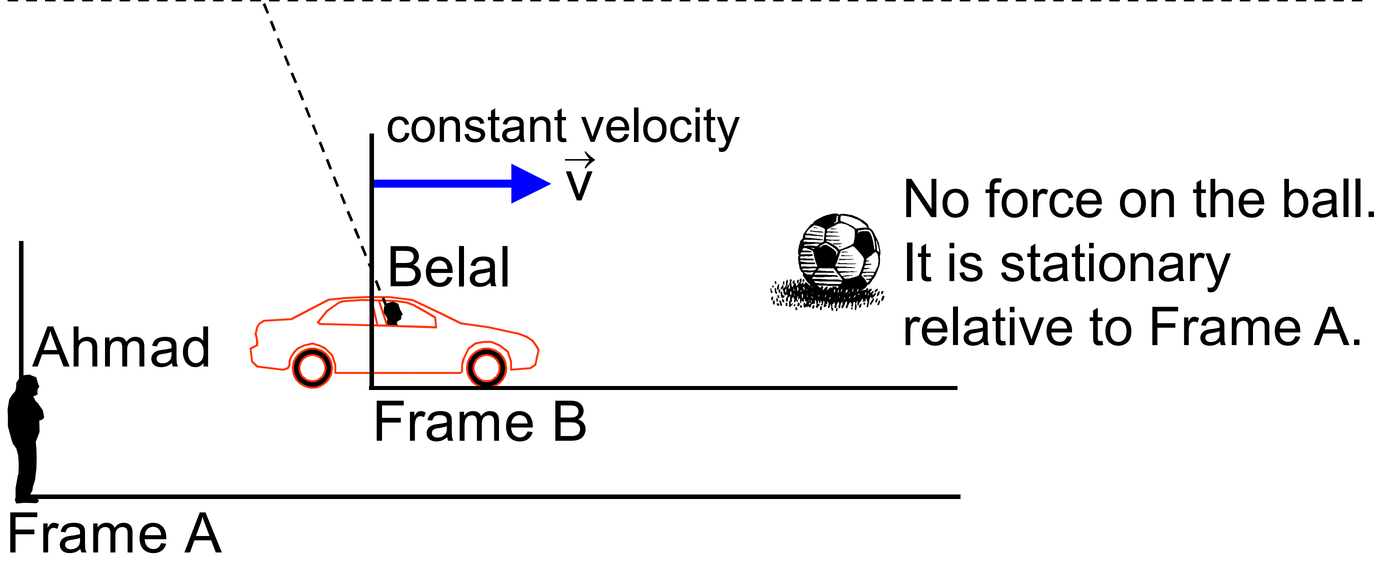
No force on the ball.
It is stationary relative to Frame A.

6-7 Applying Newton's Laws
Checkpoint 9

If frame A is an inertial reference frame and frame B is moving at constant velocity with respect to frame A. Is frame B an inertial reference frame?

Solution

Since frame B is not accelerating, it is an inertial frame.
Belal can apply Newton's first law.
He sees the ball moving at constant velocity toward left.
There is no net force on the ball and the ball's acceleration is zero.



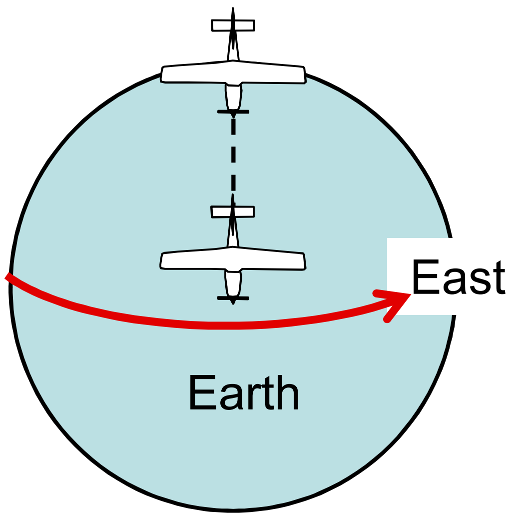
6-7 Applying Newton's Laws

Ground as an inertial reference frame

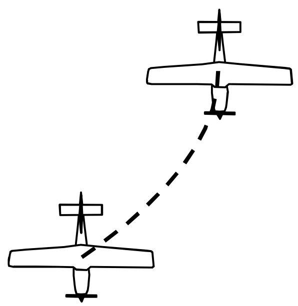
The ground can be used as an inertial frame provided we can ignore Earth's astronomical motions.

Earth's rotation cannot be ignored for an object moving very long distances.

From a stationary frame in space.



From the ground



The deflection is not caused by a force, but caused by using a noninertial frame

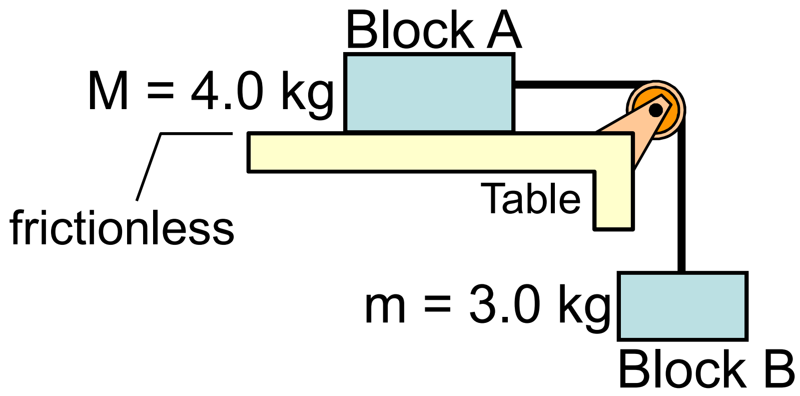
An object on the ground experiences an acceleration up to 0.03 m/s^2 directed toward the center of Earth because of the rotation of Earth around its axis and an acceleration of about 0.004 m/s^2 directed toward the Sun because of the rotation of Earth around the Sun. These accelerations often can be ignored compared with $g = 9.8\ m/s^2$.

In this course, we will assume that the ground is an inertial frame.

6-7 Applying Newton's Laws

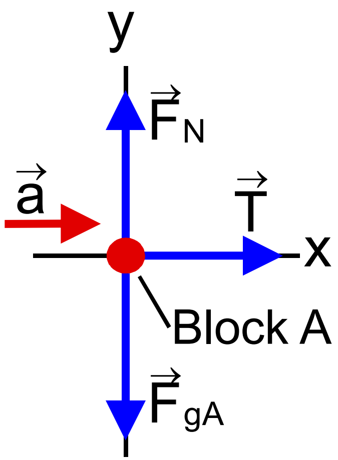
Example 6

What is the acceleration of block A and block B? What is the tension in the cord? Assume that the cord and the pulley are massless, and the cord is unstretchable.



Solution

Since the cord is unstretchable, both blocks have the same acceleration.



2nd law for block A

$$\vec{F}_{net} = M\,\vec{a}$$

Along the x axis

$$T = M\,a$$

Along the y axis

$$F_N - F_{gA} = 0$$

Block A does not accelerate vertically

2nd law for block B

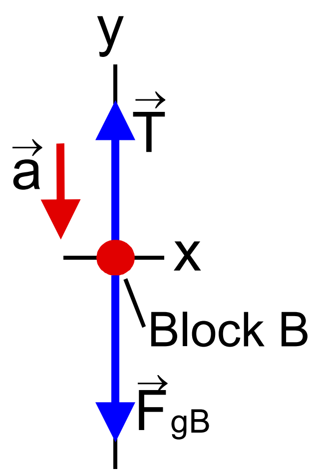
$$\vec{F}_{net} = m\,\vec{a}$$

Along the y axis

$$T - F_{gB} = -m\,a$$

$$T - m\,g = -m\,a$$

$$M\,a - m\,g = -m\,a$$



Solve for a

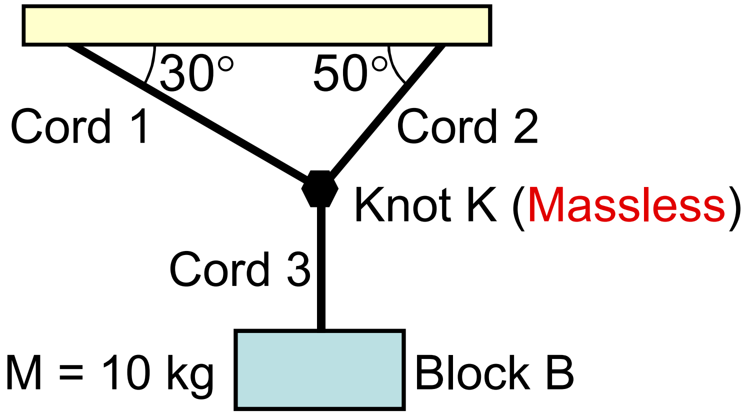
$$a = \frac{m}{M+m}\,g = 4.2\ \mathrm{m/s^2}$$

$$T = M\,\frac{m}{M+m}\,g = 17\ \mathrm{N}$$

6-7 Applying Newton's Laws

Example 7

What are the tensions in the three cords? Assume that the cords and the knot are massless, and the cords are unstretchable.



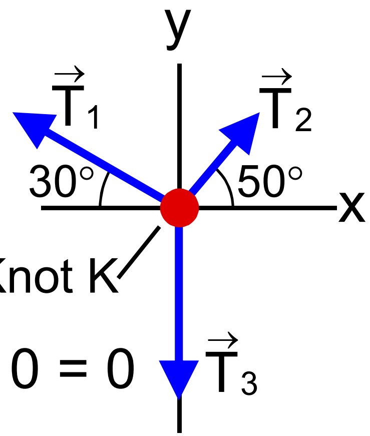
Solution

Since the knot and block are stationary, their acceleration = 0.

2nd law for the knot

$\vec{F}_{net} = m\,\vec{a} = 0$

$\vec{T}_1 + \vec{T}_2 + \vec{T}_3 = 0$



Along the x axis

$-T_1 \cos 30° + T_2 \cos 50° + 0 = 0$

$T_1 = 0.742\, T_2$

Along the y axis

$T_1 \sin 30° + T_2 \sin 50° - T_3 = 0$

$(0.742\, T_2) \sin 30° + T_2 \sin 50° - 98\ \text{N} = 0$

$T_2 = 86\ \text{N}$

2nd law for block B

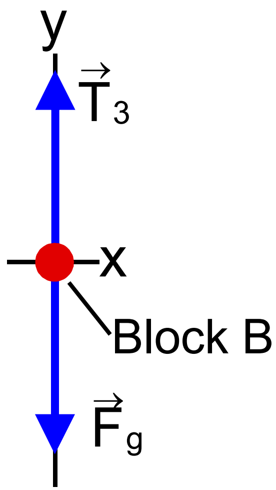
$\vec{F}_{net} = M\,\vec{a} = 0$

Along the y axis

$T_3 - F_g = 0$

$T_3 = F_g = M\,g$

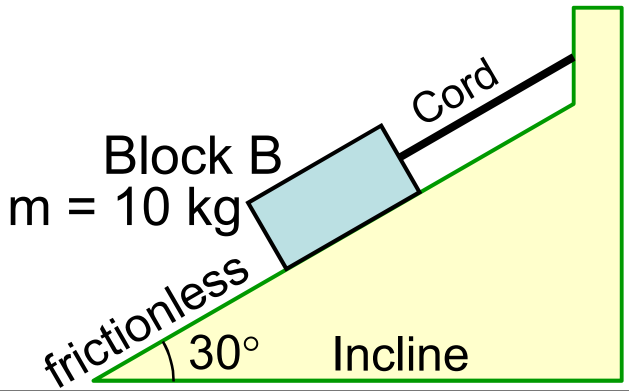
$T_3 = 98\ \text{N}$



$T_1 = 64\ \text{N}$

6-7 Applying Newton's Laws
Example 8

What is the tension in the cord and what is the normal force on the bock? Assume that the cord is massless and unstretchable.



Solution

Newton's second law for the block

$\vec{F}_{net} = m\,\vec{a} = 0$ since the block is at rest

$\vec{F}_g + \vec{F}_N + \vec{T} = 0$

$F_g = m\,g$

$F_{g,x} = -\,F_g \sin\theta = -\,m\,g \sin\theta$

$F_{g,y} = -\,F_g \cos\theta = -\,m\,g \cos\theta$

Along the x axis

$T + F_{g,x} = 0$

$T = -\,F_{g,x} = m\,g \sin\theta$

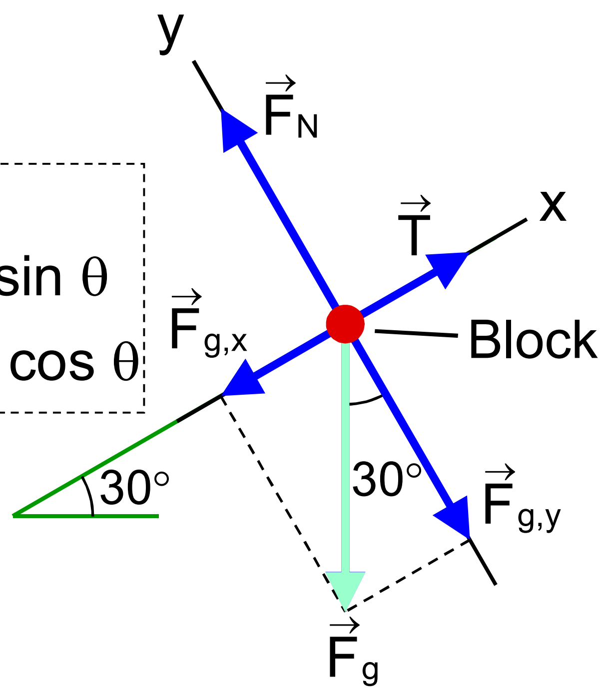
$= (10\text{ kg})(9.8\text{ m/s}^2)\sin 30° = 49\text{ N}$

Along the y axis

$F_N + F_{g,y} = 0$

$F_N = -\,F_{g,y} = m\,g \cos\theta$

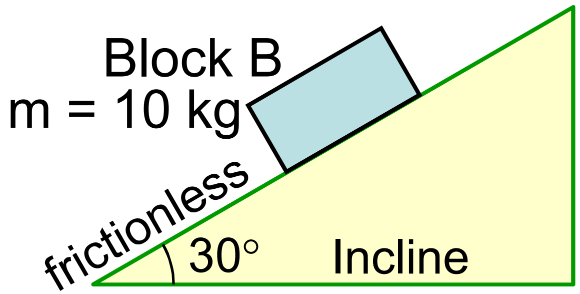
$= (10\text{ kg})(9.8\text{ m/s}^2)\cos 30° = 85\text{ N}$



Replace F_g with its components.

6-7 Applying Newton's Laws
Example 9

What is the acceleration of the bock?



Solution

Newton's second law for the block

$$\vec{F}_{net} = m\,\vec{a}$$

$$\vec{F}_g + \vec{F}_N = m\,\vec{a}$$

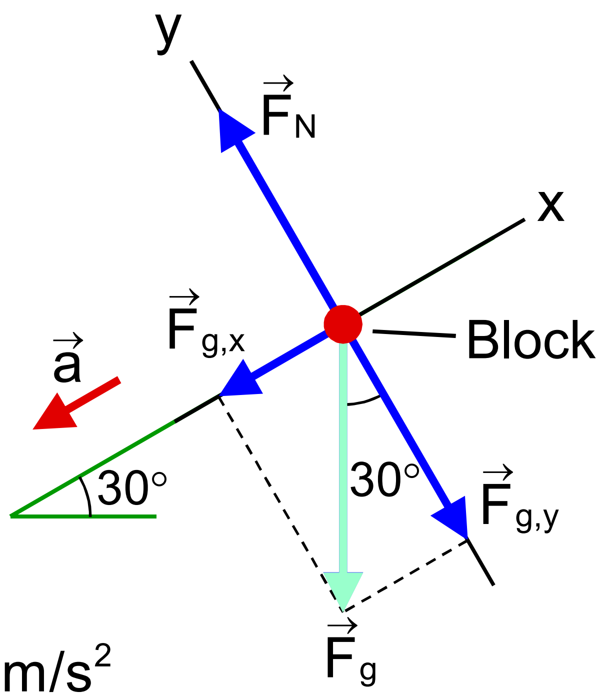
Along the x axis

$$F_{g,x} = m\,a_x$$

$$-\,m\,g\sin\theta = m\,a_x$$

$$a_x = -\,g\sin\theta = -\,(9.8\text{ m/s}^2)\sin 30^\circ = -\,4.9\text{ m/s}^2$$

The acceleration of the object is 4.9 m/s^2 along the direction of the negative x axis

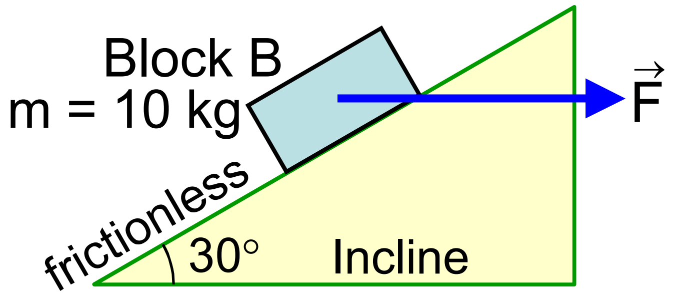


Replace F_g with its components.

6-7 Applying Newton's Laws

Checkpoint 10

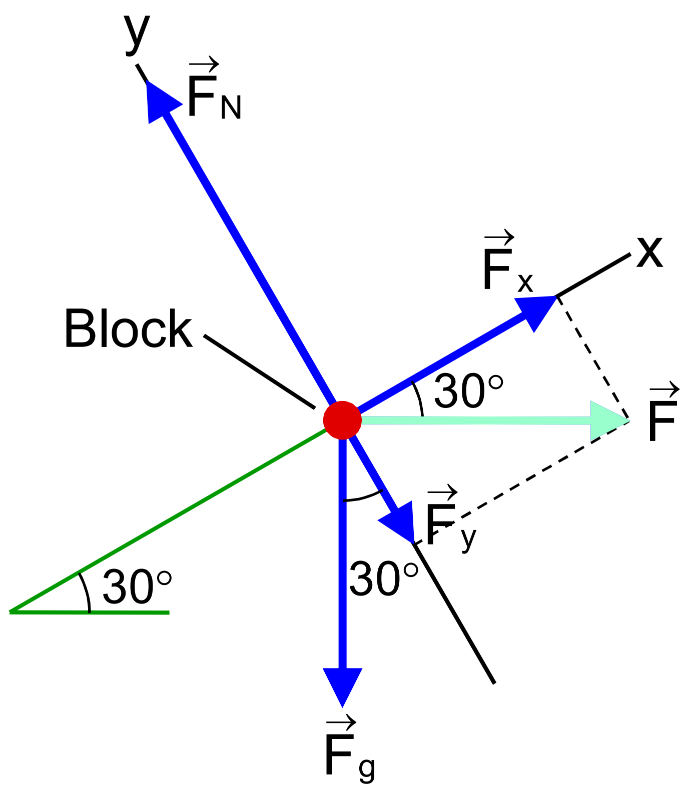
A horizontal force $\vec{F}$ is applied to a block on a ramp.
What is the component of $\vec{F}$ that is perpendicular to the ramp?
Does the presence of $\vec{F}$ increase or decrease the magnitude of the normal force on the block from the ramp?



Solution

The component of $\vec{F}$ that is perpendicular to the ramp is $F_y = - F \sin \theta$

Since its component that is normal to the surface pushes the block toward the surface, the presence of $\vec{F}$ increases the magnitude of the normal force.

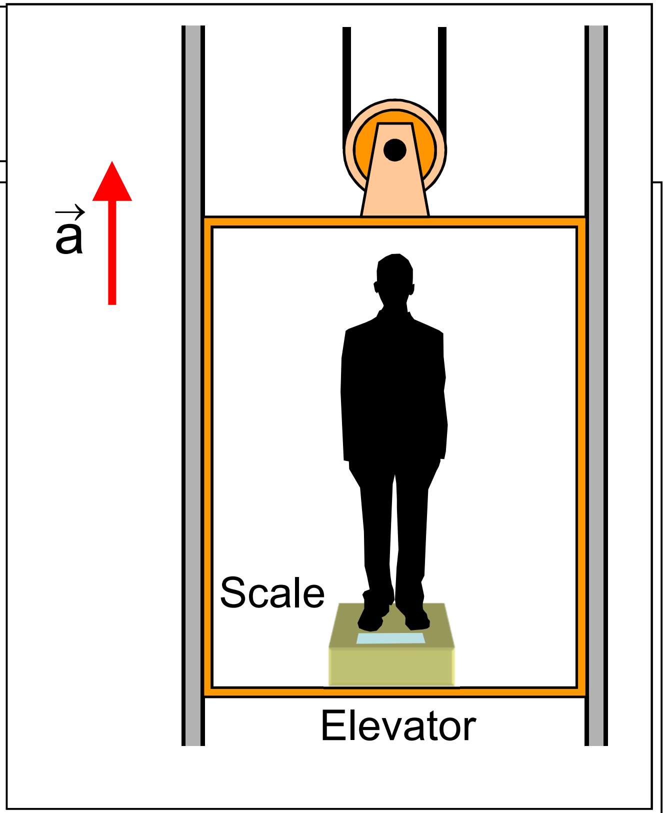


Replace F with its components.

6-7 Applying Newton's Laws

Example 10

What is the reading of the scale in terms of the elevator cab's acceleration?



Solution

The scale reads the magnitude of the force the man exerts on the scale. This force is the normal force on the scale from the man. But according to Newton's third law, the magnitude of this force is equal to the magnitude of the normal force F_N on the man from the scale.

Newton's second law

$$\vec{F}_{net} = m\,\vec{a}$$

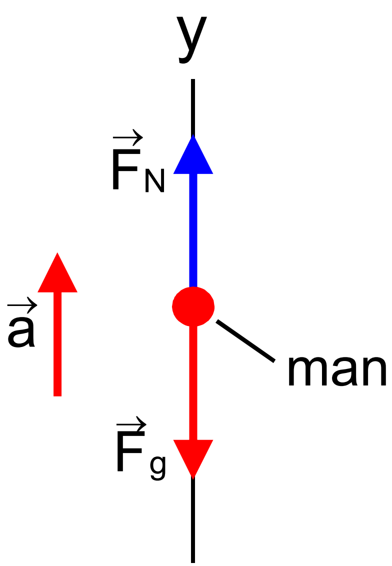
$$\vec{F}_N + \vec{F}_g = m\,\vec{a}$$

<u>Along the y axis</u>

$$F_N - F_g = m\,a$$

$$F_N = m\,a + F_g$$

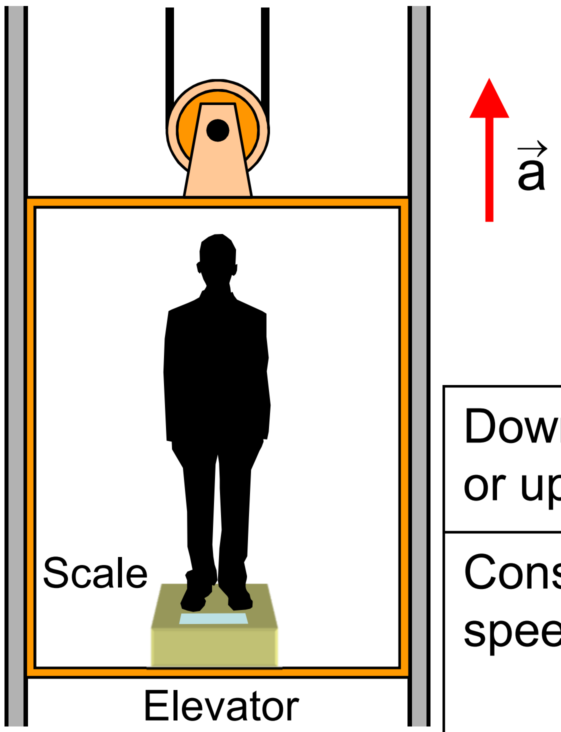
$$F_N = m\,a + m\,g$$



F_N is called the apparent weight while mg is called the actual weight.

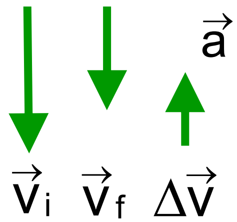
6-7 Applying Newton's Laws
Example 11

$F_N = m(g + a)$



To find the sign of acceleration

Downward motion with decreasing speed

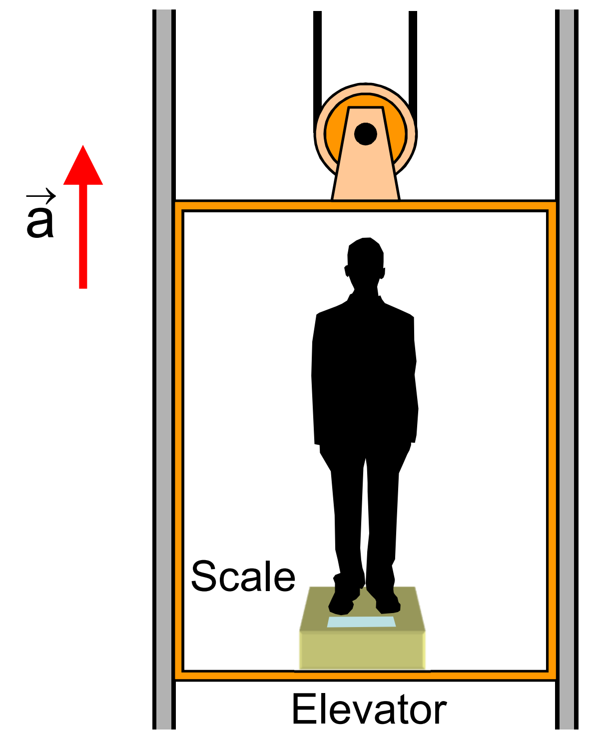


$\vec{a}$ has the same direction as $\Delta\vec{v}$

	Downward or upward	Downward	Downward	Upward	Upward
	Constant speed	Speed increases at a rate of 0.5 m/s^2	Speed decreases at a rate of 0.5 m/s^2	Speed increases at a rate of 0.5 m/s^2	Speed decreases at a rate of 0.5 m/s^2
a	0	- 0.5 m/s^2	+ 0.5 m/s^2	+ 0.5 m/s^2	- 0.5 m/s^2
Apparent weight F_N	$= F_g$	$< F_g$	$> F_g$	$> F_g$	$< F_g$

6-7 Applying Newton's Laws
Checkpoint 11

If the elevator cab accelerates upward, can the man in the cab apply Newton's laws using the cab as a reference frame?



Solution

He cannot apply Newton's law because he is in an accelerating frame. All accelerating frames are not inertial frames. The acceleration of the man relative to the frame of the cab is zero, but the net force on him is $F_N - F_g$ is not zero. So, Newton's second law is not valid from this frame.

$$\vec{F}_{net} \neq m\,\vec{a}$$

In the cab's reference frame.

6-7 Applying Newton's Laws
Checkpoint 12

What does the scale read if the elevator cable breaks so that the cab falls freely?

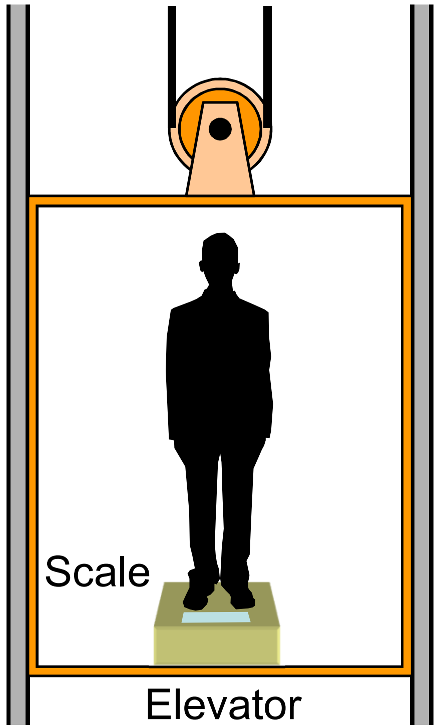
Solution

$F_N = m(g + a)$

Since for free fall, the elevator's acceleration $a = -g$,

$F_N = m(g - g) = 0$

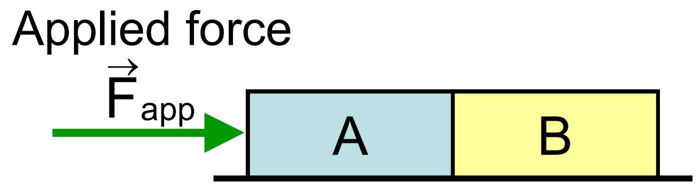
The scale reads zero.



6-7 Applying Newton's Laws

Example 12

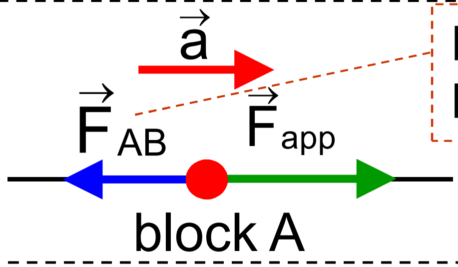
A constant horizontal force of magnitude 10 N is applied to block A of mass m_A = 2.0 kg which pushes against block B of mass m_B = 3.0 kg. What is the acceleration of the blocks?



Solution 1

Newton's second law for block A

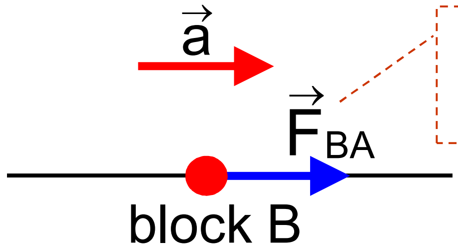
$$F_{app} - F_{AB} = m_A a$$



Normal force on Block A from Block B

Newton's second law for block B

$$F_{BA} = m_B a$$



Normal force on Block B from Block A

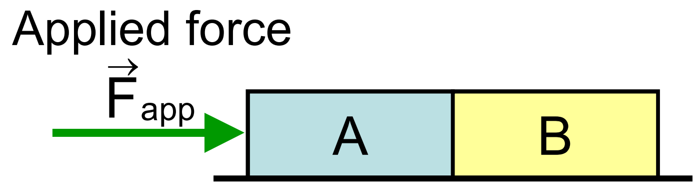
But from Newton's third law

$$F_{AB} = F_{BA}$$

$$F_{app} - m_B a = m_A a \xrightarrow{\text{Solve for a}} a = \frac{F_{app}}{m_A + m_B} = 2.0 \text{ m/s}^2$$

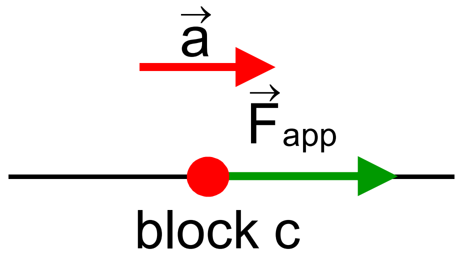
6-7 Applying Newton's Laws
Example 13

A constant horizontal force of magnitude 10 N is applied to block A of mass m_A = 2.0 kg which pushes against block B of mass m_B = 3.0 kg. What is the acceleration of the blocks?



Solution 2

Since the two blocks form a rigidly connected object, we can consider them as one object. We will call it block C which has mass of $m_A + m_B$. The only external force acting on block C is F_{app}



Newton's second law for block C

$$F_{app} = (m_A + m_B)\,a \xrightarrow{\text{Solve for a}} a = \frac{F_{app}}{m_A + m_B} = 2.0\ \text{m/s}^2$$