July 1, Week 5

Today: Finish Chapter 6 and start Chapter 9

Homework Assignment #5 - Due Monday, July 7 at 5:00PM.

No office hours on Friday.

Circular Dynamics

Objects in circular motion must have an inwards acceleration in order to change direction.

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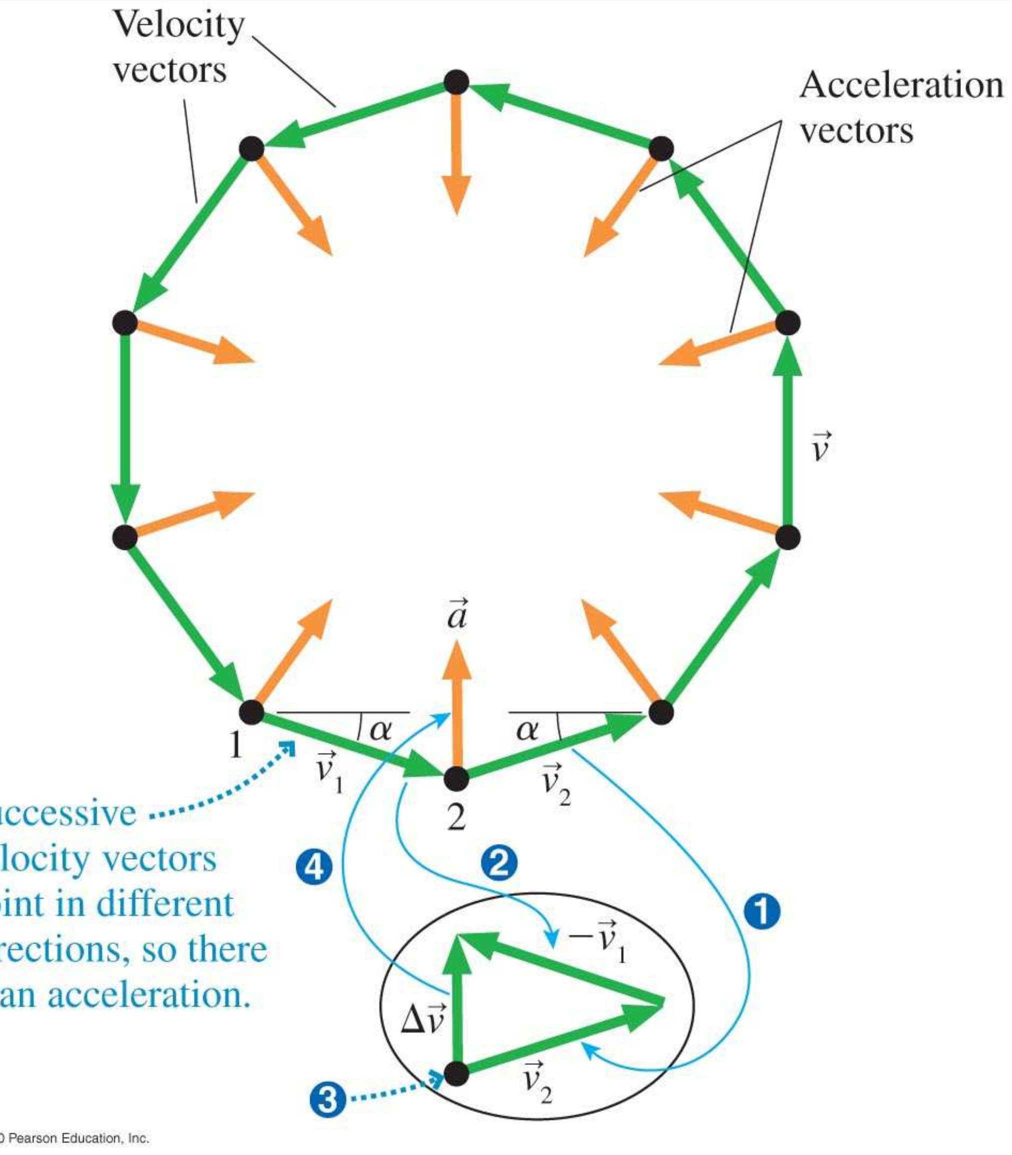

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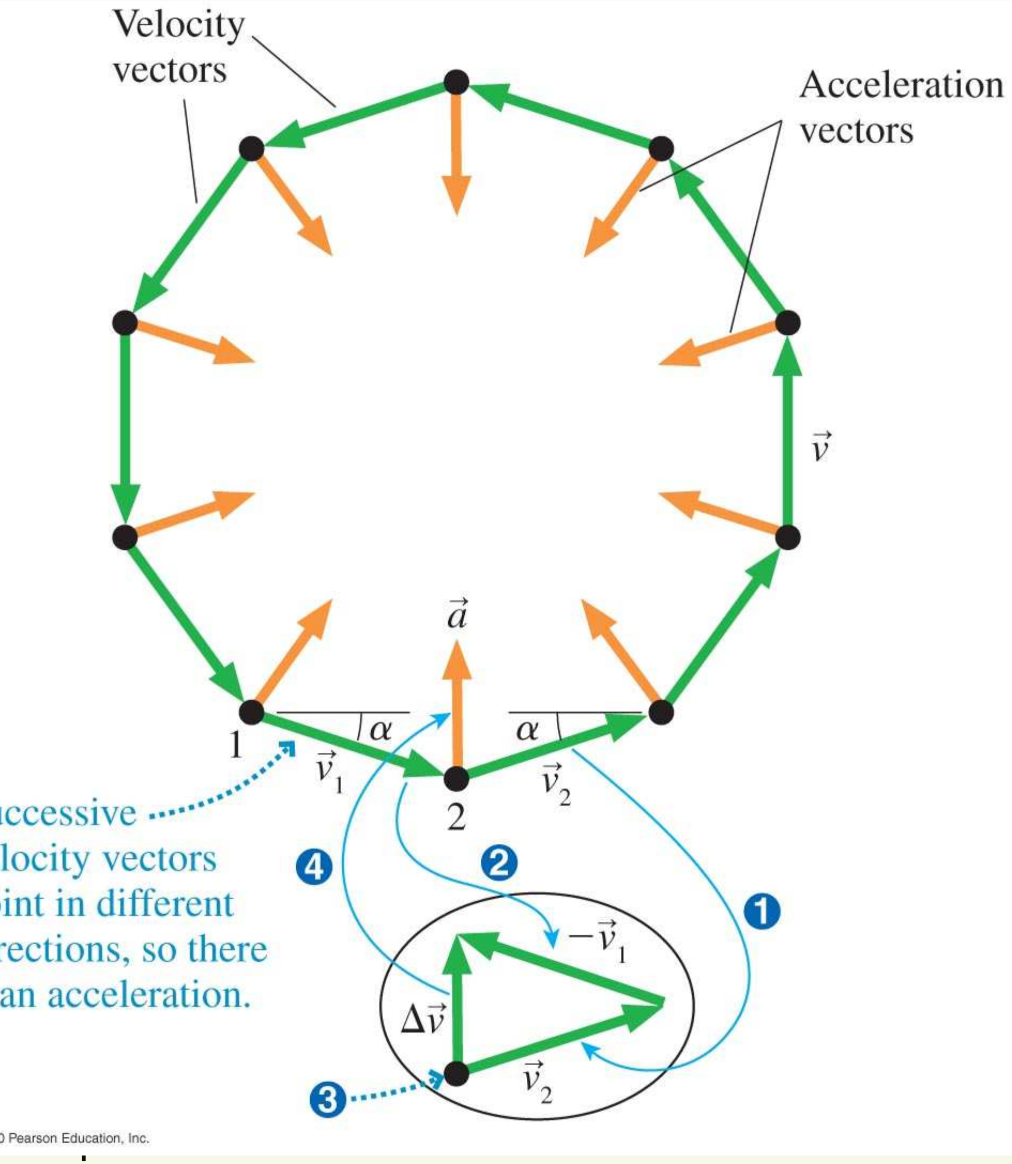

The Centripetal Acceleration - The acceleration towards the center necessary for cicular motion

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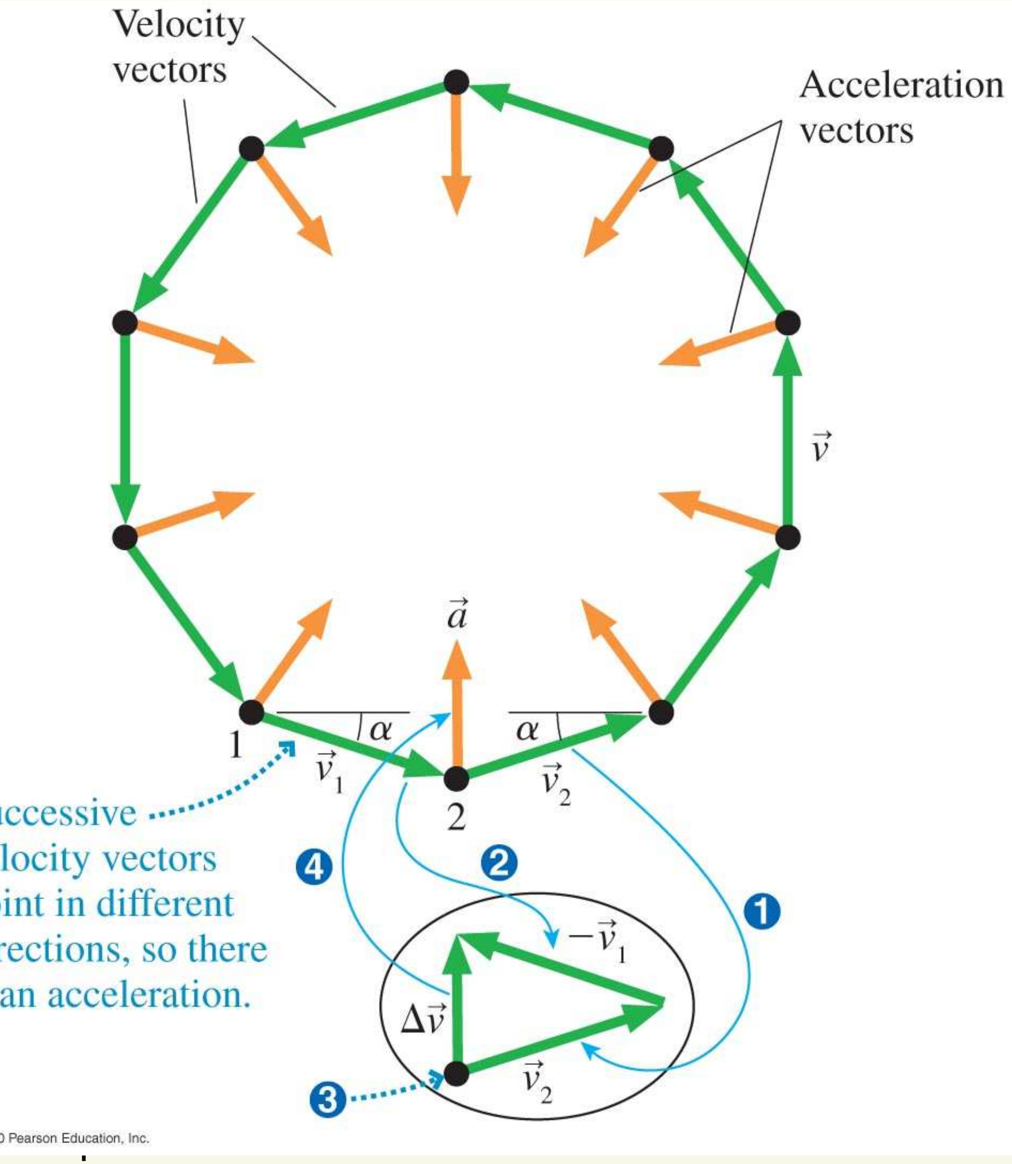

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$$a = \frac{v^2}{r} = \omega^2 r$$

Section 3.8

Circular Dynamics

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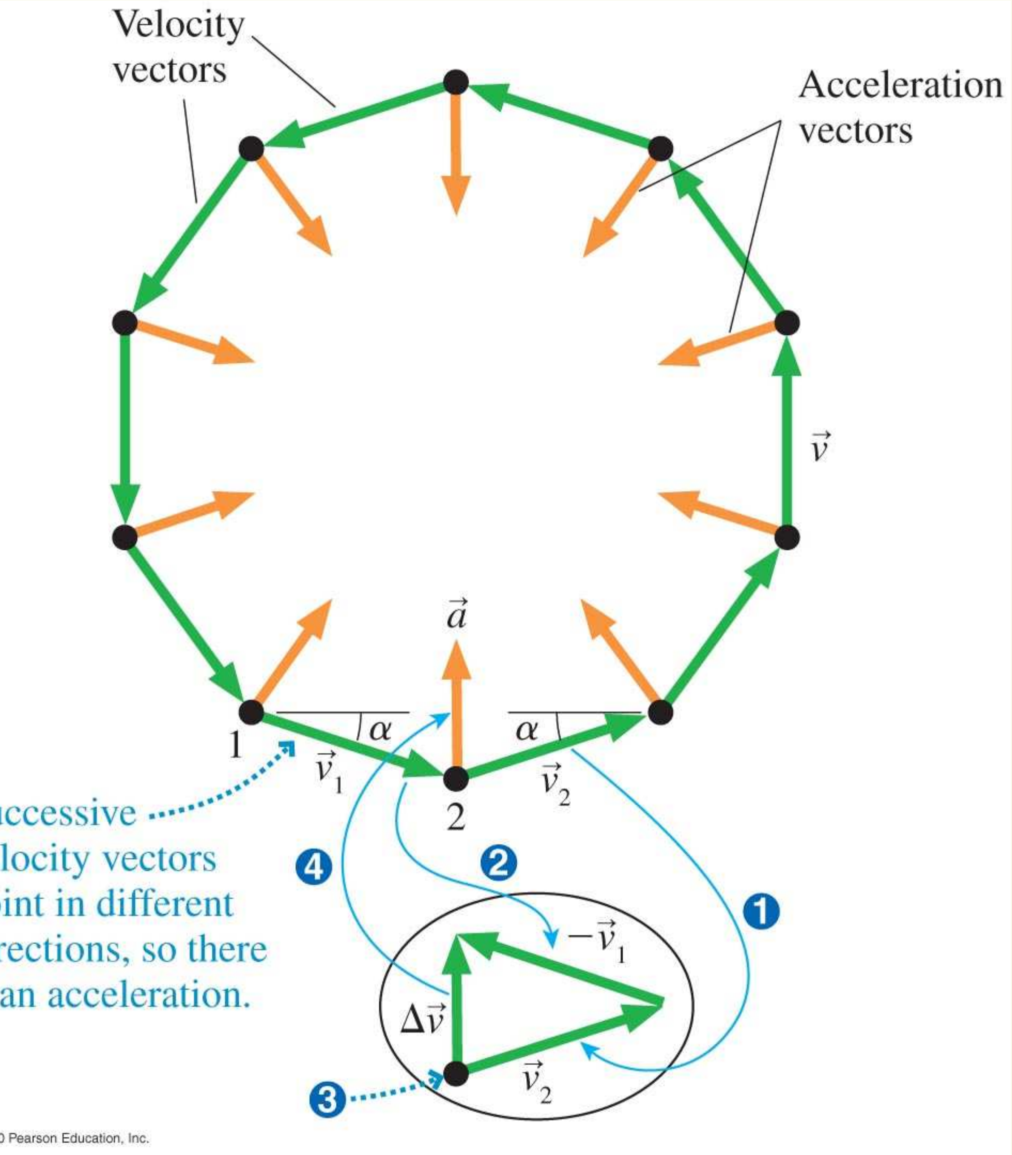

The Centripetal Acceleration - The acceleration towards the center necessary for cicular motion

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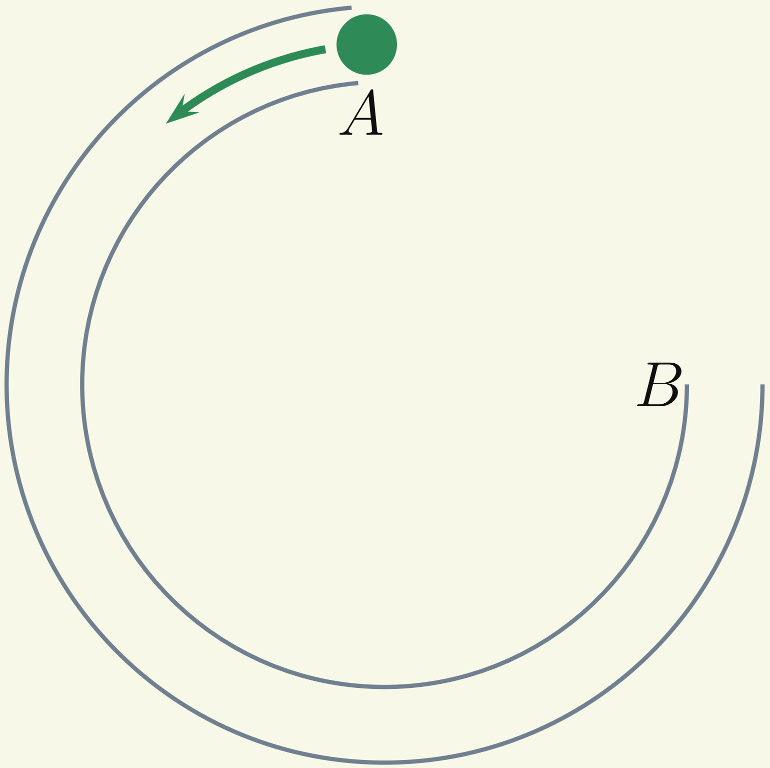
Section 3.8

The centripetal acceleration like any other is **NOT** put on free-body diagrams. It is created by other forces like weight, tension, normal, *etc.*

Centripetal-Acceleration Exercise

The figure shows a *top view* of a plastic tube that is fixed on a horizontal table top. A marble is shot into the tube at A. Which of the following is the correct trajectory for the marble after it leaves the tube at B?



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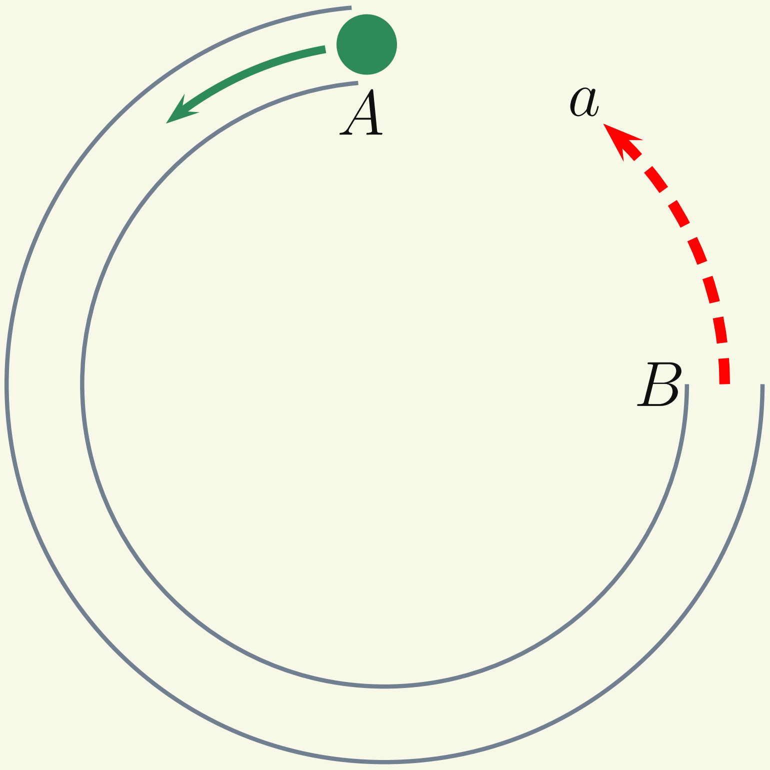

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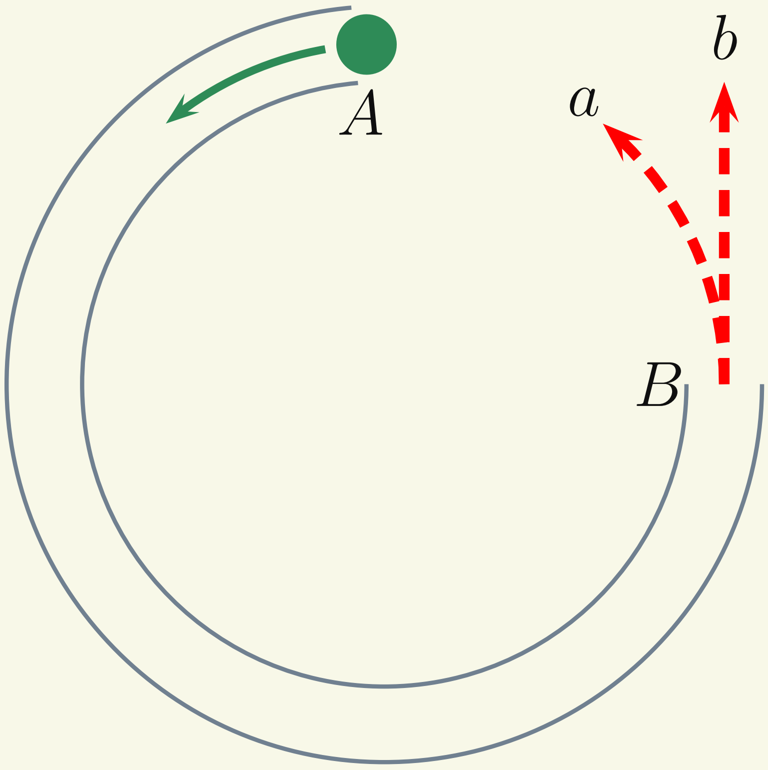

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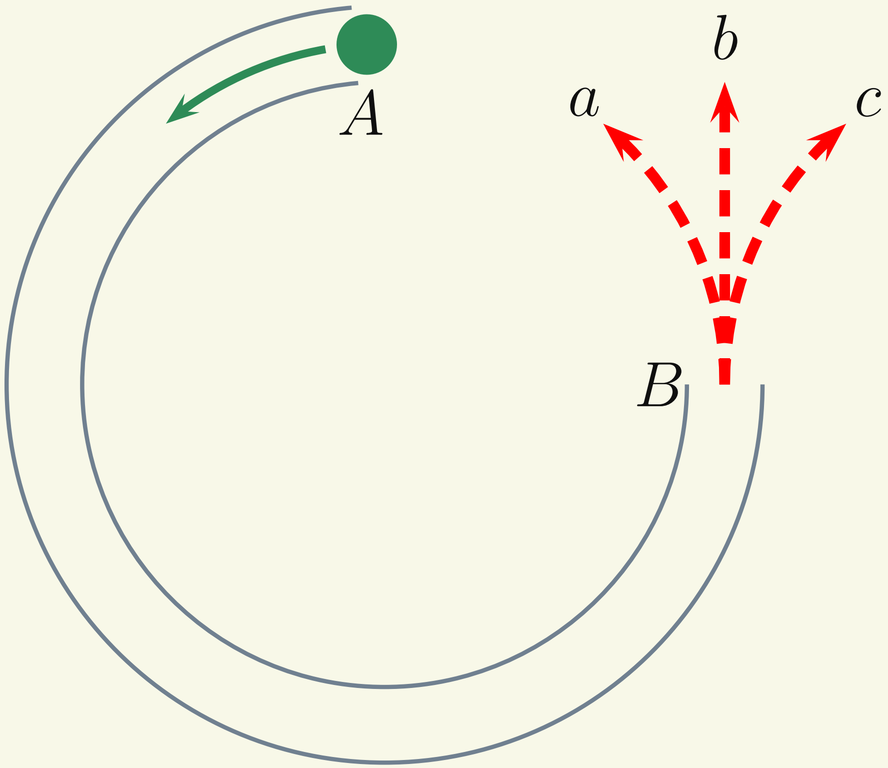

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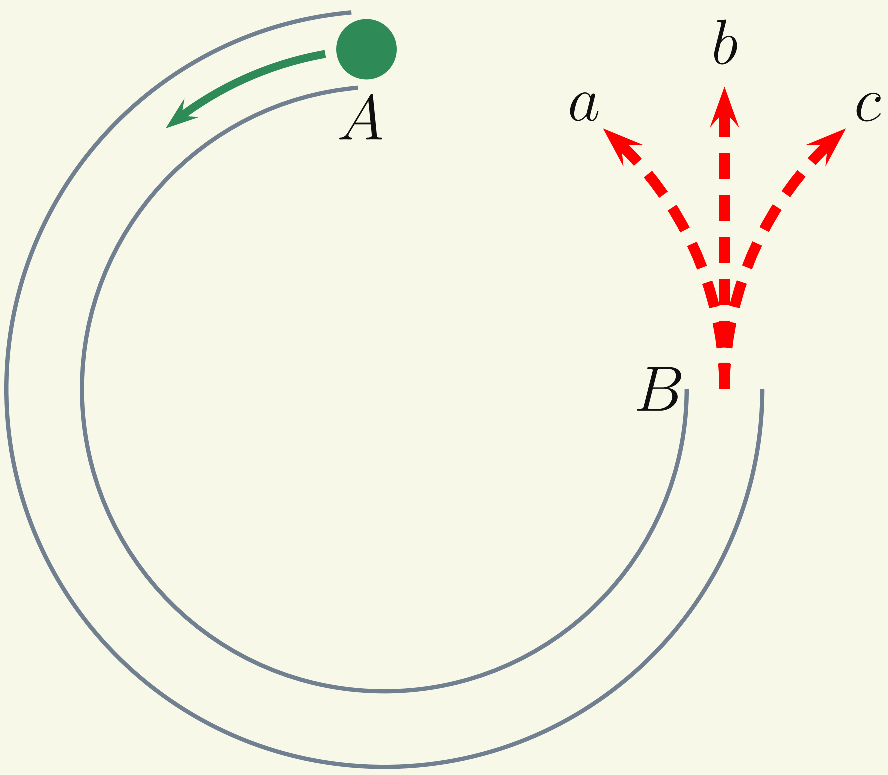

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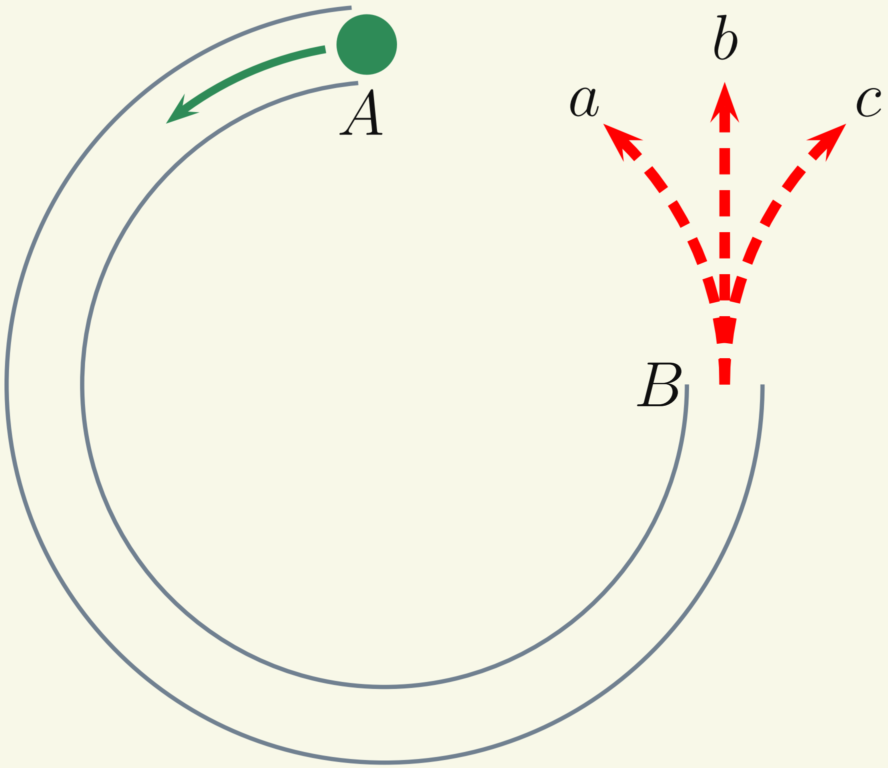

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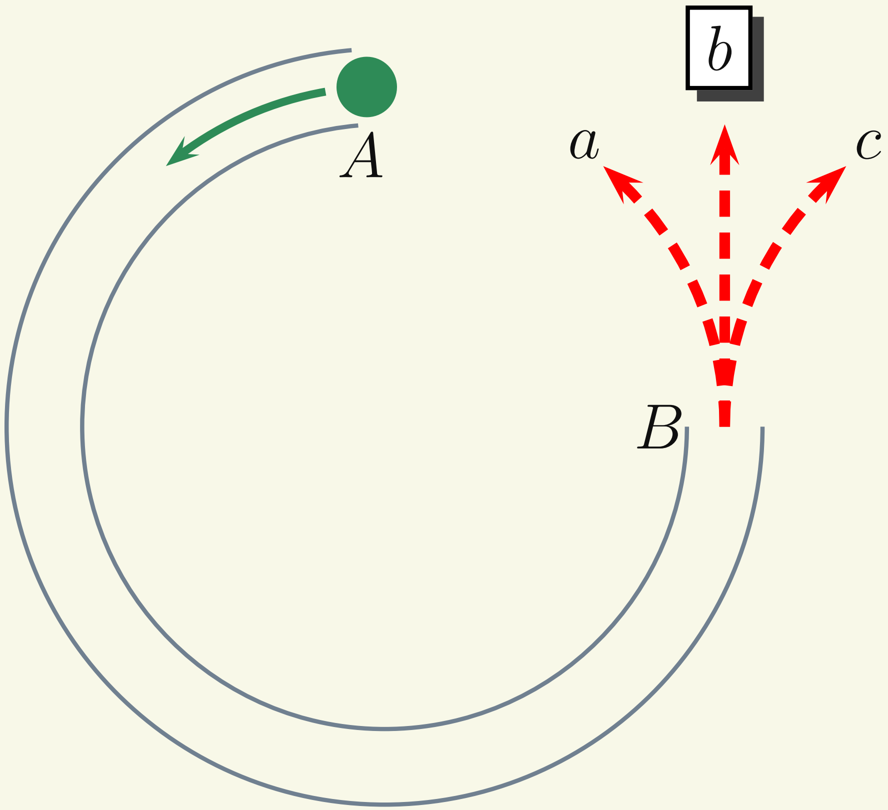

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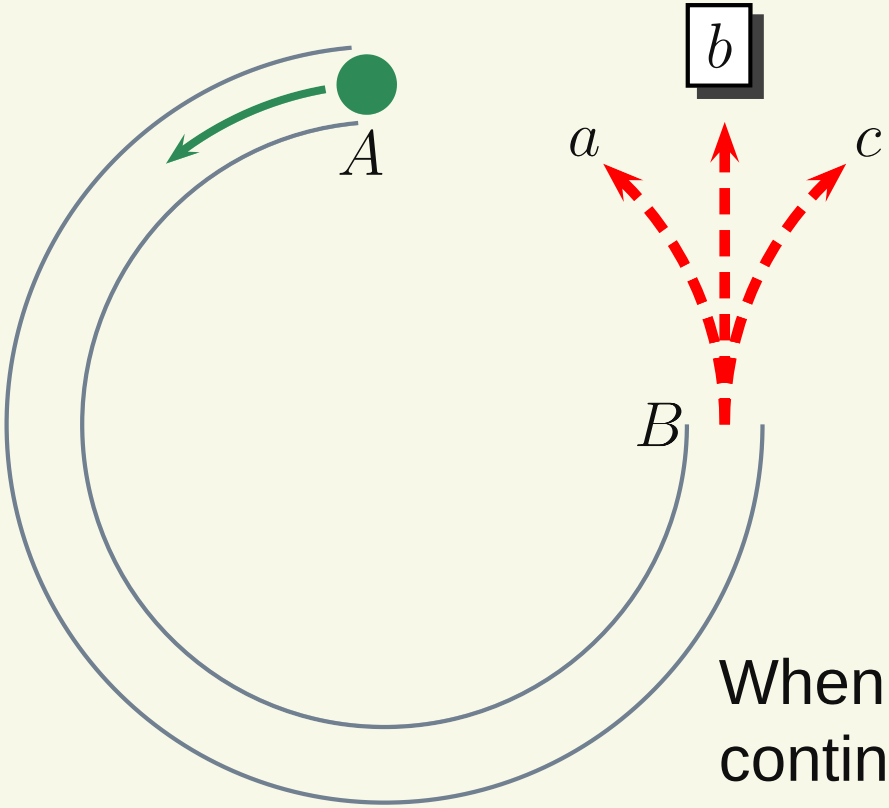


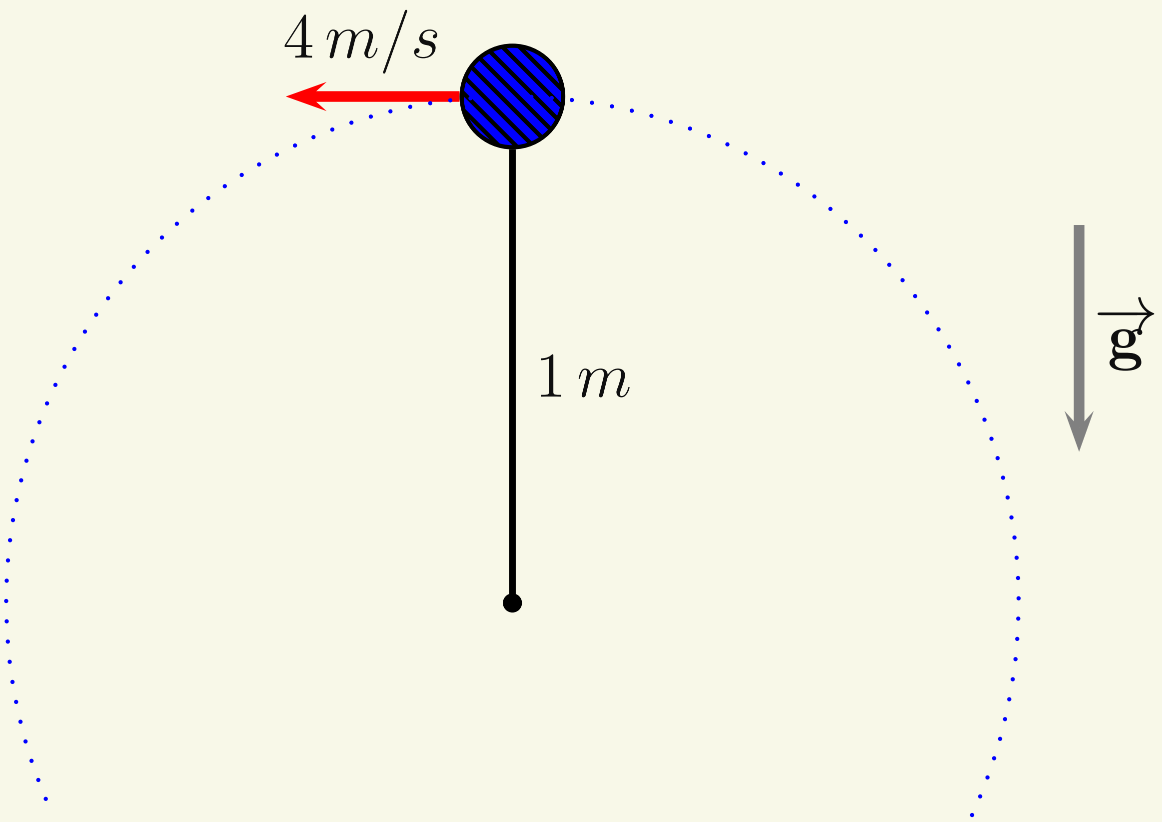
(d) Any of these are possible.

(e) None of these are possible.

When the centripetal force ends, an object continues in the direction of its velocity

Calculation Exercise

A 10-N ball, attached to a massless string, is swung in a vertical circle of radius $1\,m$. If at the top of the circle the ball's speed is $4\,m/s$, what is tension in the string? For ease of calculation assume $g = 10\,m/s^2$ so that $m = 1\,kg$.



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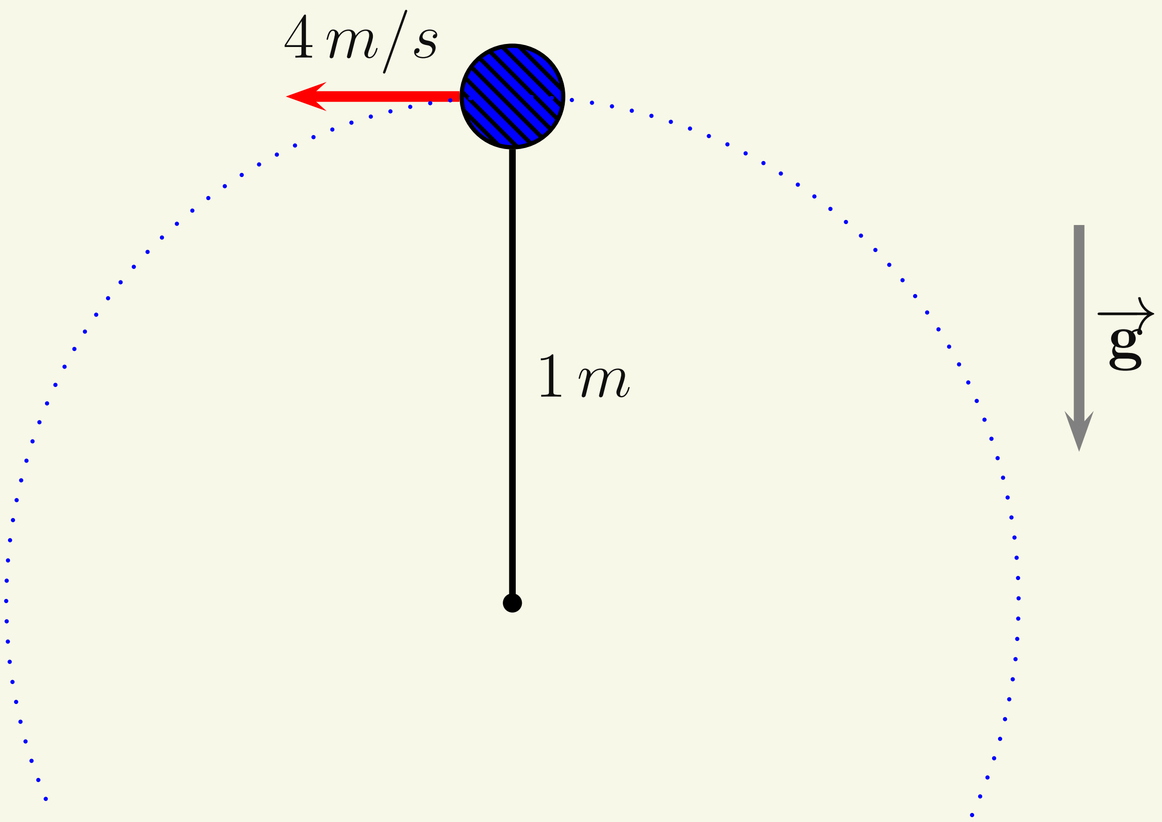

(a) $26\,N$

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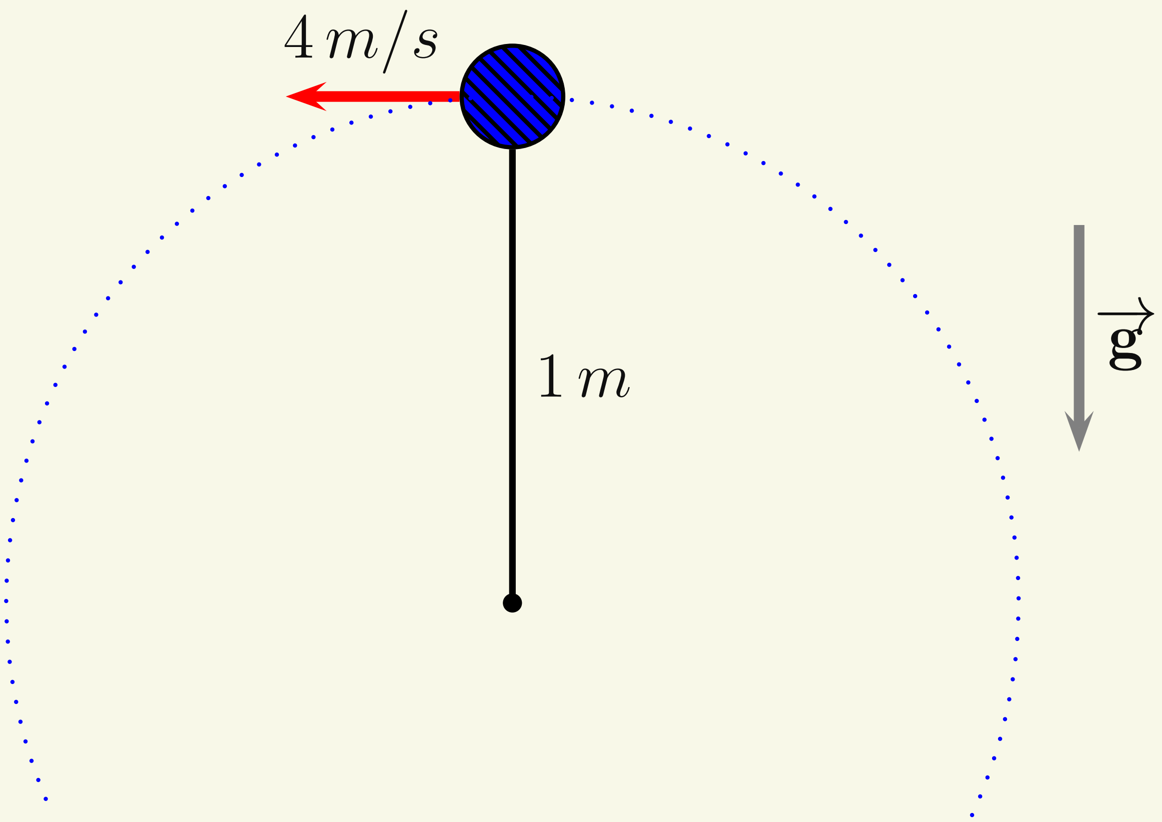

(a) $26\,N$

(b) $16\,N$

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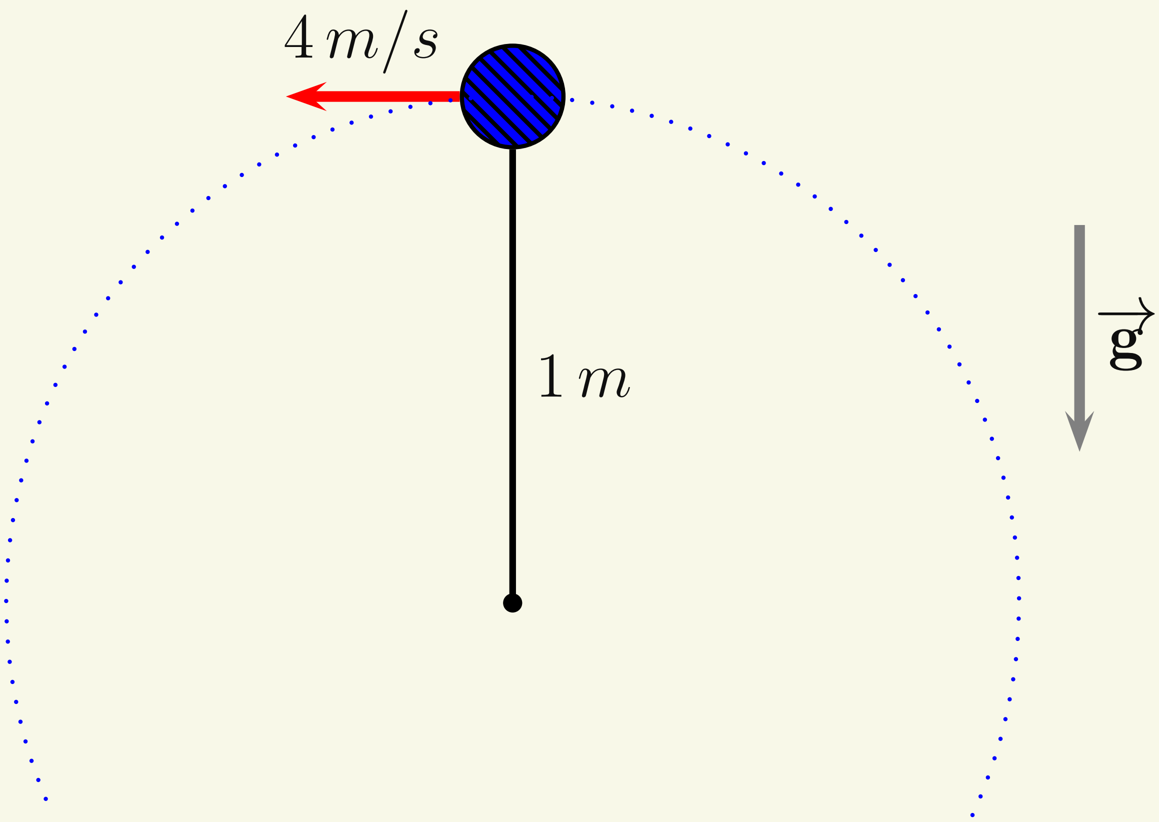

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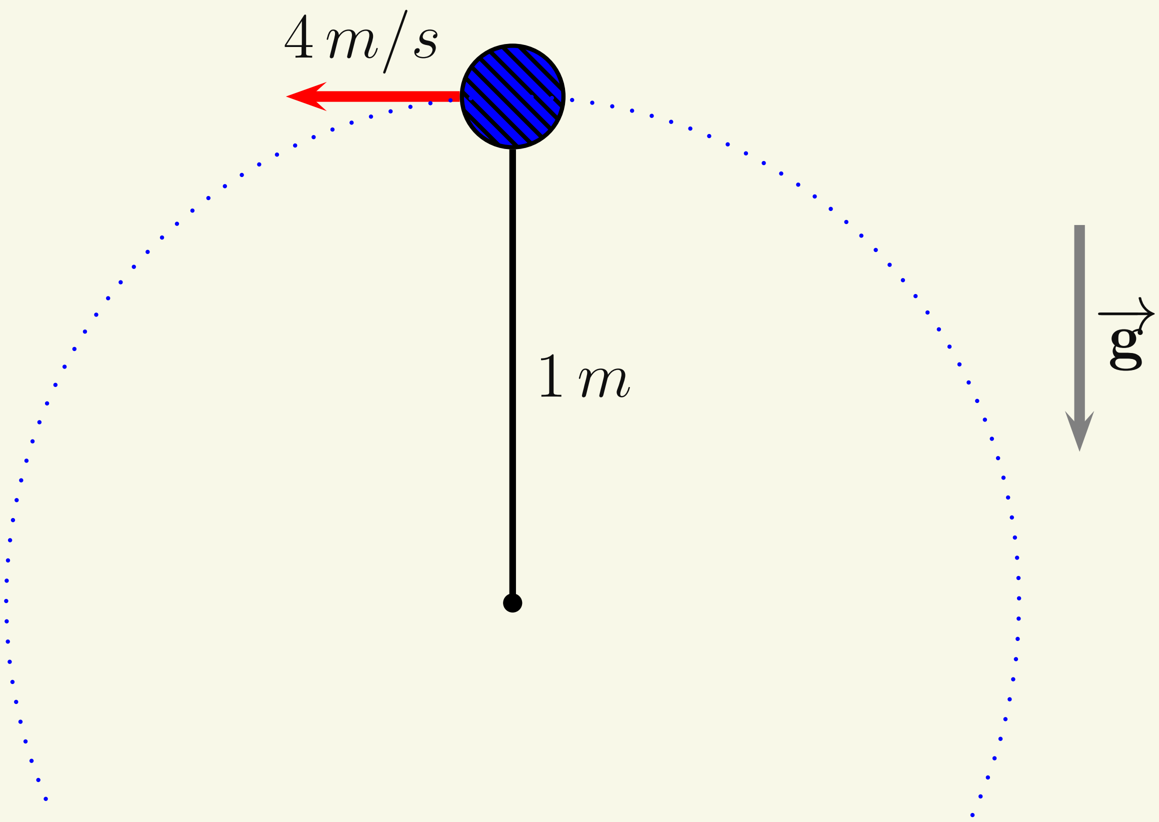

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(d) $6\,N$

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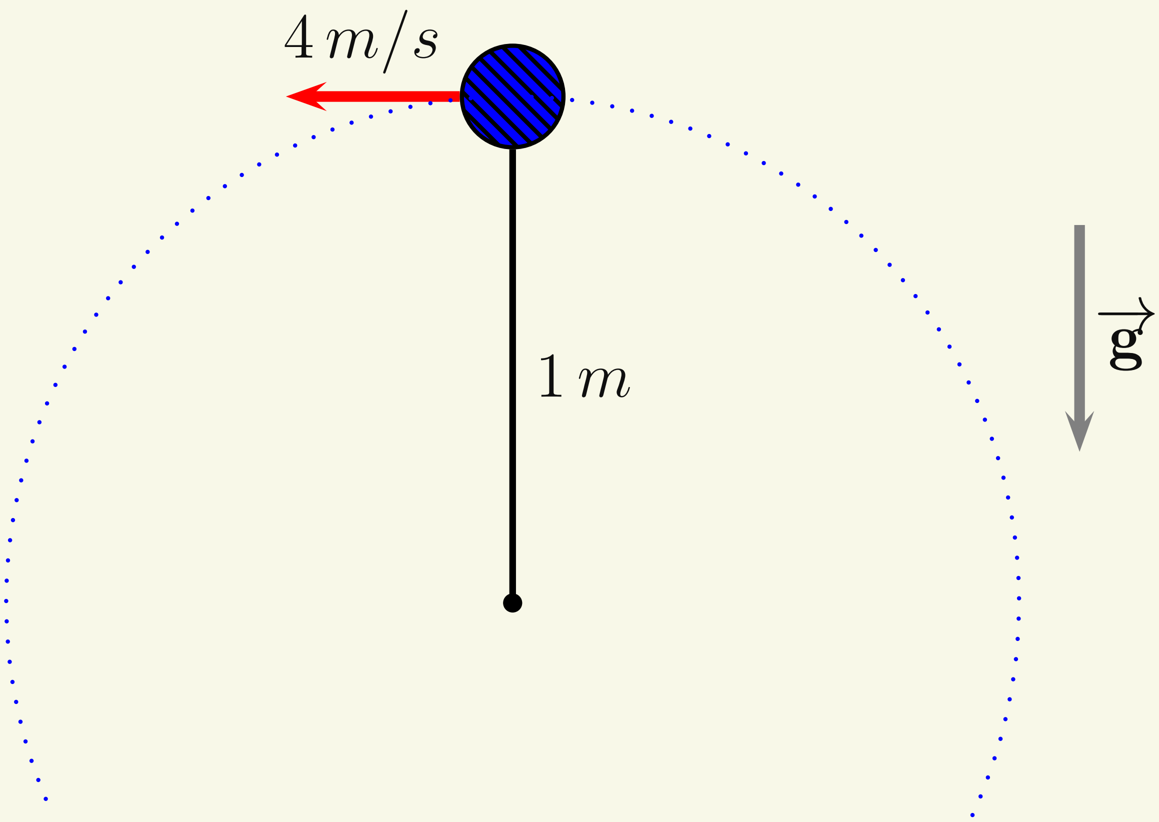

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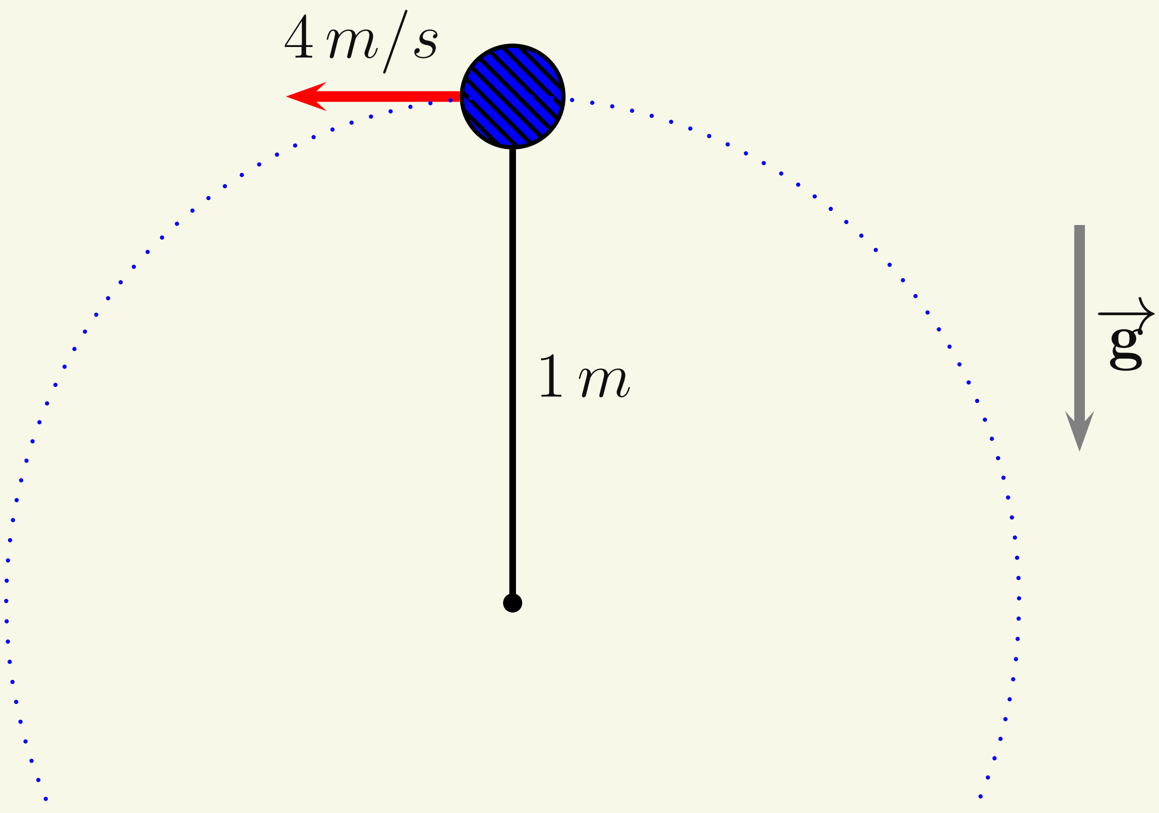

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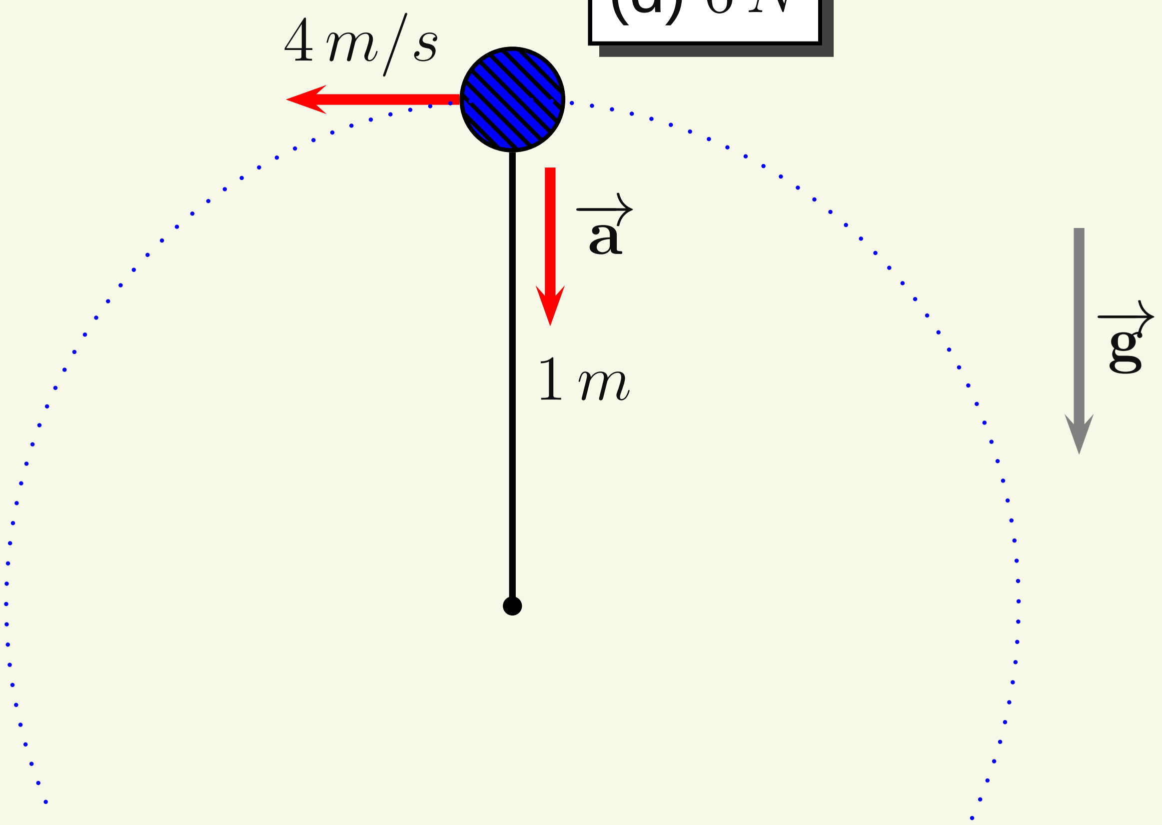

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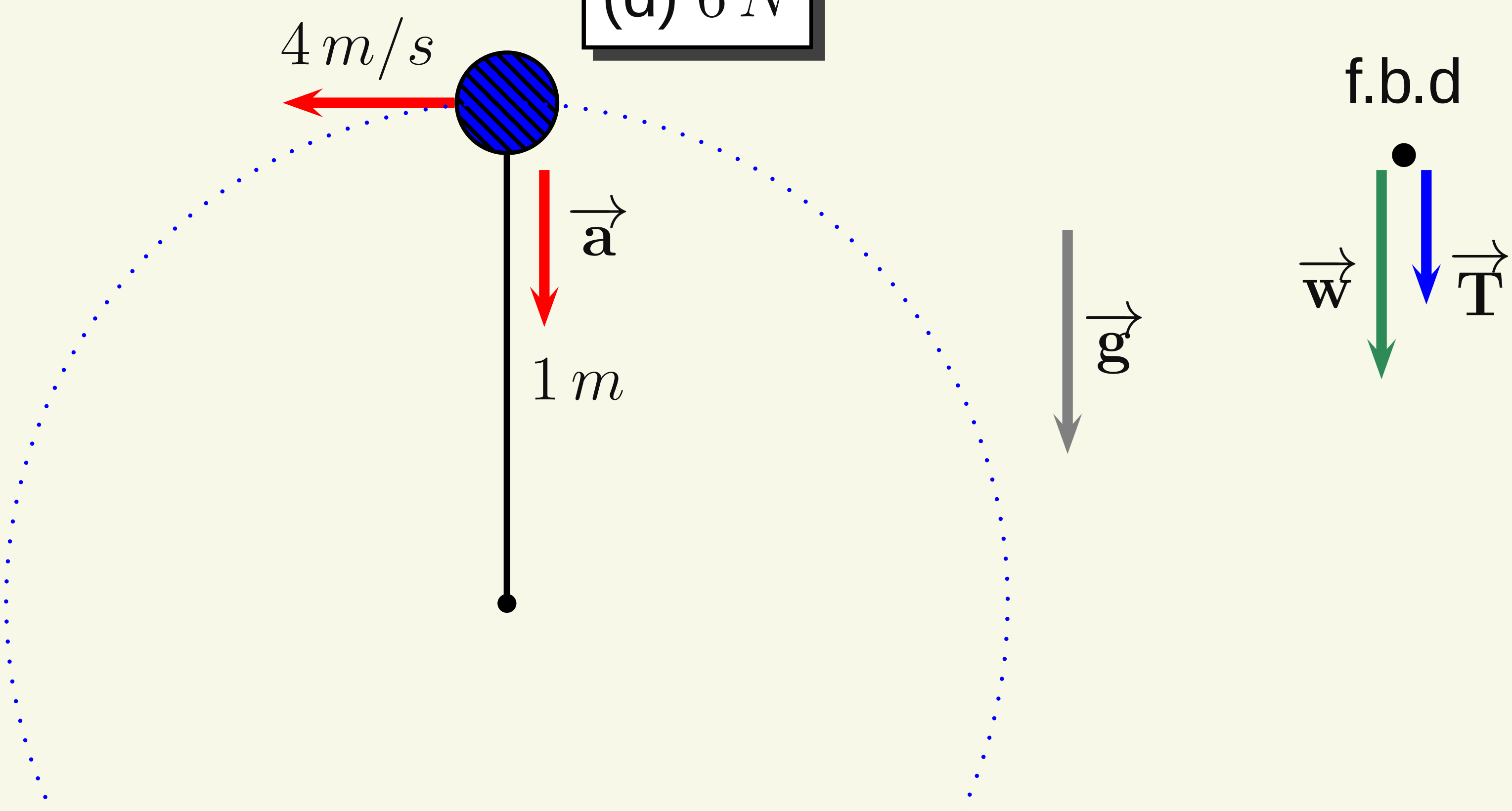

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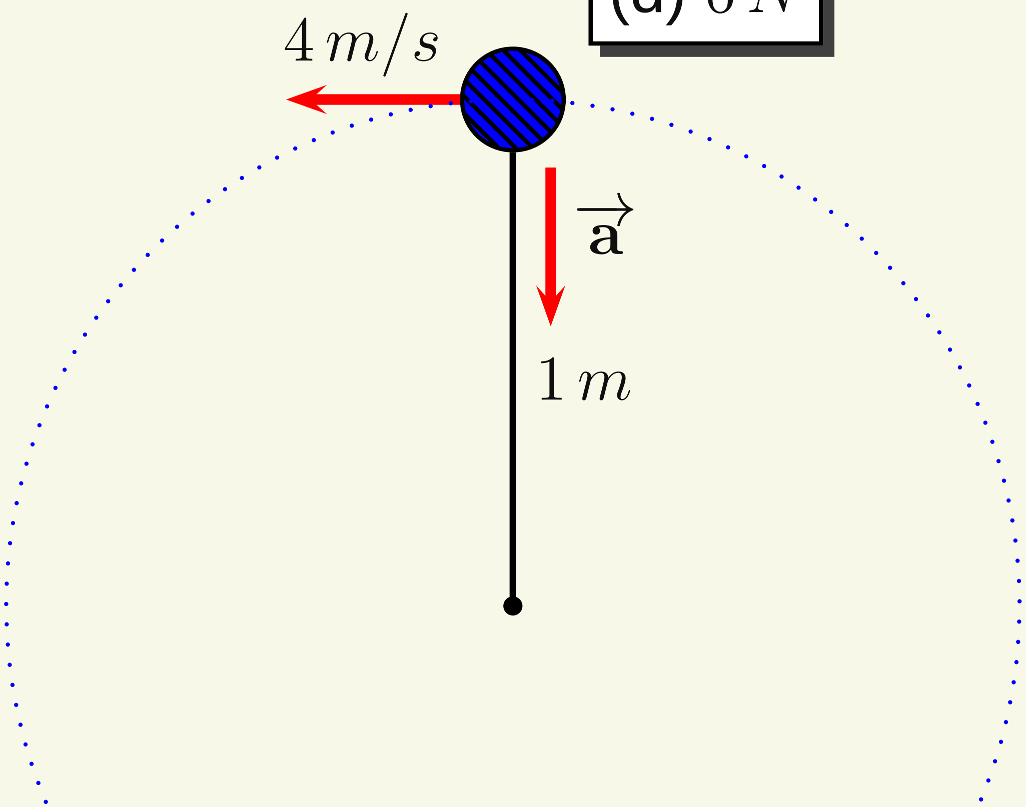

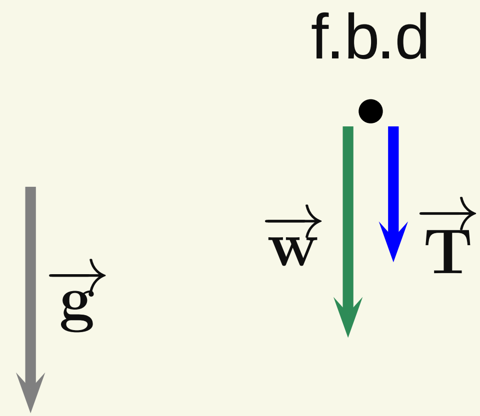

$$\sum F_y = ma_y \Rightarrow$$
$$T_y + w_y = ma_y \Rightarrow$$
$$-T - w = m\left(-v^2/r\right) \Rightarrow$$
$$-T - 10\,N = -\left(1\,kg\right)\left(16\,m/s^2\right)$$

Momentum

We can rewrite Newton's Second law in a slightly different way:

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

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Momentum: $\boxed{\vec{\mathbf{p}} = m\,\vec{\mathbf{v}}}$

Unit: $kg \cdot m/s$

↑ No fancy name!

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Momentum: $\boxed{\vec{\mathbf{p}} = m\,\vec{\mathbf{v}}}$ Unit: $kg \cdot m/s$

No fancy name!

Momentum measures how "hard" it is to change the velocity of an object in a given period of time.

Impulse

Related to Momentum is Impulse, $\vec{\mathbf{J}}$:

Impulse

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$$\boxed{\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t}$$

Unit: $N \cdot s = (kg \cdot m/s^2) \cdot s = kg \cdot m/s$

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Impulse-Momentum Theorem (Average Force Version):

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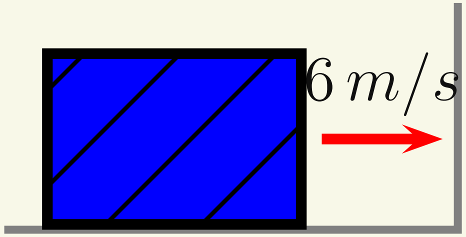
Impulse-Momentum Exercise I

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. What impulse is imparted to the block?



BEFORE

Impulse-Momentum Exercise I

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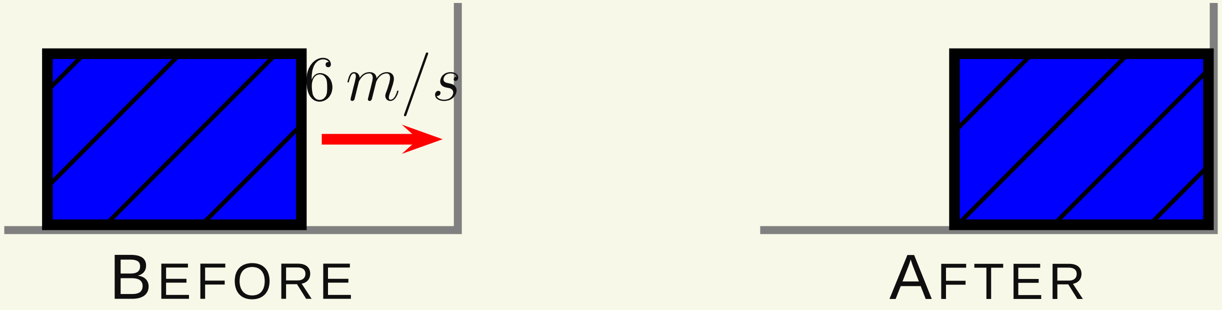

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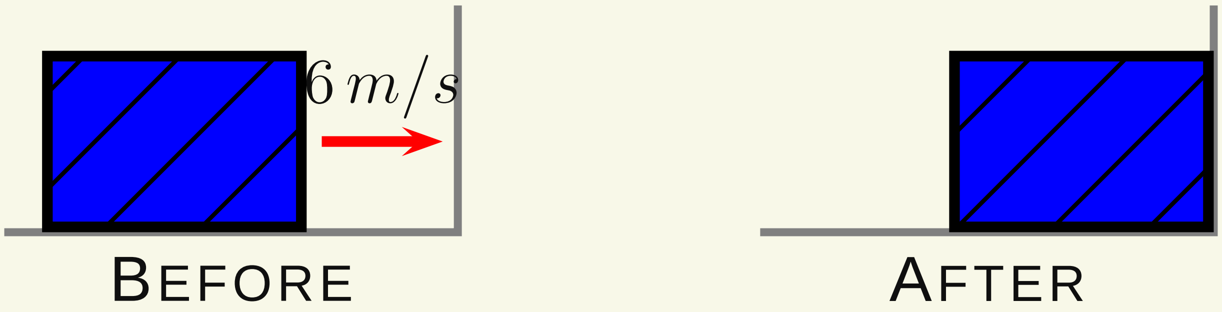

(a) $60\,kg \cdot m/s, \leftarrow$

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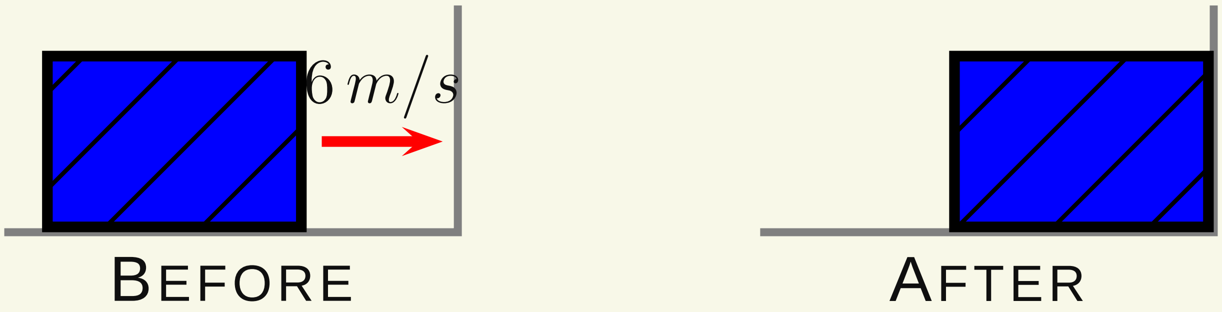

(a) $60\,kg \cdot m/s, \leftarrow$ (b) $60\,kg \cdot m/s, \rightarrow$

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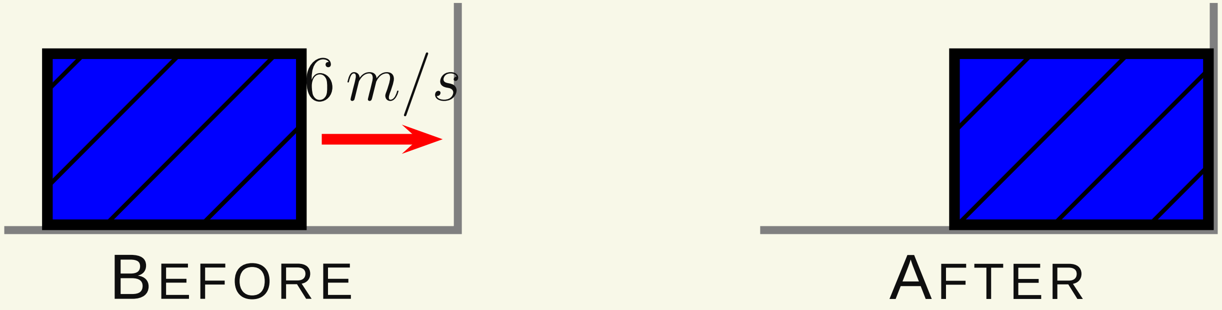

(a) $60\,kg \cdot m/s, \leftarrow$ (b) $60\,kg \cdot m/s, \rightarrow$ (c) $30\,kg \cdot m/s, \leftarrow$

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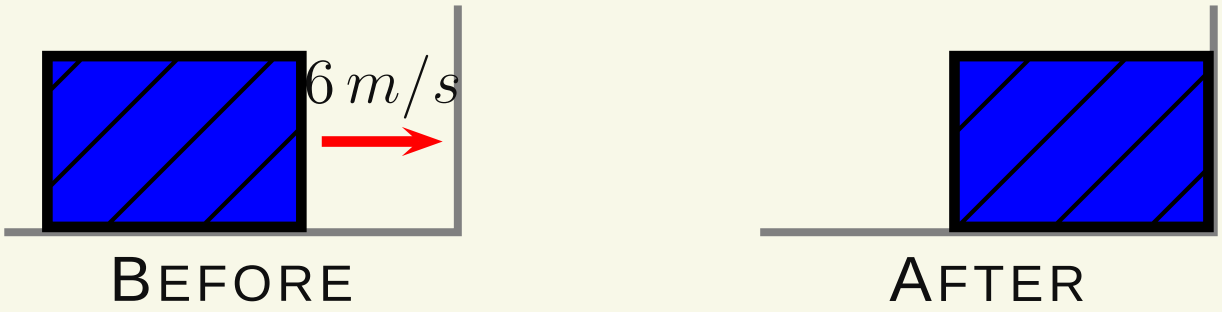

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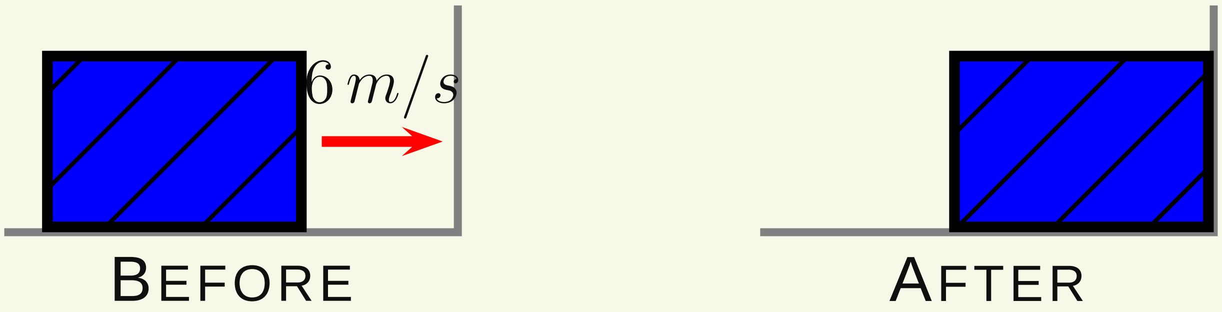

(a) $60\,kg \cdot m/s, \leftarrow$ (b) $60\,kg \cdot m/s, \rightarrow$ (c) $30\,kg \cdot m/s, \leftarrow$

(d) $30\,kg \cdot m/s, \rightarrow$ (e) $15\,kg \cdot m/s, \leftarrow$

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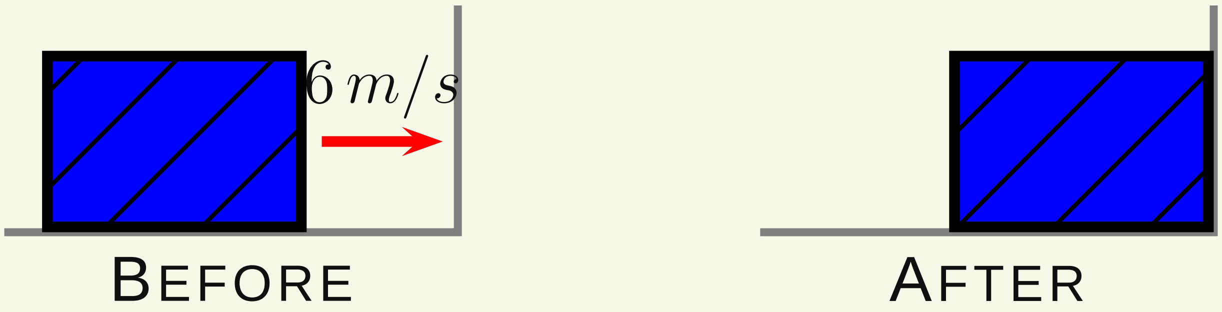
$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. What impulse is imparted to the block?



(a) $60\,kg\cdot m/s, \leftarrow$

(b) $60\,kg\cdot m/s, \rightarrow$

(c) $30\,kg\cdot m/s, \leftarrow$

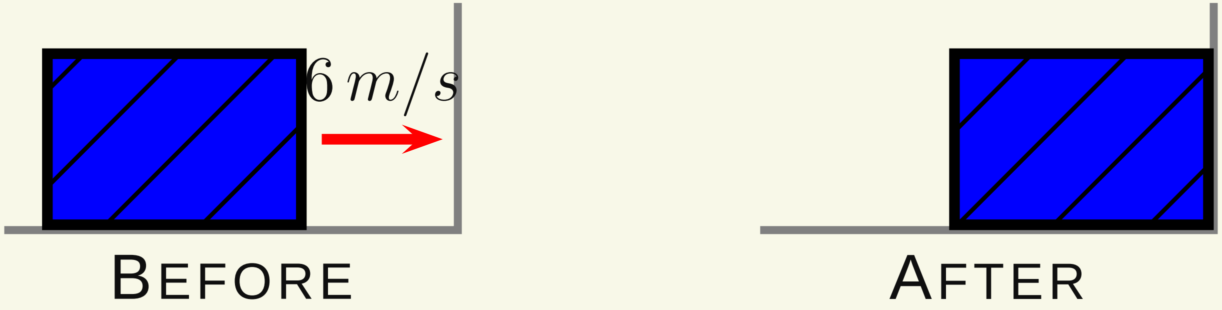
(d) $30\,kg\cdot m/s, \rightarrow$

(e) $15\,kg\cdot m/s, \leftarrow$

Impulse-Momentum Exercise I

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. What impulse is imparted to the block?



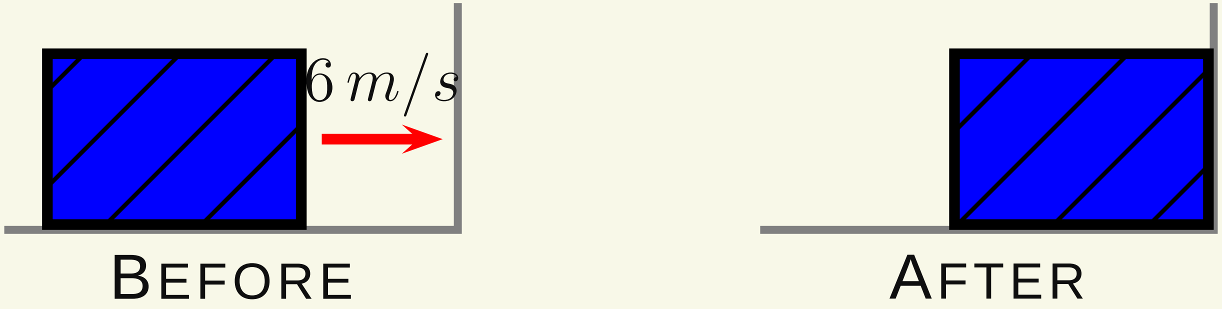
(c) $30\,kg \cdot m/s, \leftarrow$

$$J_x = \Delta p_x = 0 - 30\,kg \cdot m/s = -30\,kg \cdot m/s$$

Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

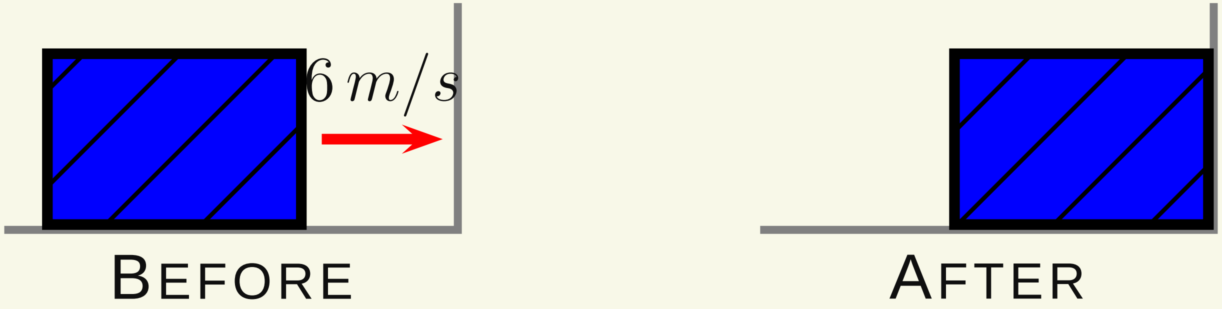
A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?



Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?

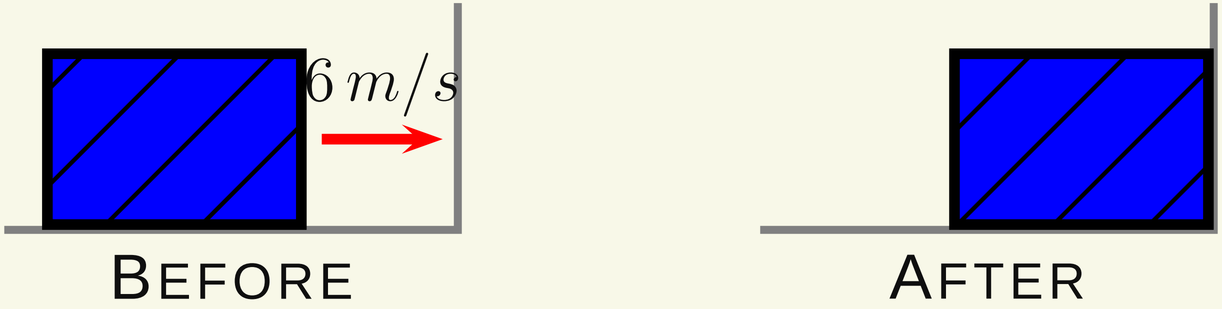


(a) $300\,N, \leftarrow$

Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?

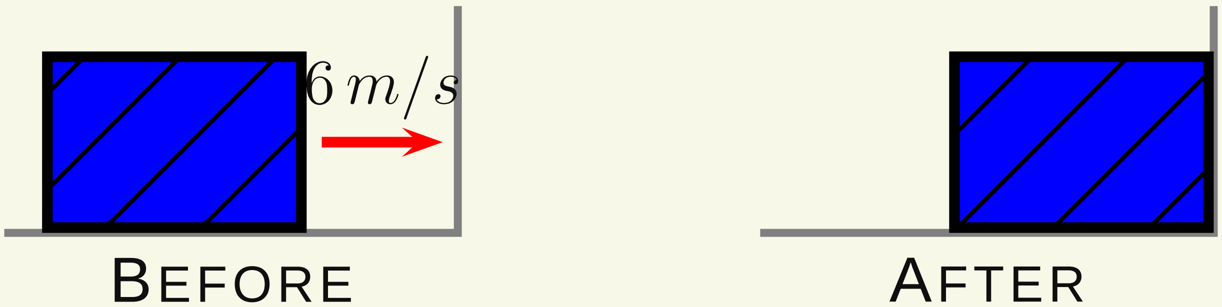


(a) $300\,N, \leftarrow$ (b) $300\,N, \rightarrow$

Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?

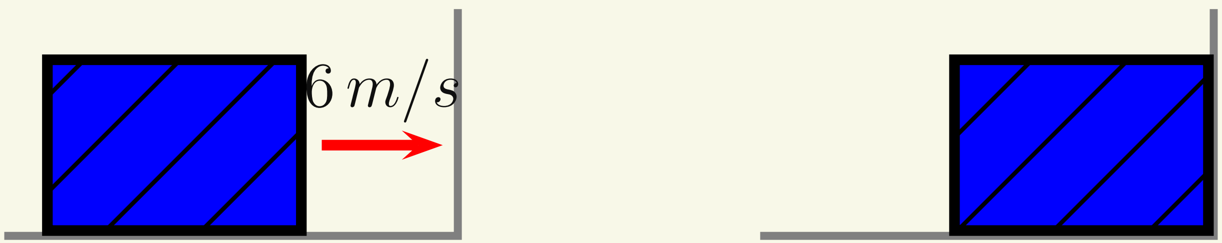


(a) $300\,N, \leftarrow$ (b) $300\,N, \rightarrow$ (c) $3\,N, \leftarrow$

Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?



BEFORE AFTER

(a) $300\,N, \leftarrow$

(b) $300\,N, \rightarrow$

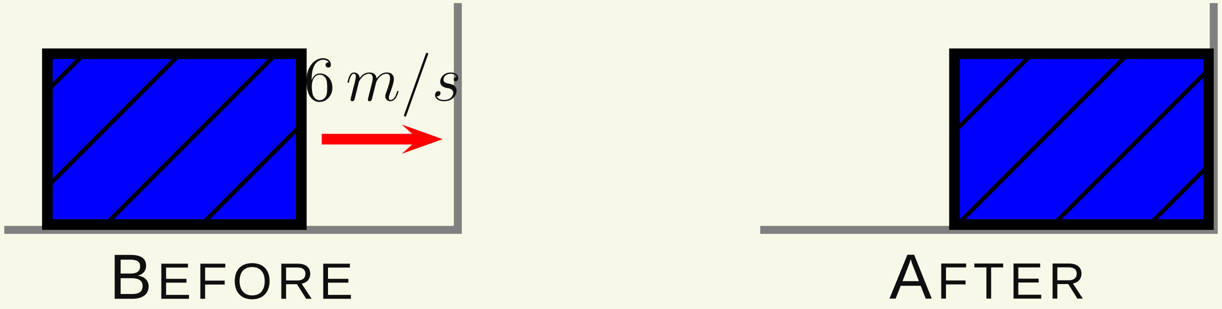
(c) $3\,N, \leftarrow$

(d) $3\,N, \rightarrow$

Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?

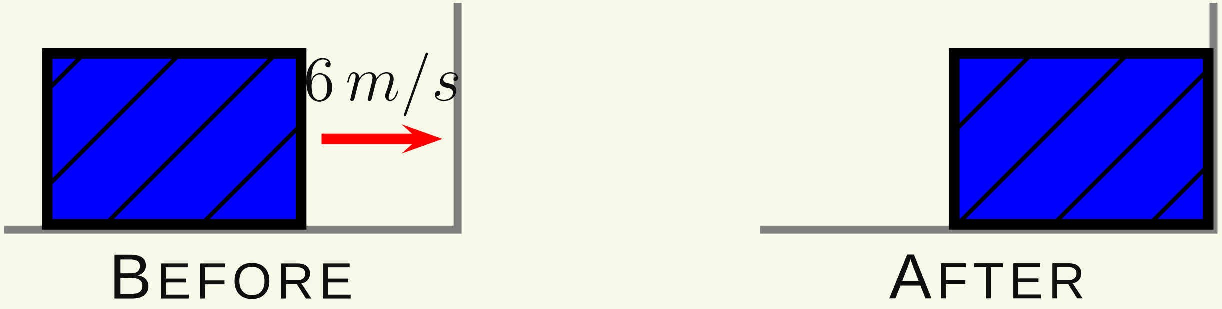


(a) $300\,N, \leftarrow$ (b) $300\,N, \rightarrow$ (c) $3\,N, \leftarrow$

(d) $3\,N, \rightarrow$ (e) $600\,N, \leftarrow$

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?



(a) $300\,N, \leftarrow$

(b) $300\,N, \rightarrow$

(c) $3\,N, \leftarrow$

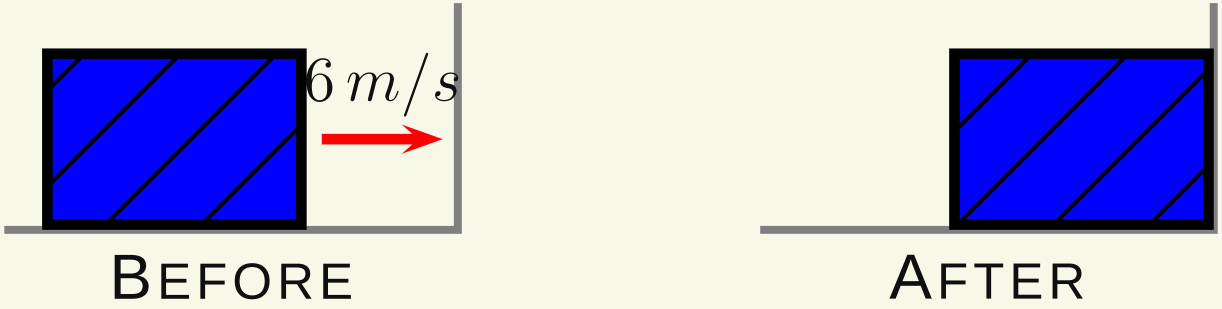
(d) $3\,N, \rightarrow$

(e) $600\,N, \leftarrow$

Impulse-Momentum Exercise II

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?



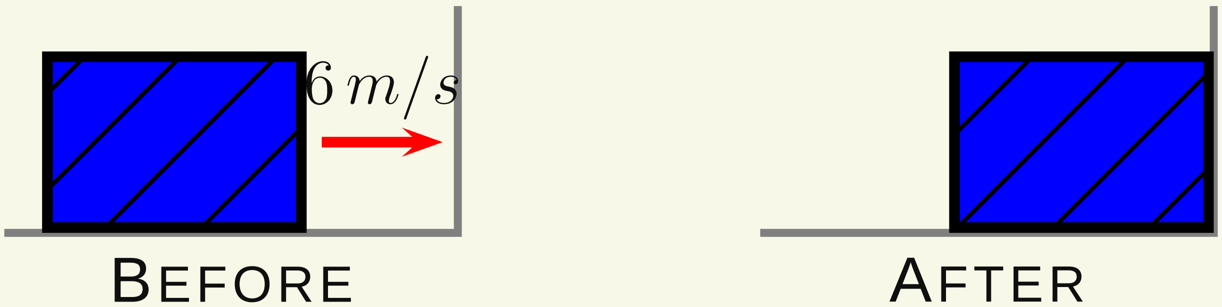
(a) $300\,N, \leftarrow$

$$F_{av} = \frac{\Delta p}{\Delta t} = \frac{J}{\Delta t}$$

Impulse-Momentum Exercise II

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the right when it hits a wall and stops. If the block stops in $0.1\,s$, what is the average force acting on it?



(a) $300\,N, \leftarrow$

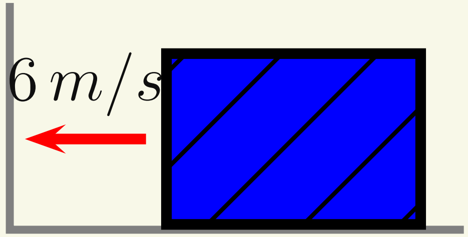
$$F_{av} = \frac{\Delta p}{\Delta t} = \frac{J}{\Delta t}$$

Average force, impulse, and change in momentum always have the same direction

Impulse-Momentum Exercise III

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?

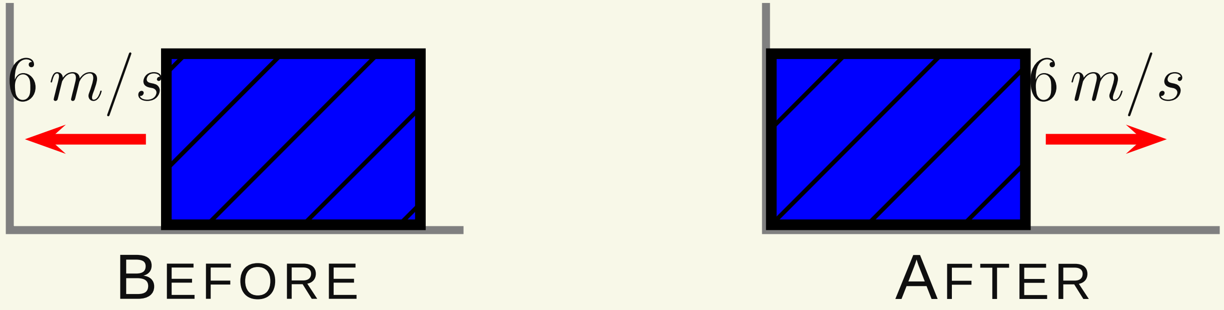


BEFORE

Impulse-Momentum Exercise III

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

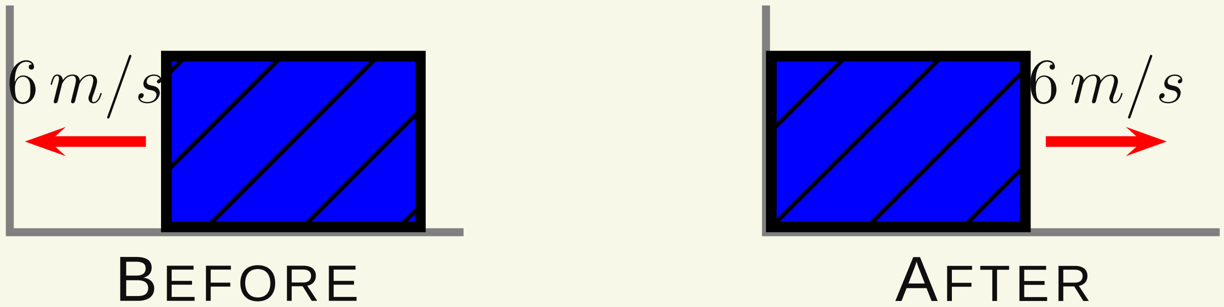
A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?



Impulse-Momentum Exercise III

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?

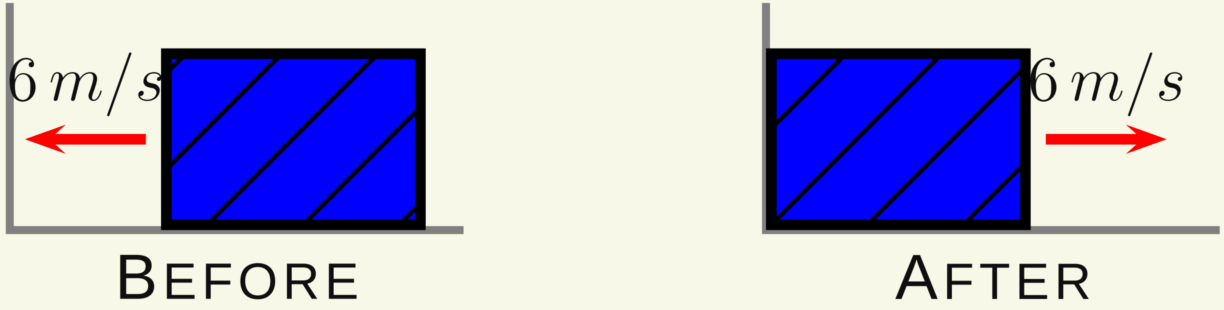


(a) $60\,kg\cdot m/s, \leftarrow$

Impulse-Momentum Exercise III

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?

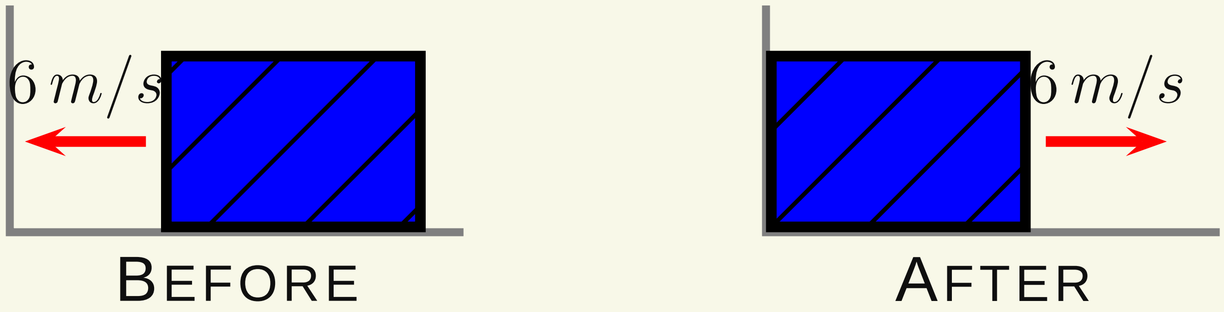


(a) $60\,kg \cdot m/s, \leftarrow$ (b) $60\,kg \cdot m/s, \rightarrow$

Impulse-Momentum Exercise III

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?

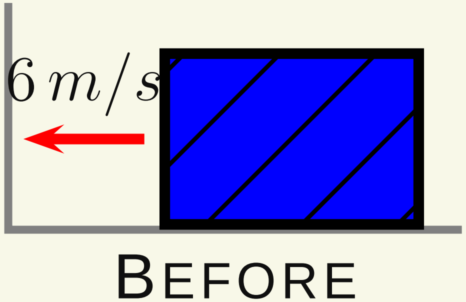


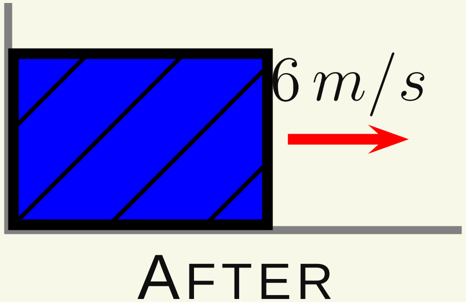
(a) $60\,kg \cdot m/s, \leftarrow$ (b) $60\,kg \cdot m/s, \rightarrow$ (c) $30\,kg \cdot m/s, \leftarrow$

Impulse-Momentum Exercise III

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?





(a) $60\,kg \cdot m/s, \leftarrow$

(b) $60\,kg \cdot m/s, \rightarrow$

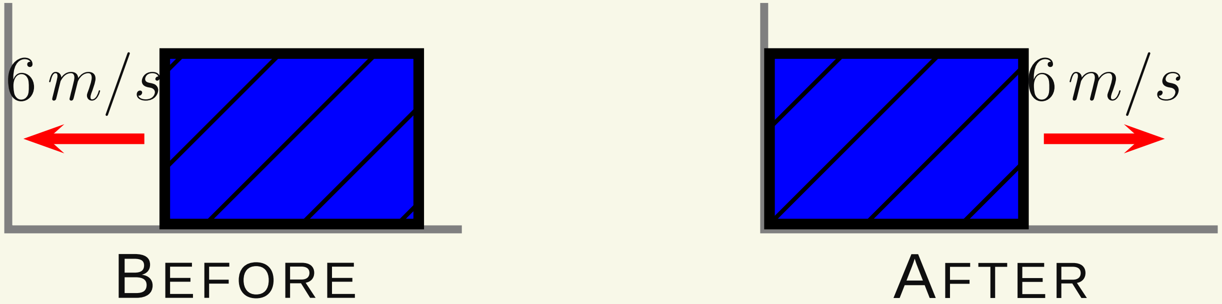
(c) $30\,kg \cdot m/s, \leftarrow$

(d) $30\,kg \cdot m/s, \rightarrow$

Impulse-Momentum Exercise III

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?



(a) $60\,kg\cdot m/s, \leftarrow$ (b) $60\,kg\cdot m/s, \rightarrow$ (c) $30\,kg\cdot m/s, \leftarrow$

(d) $30\,kg\cdot m/s, \rightarrow$ (e) $0\,kg\cdot m/s, \leftarrow$

Impulse-Momentum Exercise III

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?

(a) $60\,kg\cdot m/s, \leftarrow$

(b) $60\,kg\cdot m/s, \rightarrow$

(c) $30\,kg\cdot m/s, \leftarrow$

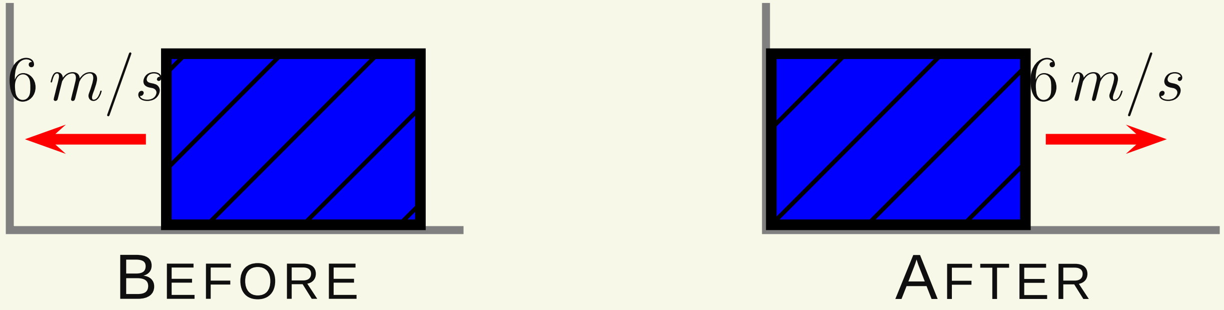
(d) $30\,kg\cdot m/s, \rightarrow$

(e) $0\,kg\cdot m/s, \leftarrow$

Impulse-Momentum Exercise III

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. What impulse is imparted to the block?



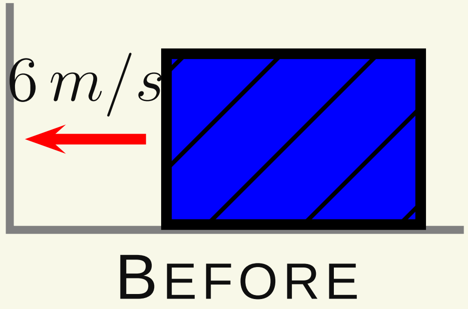
(b) $60\,kg\cdot m/s, \rightarrow$

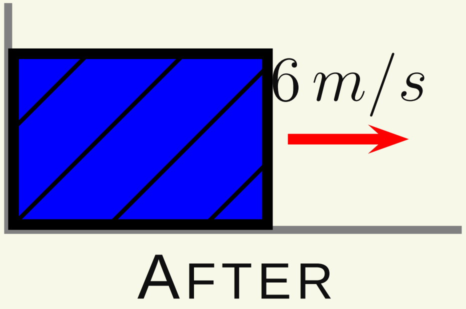
$$J_x = \Delta p_x = +30\,kg\cdot m/s - (-30\,kg\cdot m/s) = +60\,kg\cdot m/s$$

Impulse-Momentum Exercise IV

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?

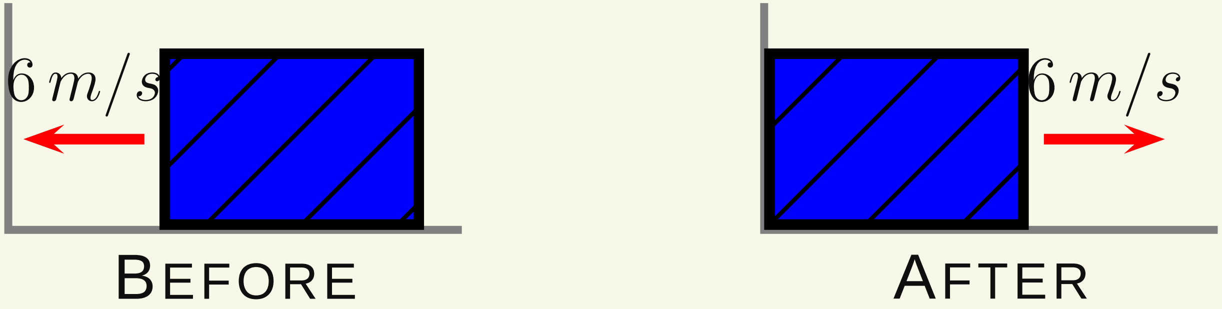




Impulse-Momentum Exercise IV

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?



(a) $6\,N, \rightarrow$

Impulse-Momentum Exercise IV

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?

(a) $6\,N, \rightarrow$

(b) $300\,N, \leftarrow$

Impulse-Momentum Exercise IV

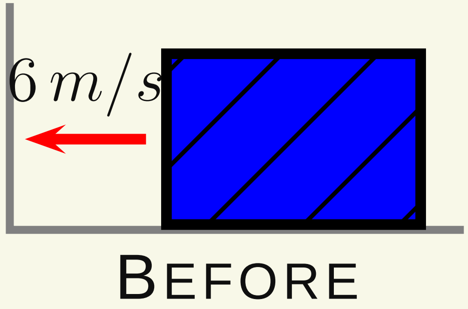
$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

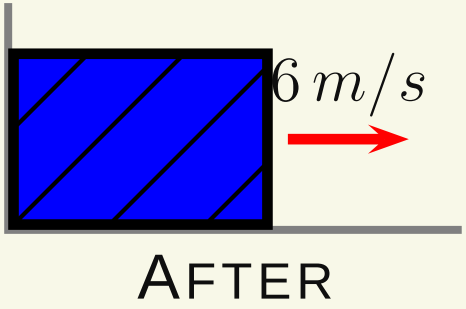
A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?

(a) $6\,N, \rightarrow$ (b) $300\,N, \leftarrow$ (c) $300\,N, \rightarrow$

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?





(a) $6\,N, \rightarrow$

(b) $300\,N, \leftarrow$

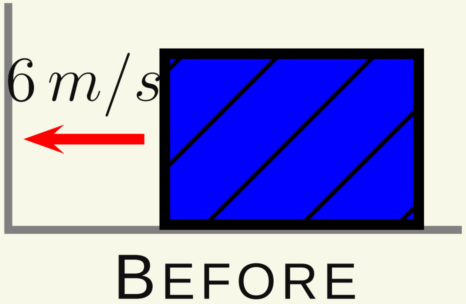
(c) $300\,N, \rightarrow$

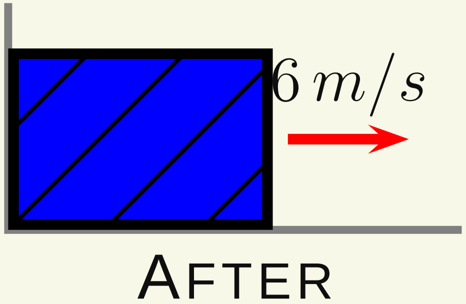
(d) $600\,N, \leftarrow$

Impulse-Momentum Exercise IV

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?





(a) $6\,N, \rightarrow$

(b) $300\,N, \leftarrow$

(c) $300\,N, \rightarrow$

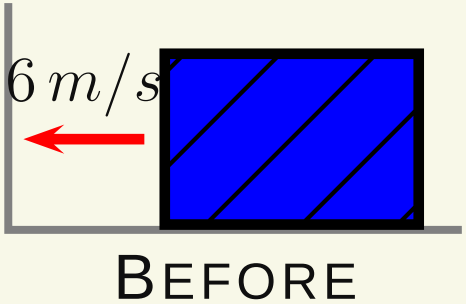
(d) $600\,N, \leftarrow$

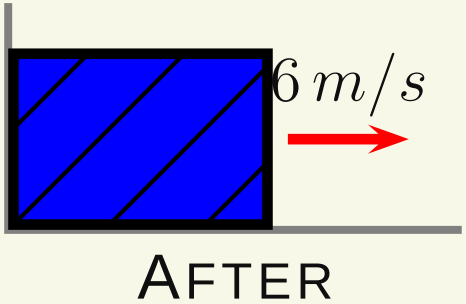
(e) $600\,N, \rightarrow$

Impulse-Momentum Exercise IV

$$\overrightarrow{\mathbf{J}} = \overrightarrow{\mathbf{F}}_{av}\Delta t = \Delta\overrightarrow{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?





(a) $6\,N, \rightarrow$

(b) $300\,N, \leftarrow$

(c) $300\,N, \rightarrow$

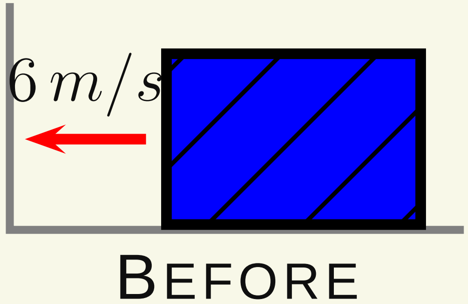
(d) $600\,N, \leftarrow$

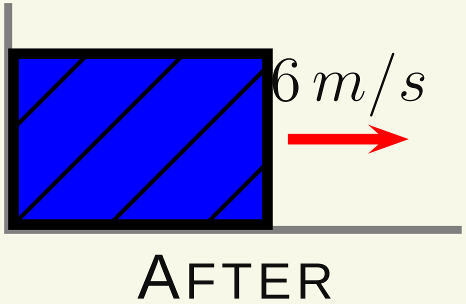
(e) $600\,N, \rightarrow$

Impulse-Momentum Exercise IV

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?





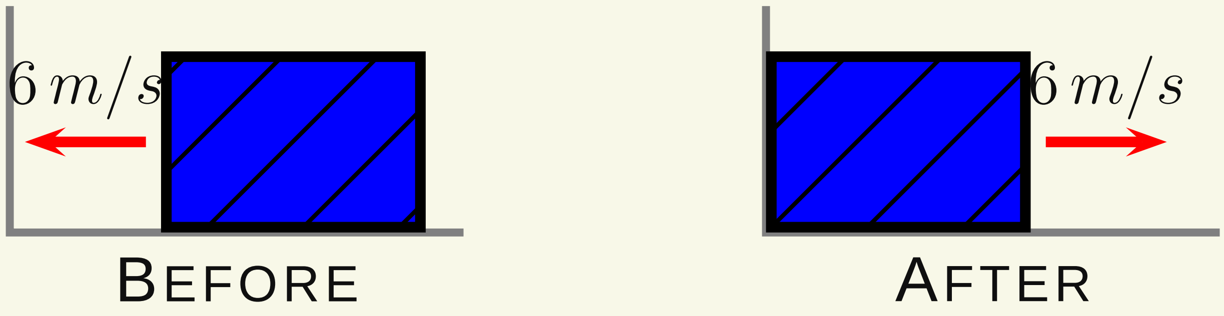
(e) $600\,N, \rightarrow$

$$\vec{\mathbf{F}}_{av} = \frac{\vec{\mathbf{J}}}{\Delta t}$$

Impulse-Momentum Exercise IV

$$\vec{\mathbf{J}} = \vec{\mathbf{F}}_{av}\Delta t = \Delta\vec{\mathbf{p}}$$

A 5.0-kg block is sliding on a frictionless, horizontal surface going $6.0\,m/s$ to the left when it hits a wall and bounces back with the same speed. If this bounce takes $0.1\,s$, what is the average force?



(e) $600\,N, \rightarrow$

$$\vec{\mathbf{F}}_{av} = \frac{\vec{\mathbf{J}}}{\Delta t}$$

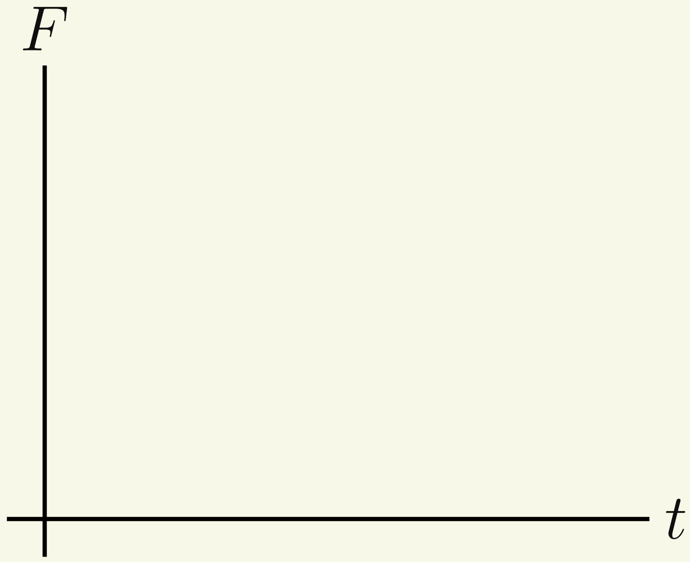
Bouncing doubles the force

Impulse-Momentum Theorem - Variable Forces

The Impulse-Momentum Theorem also holds for non-constant forces!

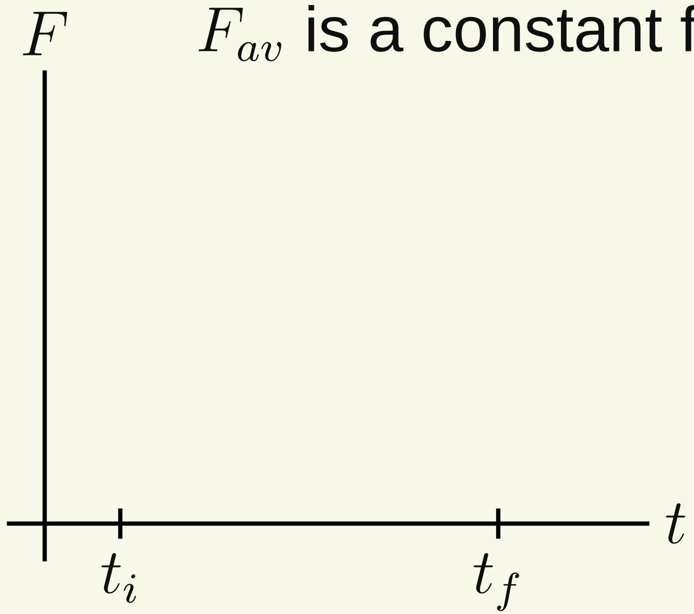
Impulse-Momentum Theorem - Variable Forces

The Impulse-Momentum Theorem also holds for non-constant forces!



Impulse-Momentum Theorem - Variable Forces

The Impulse-Momentum Theorem also holds for non-constant forces!

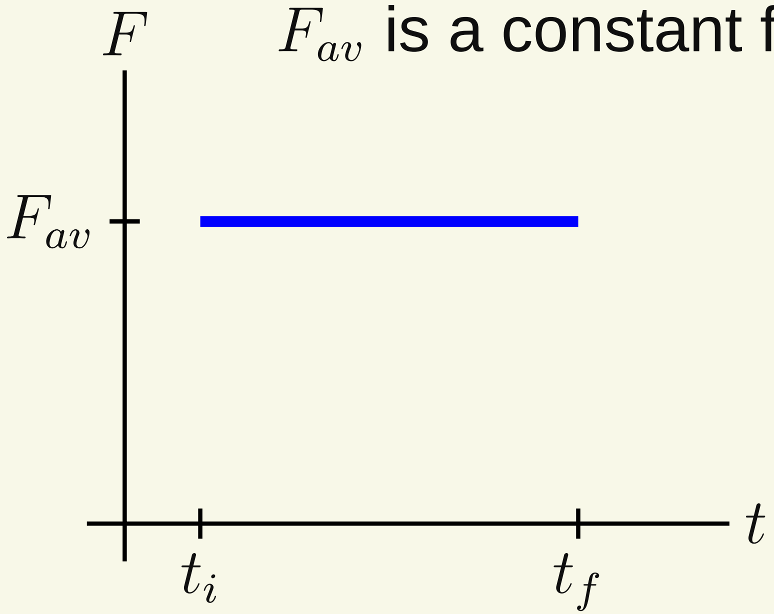


F_{av} is a constant force

Impulse-Momentum Theorem - Variable Forces

The Impulse-Momentum Theorem also holds for non-constant forces!

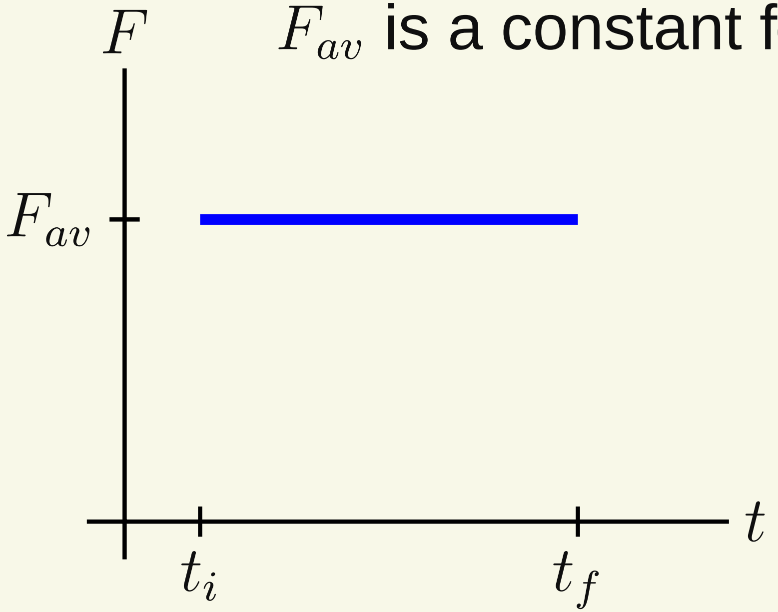
F_{av} is a constant force



Impulse-Momentum Theorem - Variable Forces

The Impulse-Momentum Theorem also holds for non-constant forces!

F_{av} is a constant force

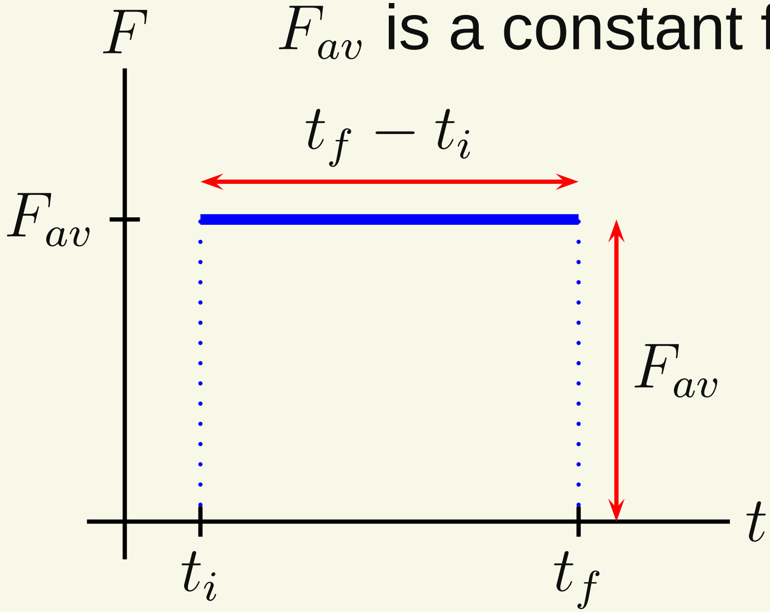


$$J = F_{av}\Delta t = F_{av}\left(t_f - t_i\right)$$

Impulse-Momentum Theorem - Variable Forces

The Impulse-Momentum Theorem also holds for non-constant forces!

F_{av} is a constant force



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Impulse-Momentum Theorem - Variable Forces

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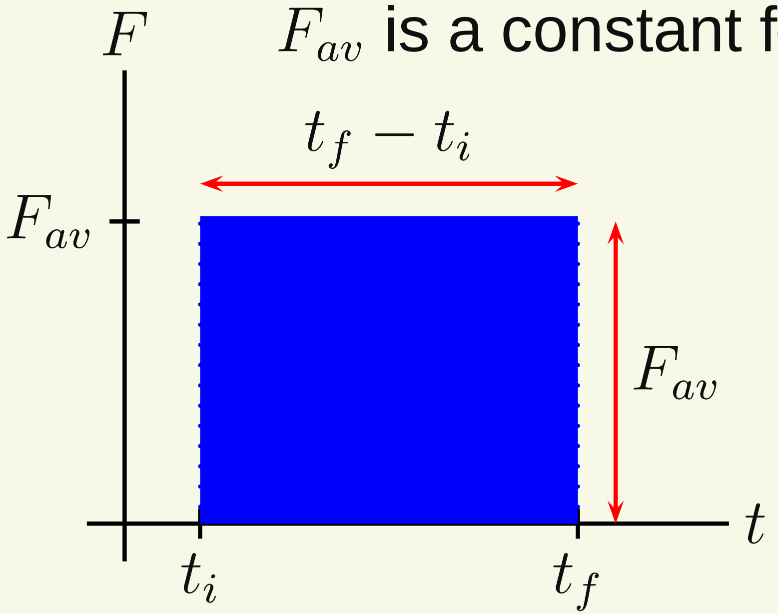

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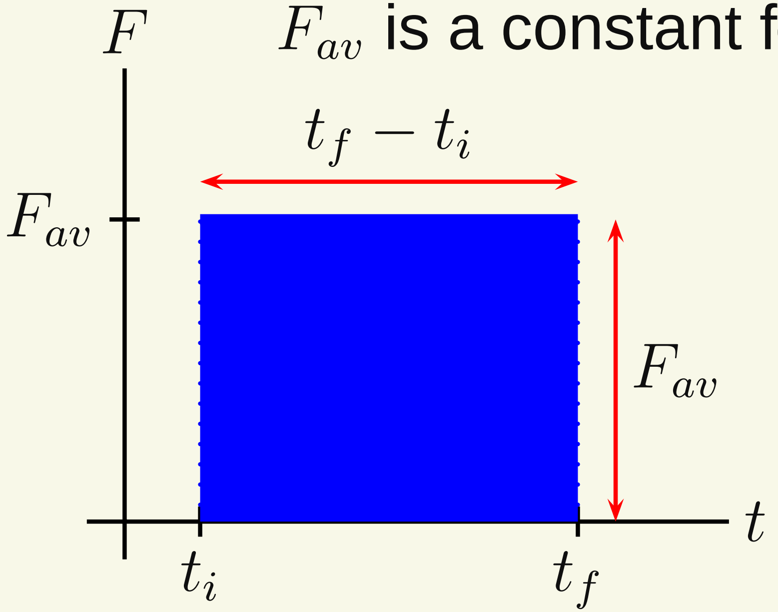

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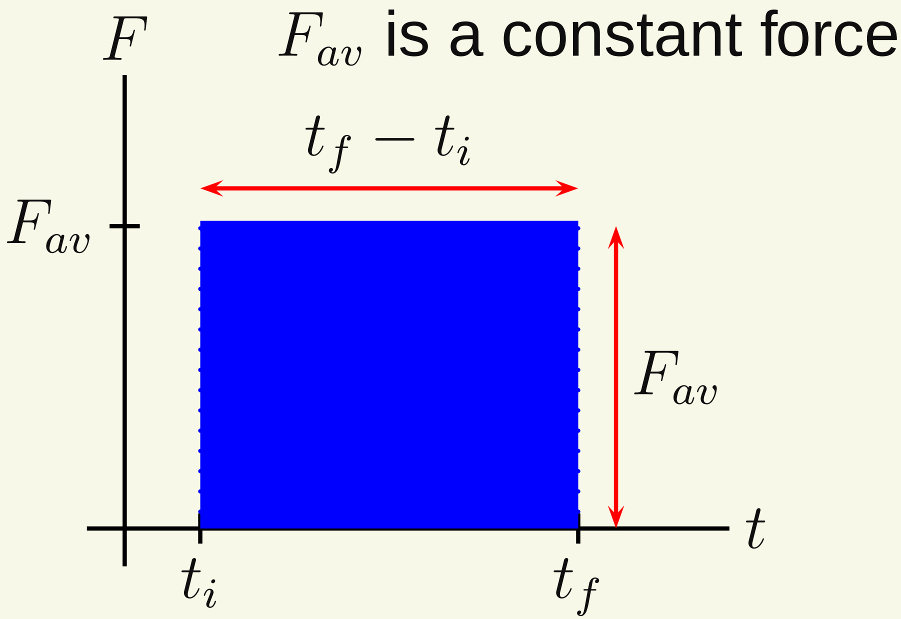

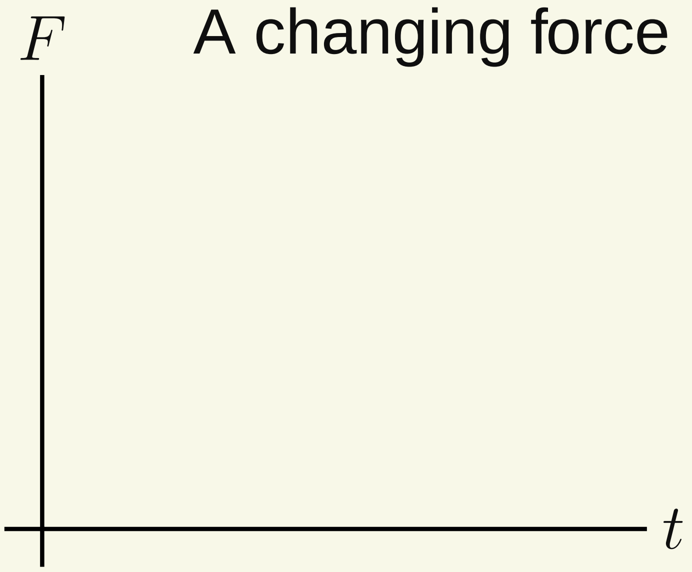

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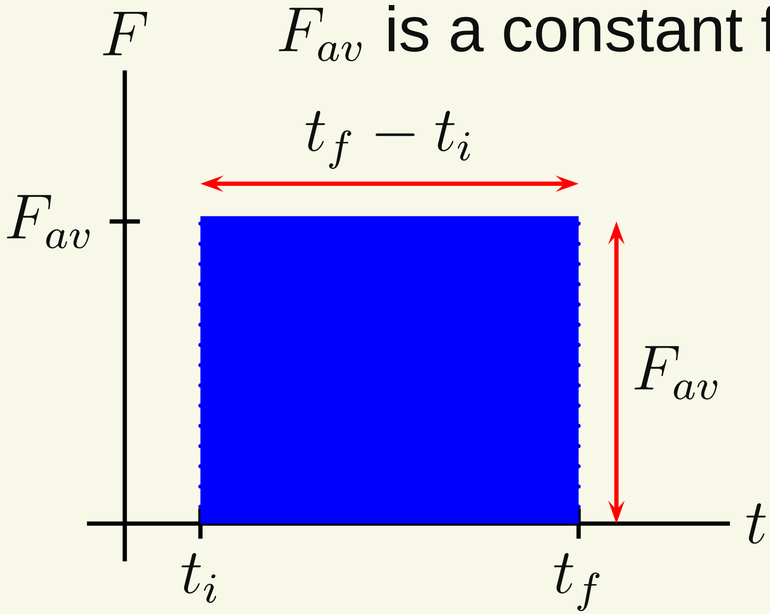
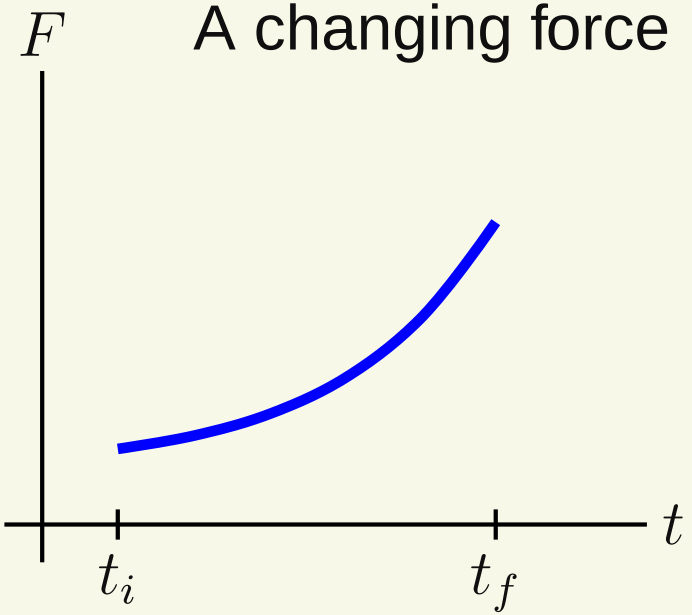


A changing force



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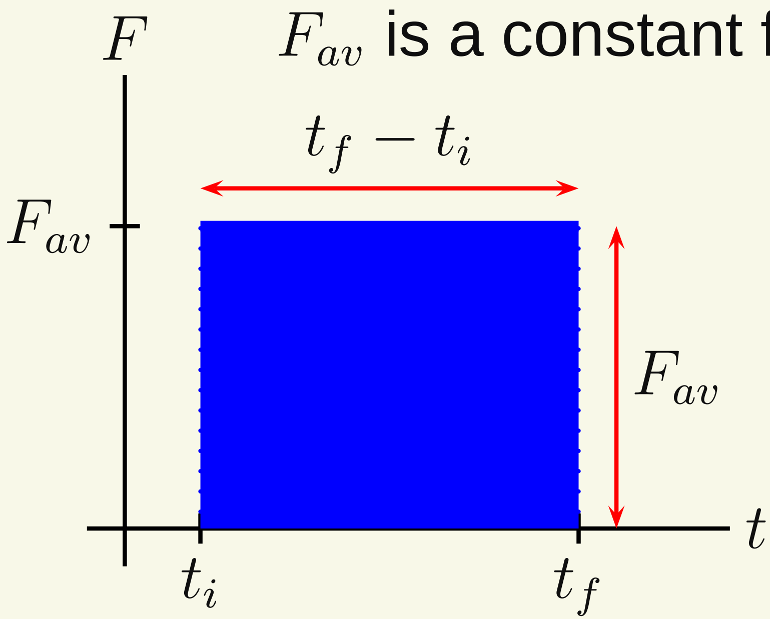

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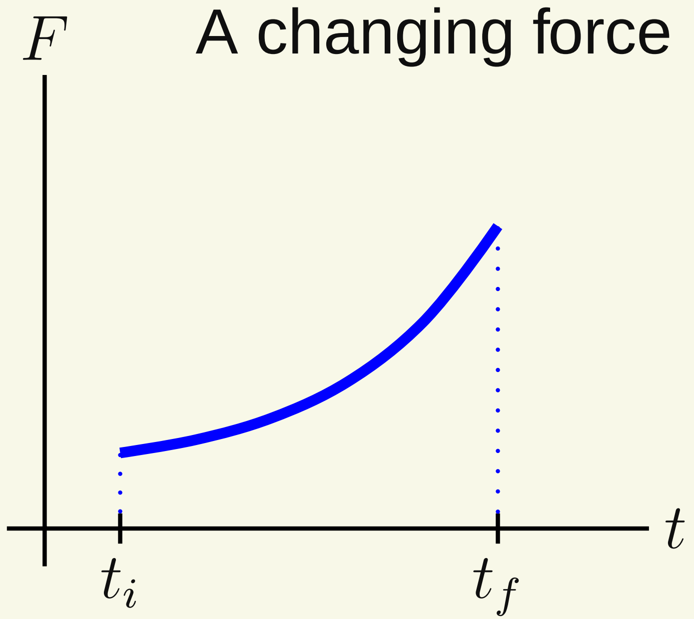

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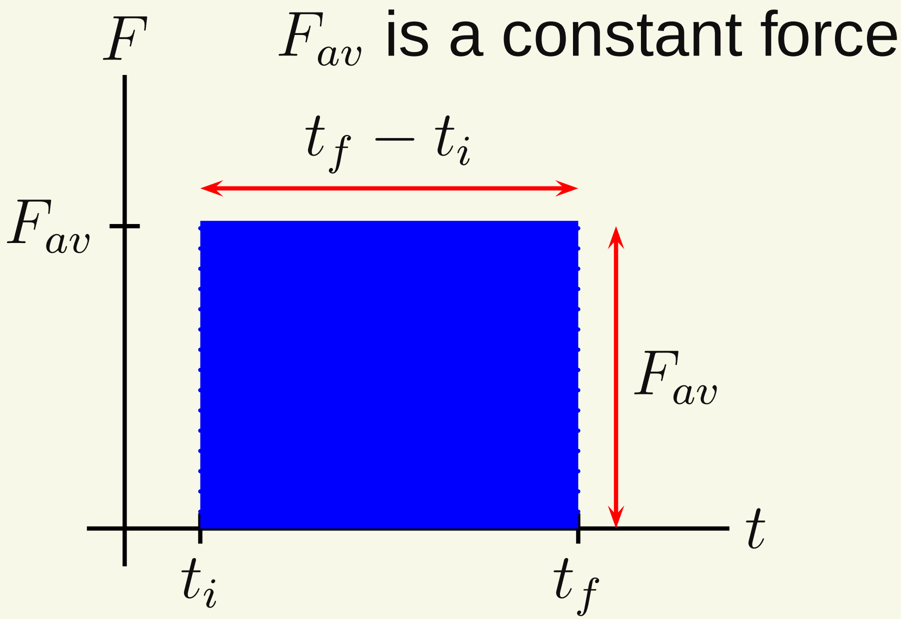

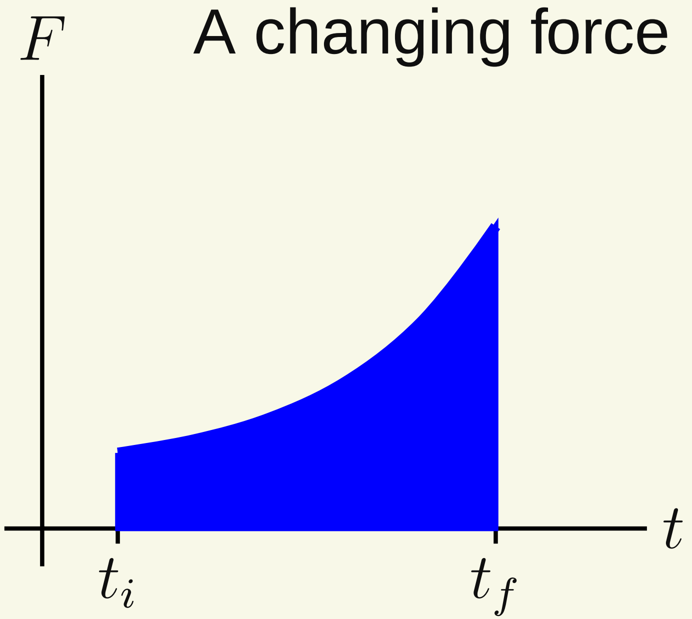

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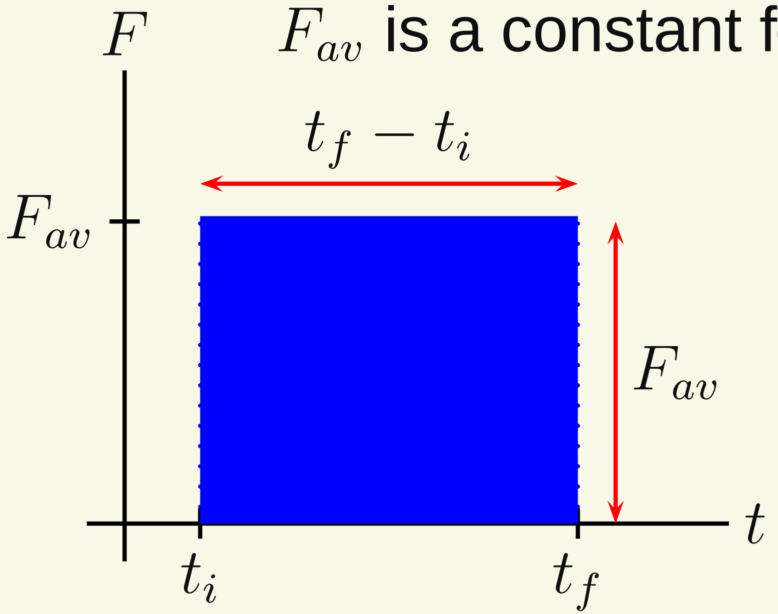

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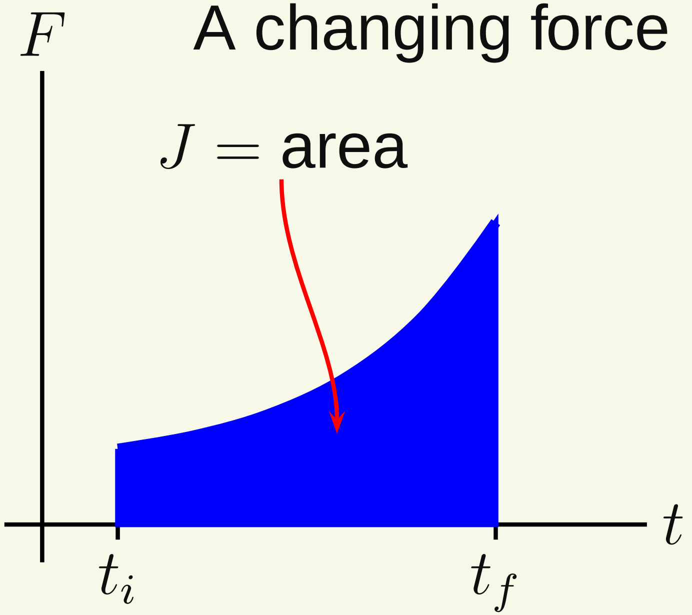

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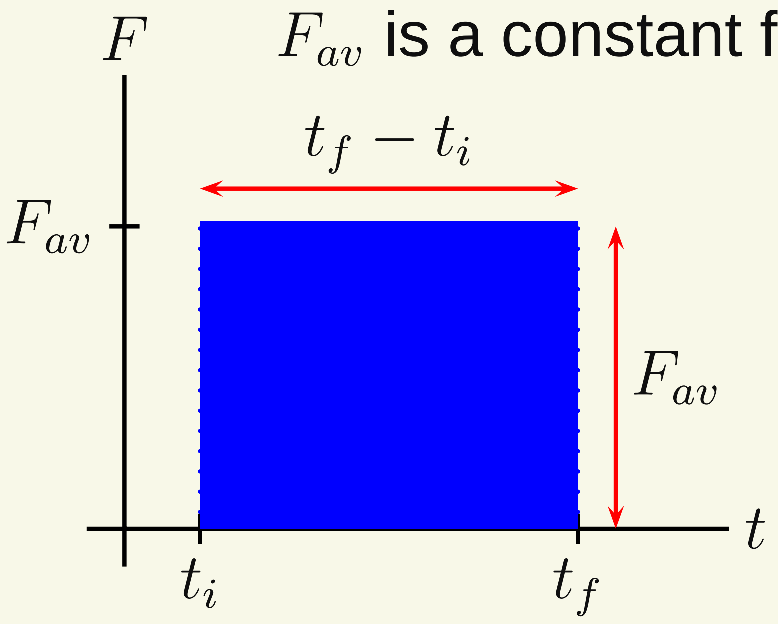

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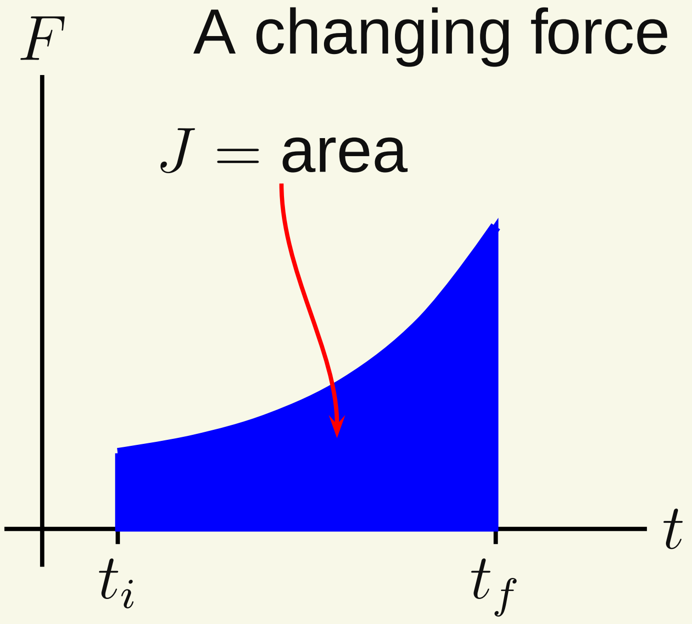

It is beyond the scope of this course but $\boxed{J = \Delta p}$ still!