You can draw here

**GET READY:** Go here and make sure you see the “Are you Ready” Sli.do Q
*Canvas -> Course Content -> Lecture (under Week 9 - Chapter 8)*

# Physics 111 - Lecture 12

November 26, 2020

Do not draw in/on this box!

You can draw here

You can draw here

## Reminders/Announcements

- Lab related:
    - Lab 7 and 8 are the same as last year; highly recommend you come to the scheduled lab and work on the analysis with the TA
    - Report Sheet 8 is due <u>3 days after</u> Lab 8!
    - Department has decided Physics 111 and 112 Labs will **NOT** be evaluated this term (for several reasons)

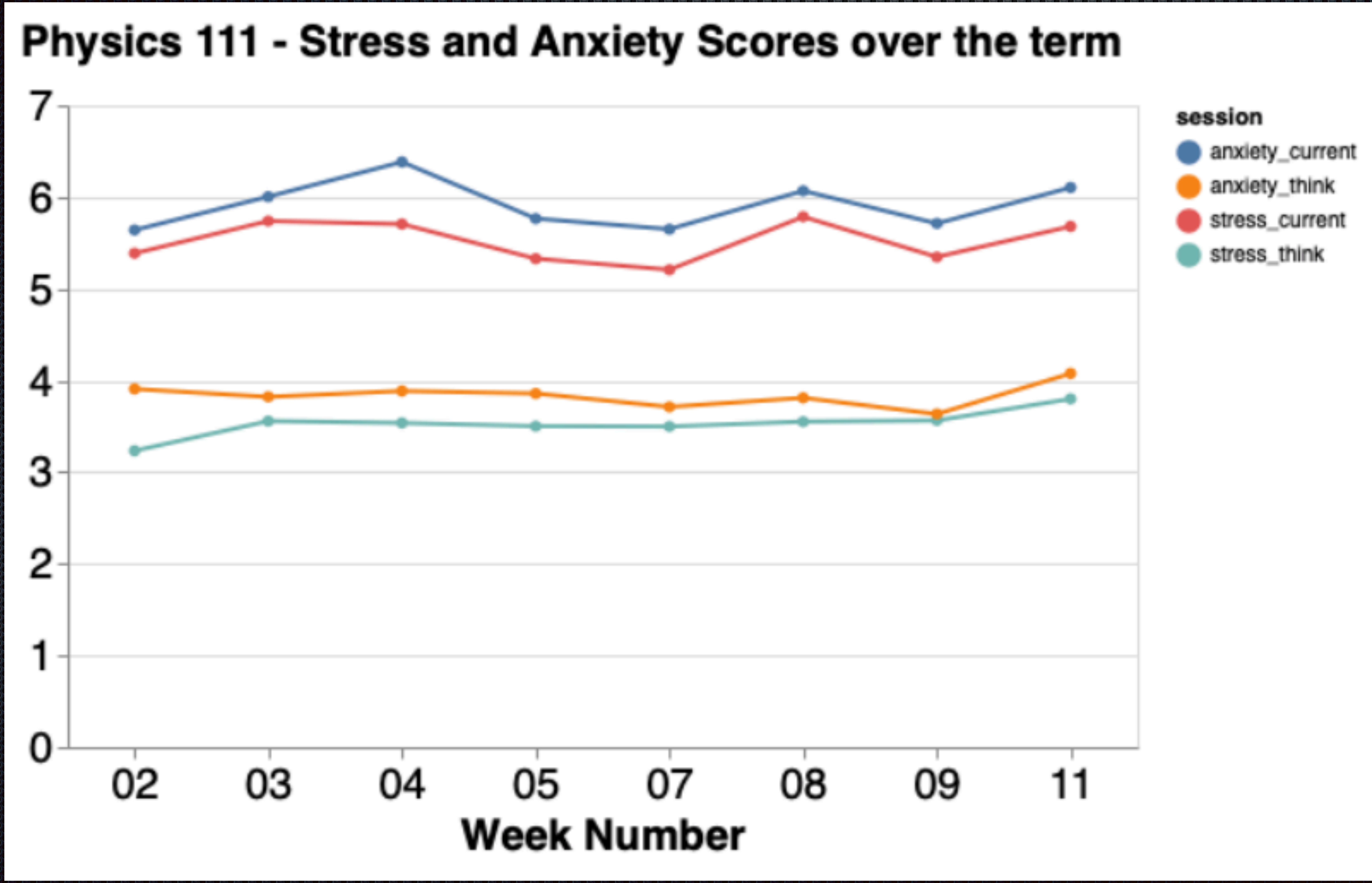
**Reminders/Announcements**

- Test/Bonus Test structure vs. 1 or 2 midterms (LL 5)

| | | |
|---|---|---|
| I would prefer 2 midterms over 5 tests and bonus tests. | 17 respondents | 7 % |
| I would prefer 1 midterm over 5 tests and bonus tests. | 30 respondents | 12 % |
| I would prefer a final exam worth more than 20% of my total course grade. | 13 respondents | 5 % |
| I would prefer 5 tests and bonus tests over 1 OR 2 midterms. | 213 respondents | 88 % |
| No Answer | 2 respondents | 1 % |

## Reminders/Announcements

- Student Stress and anxiety measures over the term (LL1-8)



## Reminders/Announcements

- Next week: Review sessions (recorded) by me and two TAs

- Submit your questions that you want us to do a worked example of by Tuesday on Piazza!

- Review session will likely be on Friday morning…

- It will be recorded

## Reminders/Announcements

- A present for you all…

**Reminders/Announcements**

*(Note: for full disclosure, I am definitely tricking you into doing more physics problems for extra marks so you can be more prepared for the final so you can get a better mark!)*

*This is OPTIONAL! If you have other courses you're struggling more in, obviously spend this time there rather than trying to get an extra few marks on HW or Tests*

# Reminders/Announcements

| | Homework (due Thurs 6 pm) | Test/Bonus Test (Thurs 6pm - Sat 6pm) | Learning Log (Sat 6pm) |
|---|---|---|---|
| Week 1 | - | - | - |
| Week 2 | HW01 - Intro to Mastering Physics | Test 0 **(not for marks)** | Learning Log 1 |
| Week 3 | HW02 - Chapter 2<br>HW03 - Chapter 3 | Test 1 (on Chapters 2 & 3) | Learning Log 2 |
| Week 4 | HW04 - Chapter 4 | Bonus Test 1 | Learning Log 3 |
| Week 5 | HW05 - Chapter 5 | Test 2 (on Chapters 4 and 5) | Learning Log 4 |
| Week 6 | N/A | N/A | N/A |
| Week 7 | HW06 - Chapter 6 | Bonus Test 2 | Learning Log 5 |
| Week 8 | HW07 - Chapter 7 | Test 3 | Learning Log 6 |
| Week 9 | HW08 - Chapter 8 | Bonus Test 3 | Learning Log 7 |
| Week 10 | HW09 - Chapter 9 (deadline extended) | Test 4 (window moved to Sun Nov 15 - Tues Nov 17 due to Fall mini-break) | No Learning Log |
| Week 11 | HW10 | Bonus Test 4 | Learning Log 8 |
| Week 12 | HW 11 | Test 5 | Learning Log 9 |
| Week 13 | No HW!!! | Bonus Test 5 | Learning Log 10 |

# Final Exam Information

# Final Exam Info

The moment you've all been waiting for. Here is what I can tell you now.

The final exam will:

- be conducted on Canvas (most likely).
- be scheduled and a sit-down exam
- have the same rules as Tests (but no test window)
- include multiple choice questions (similar to Tests).
- include short answer questions (similar to Test & Practice Qs).
- require you to solve some problems with symbols/algebra.
- NOT include questions on deriving formulas.
- have some choice in which problems you choose

# Final Exam Practice Qs

| | |
|---|---|
| **Jake Bobowski** | SCI 261 |
| ~Home~ | jake.bobowski@ubc.ca |
| | |
| PHYS 111 | **Introductory Physics for the Physical Sciences I** |
| MWF 08:30-09:30 | Room: COM 201 |
| My Schedule | **Term 1** |

UBC Okanagan

**UBC Canvas Login**

**MasteringPhysics Login**

https://people.ok.ubc.ca/jbobowsk/phys111.html

# Final Exam Practice Qs

2012 PHYS 111-002 Midterm 1
2012 PHYS 111-002 Midterm 1 Solns

2012 PHYS 111-002 Midterm 2
2012 PHYS 111-002 Midterm 2 Solns

2012 PHYS 111 Practice Final
2012 PHYS 111 Practice Final Solns

2012 PHYS 111 Final
2012 PHYS 111 Final Solns

2013 PHYS 111-001 Midterm 1
2013 PHYS 111-001 Midterm 1 Solns

2013 PHYS 111-002 Midterm 1
2013 PHYS 111-002 Midterm 1 Solns

2013 PHYS 111-001 Midterm 2
2013 PHYS 111-001 Midterm 2 Solns

2013 PHYS 111-002 Midterm 2
2013 PHYS 111-002 Midterm 2 Solns

2013 PHYS 111 Practice Final
2013 PHYS 111 Practice Final Solns

2013 PHYS 111 Final
2013 PHYS 111 Final Solns

2014 PHYS 111-001 Midterm 1
2014 PHYS 111-001 Midterm 1 Solns

2014 PHYS 111-001 Midterm 2
2014 PHYS 111-001 Midterm 2 Solns

2014 PHYS 111 Final
2014 PHYS 111 Final Solns

2015 PHYS 111 Practice Midterm 1
2015 PHYS 111 Practice Midterm 1 Solns

2015 PHYS 111-001 Midterm 1
2015 PHYS 111-001 Midterm 1 Solns

2015 PHYS 111 Practice Midterm 2
2015 PHYS 111 Practice Midterm 2 Solns

2015 PHYS 111-001 Midterm 2
2015 PHYS 111-001 Midterm 2 Solns

2015 PHYS 111 Final
2015 PHYS 111 Final Solns

2016 PHYS 111 Final
2016 PHYS 111 Final Solns

2017 PHYS 111-002 Midterm 1
2017 PHYS 111-002 Midterm 1 Solns

2017 PHYS 111-002 Midterm 2
2017 PHYS 111-002 Midterm 2 Solns

2017 PHYS 111 Final
2017 PHYS 111 Final Solns

# Chapter 11
# Important Concepts

## Law of Conservation of Momentum

The total momentum $\vec{P} = \vec{p}_1 + \vec{p}_2 + \cdots$ of an isolated system is a constant. Thus

$$\vec{P}_{\mathrm{f}} = \vec{P}_{\mathrm{i}}$$

## Newton's Second Law

In terms of momentum, Newton's second law is

$$\vec{F} = \frac{d\vec{p}}{dt}$$

## Solving Momentum Conservation Problems

**MODEL** Choose an isolated system or a system that is isolated during at least part of the problem.

**VISUALIZE** Draw a pictorial representation of the system before and after the interaction.

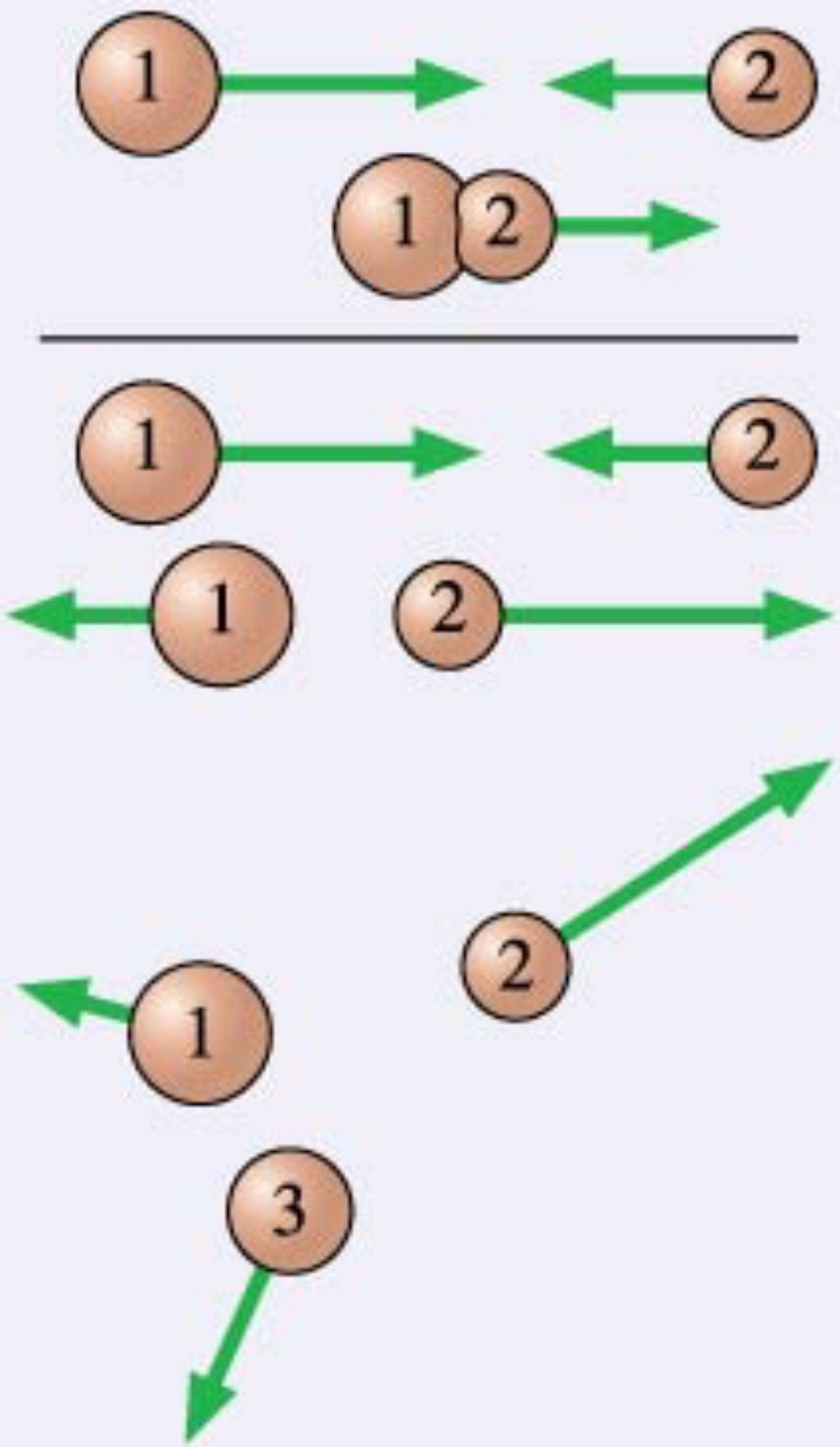
**SOLVE** Write the law of conservation of momentum in terms of vector components:

$$(p_{\mathrm{fx}})_1 + (p_{\mathrm{fx}})_2 + \cdots = (p_{\mathrm{ix}})_1 + (p_{\mathrm{ix}})_2 + \cdots$$
$$(p_{\mathrm{fy}})_1 + (p_{\mathrm{fy}})_2 + \cdots = (p_{\mathrm{iy}})_1 + (p_{\mathrm{iy}})_2 + \cdots$$

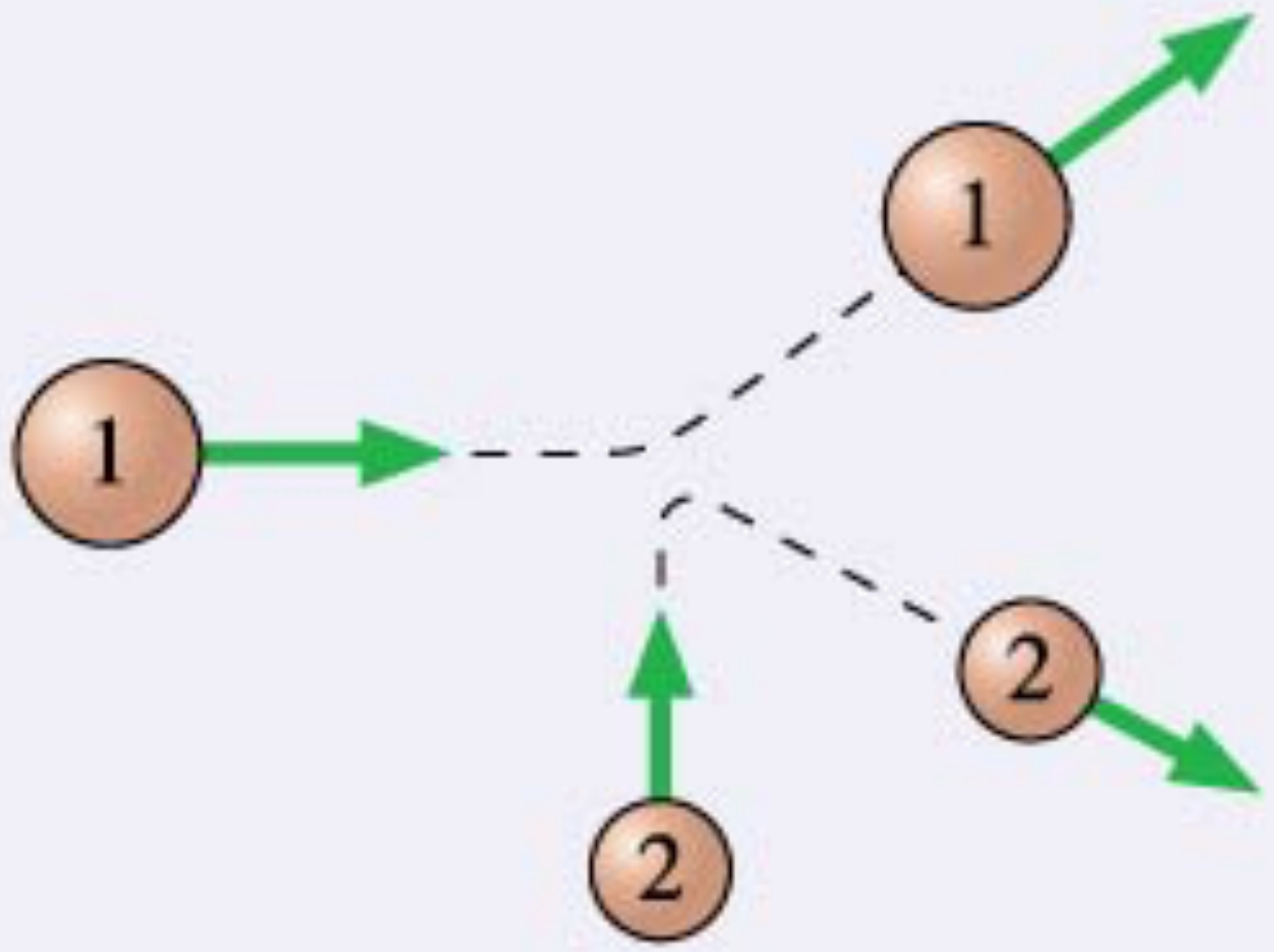
**ASSESS** Is the result reasonable?

**Collisions** In a **perfectly inelastic collision,** two objects stick together and move with a common final velocity. In a **perfectly elastic collision,** they bounce apart and conserve mechanical energy as well as momentum.

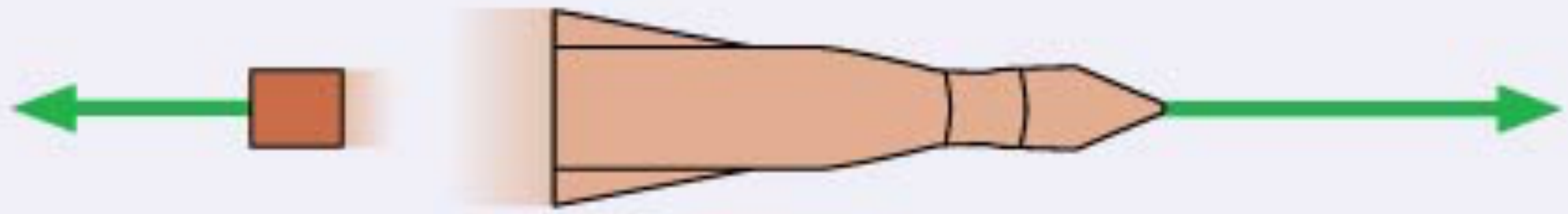
**Explosions** Two or more objects fly apart from each other. Their total momentum is conserved.



**Two dimensions** The same ideas apply in two dimensions. Both the $x$- and $y$-components of $\vec{P}$ must be conserved. This gives two simultaneous equations to solve.

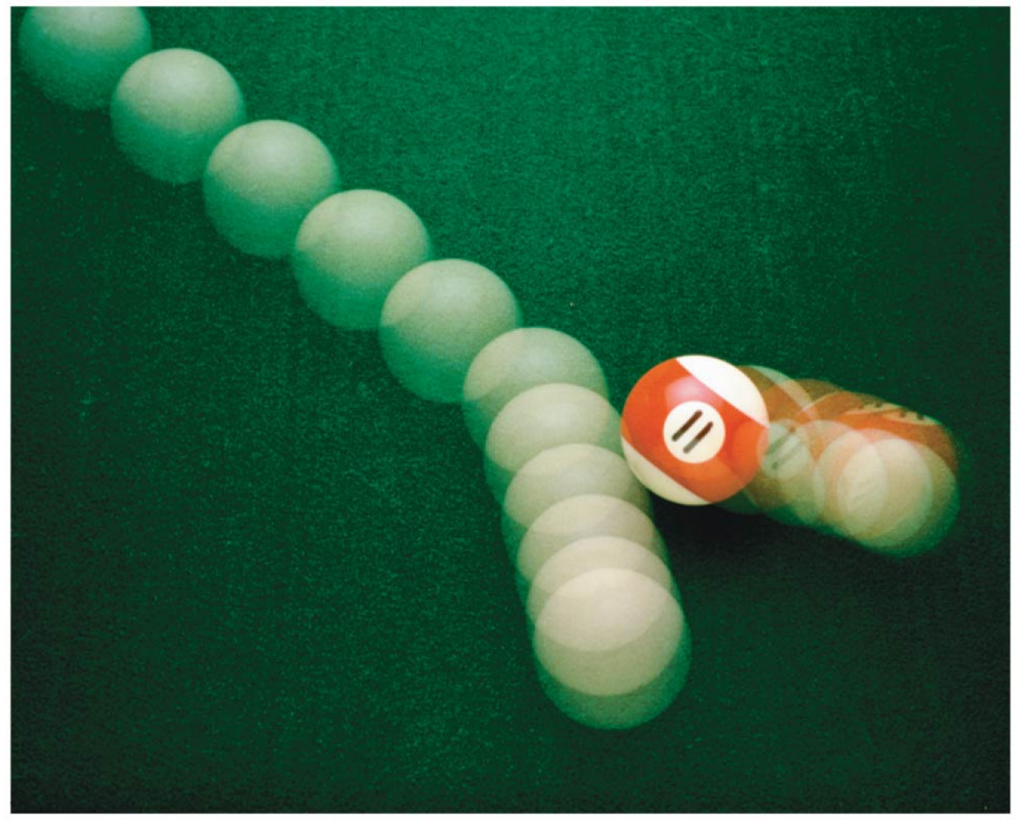



**Rockets** The momentum of the exhaust-gas + rocket system is conserved. **Thrust** is the product of the exhaust speed and the rate at which fuel is burned.



# Momentum in Two Dimensions

- The total momentum $\vec{P}$ is a vector sum of the momenta $\vec{p} = m\vec{v}$ of the individual particles.



- Momentum is conserved only if each component of $\vec{P}$ is conserved:

$$(p_{fx})_1 + (p_{fx})_2 + (p_{fx})_3 + \cdots = (p_{ix})_1 + (p_{ix})_2 + (p_{ix})_3 + \cdots$$

$$(p_{fy})_1 + (p_{fy})_2 + (p_{fy})_3 + \cdots = (p_{iy})_1 + (p_{iy})_2 + (p_{iy})_3 + \cdots$$





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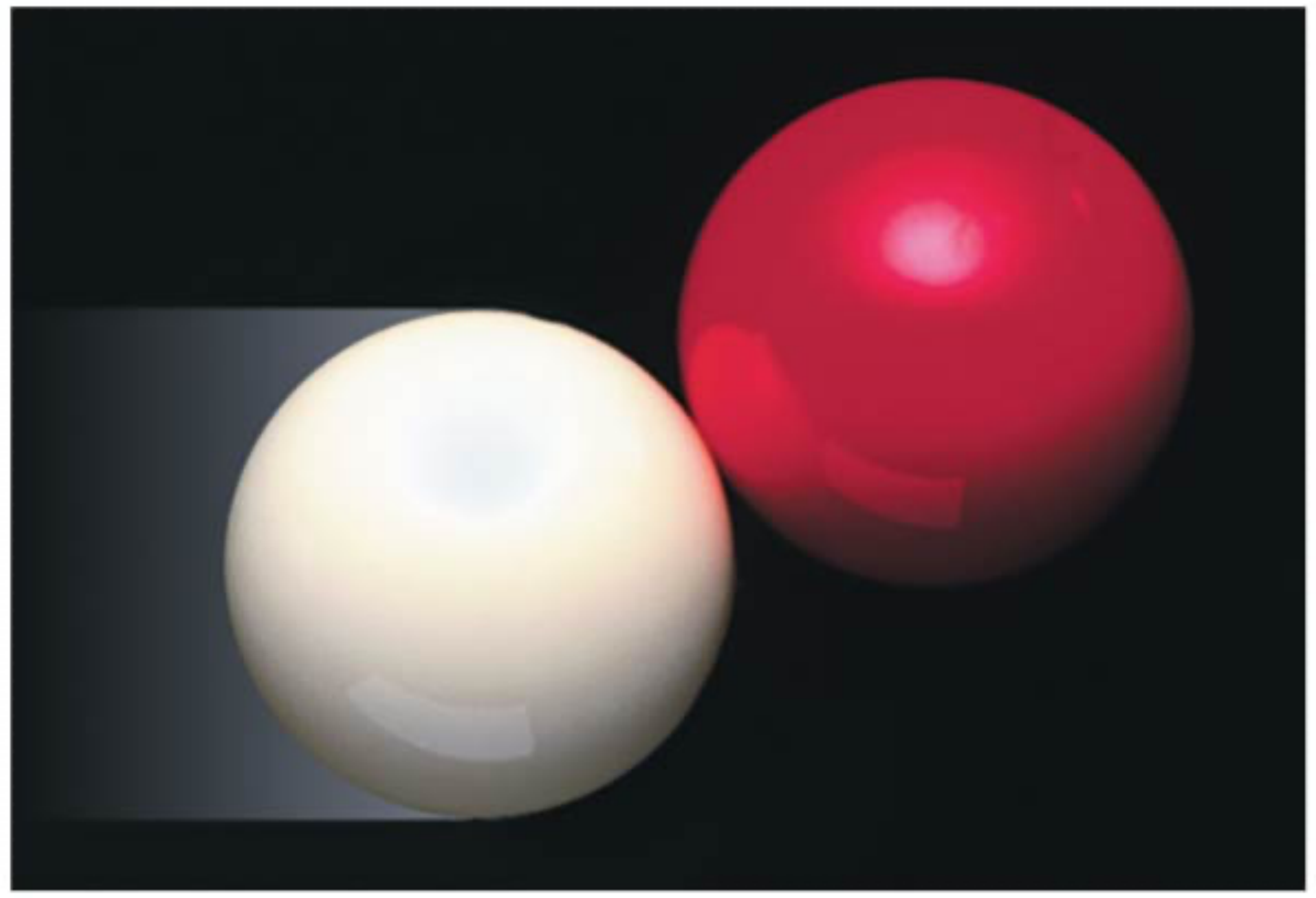
# Elastic Collisions

- During an inelastic collision of two objects, some of the mechanical energy is dissipated inside the objects as thermal energy.
- A collision in which mechanical energy is conserved is called a **perfectly elastic collision**.
- Collisions between two very hard objects, such as two billiard balls or two steel balls, come close to being perfectly elastic.



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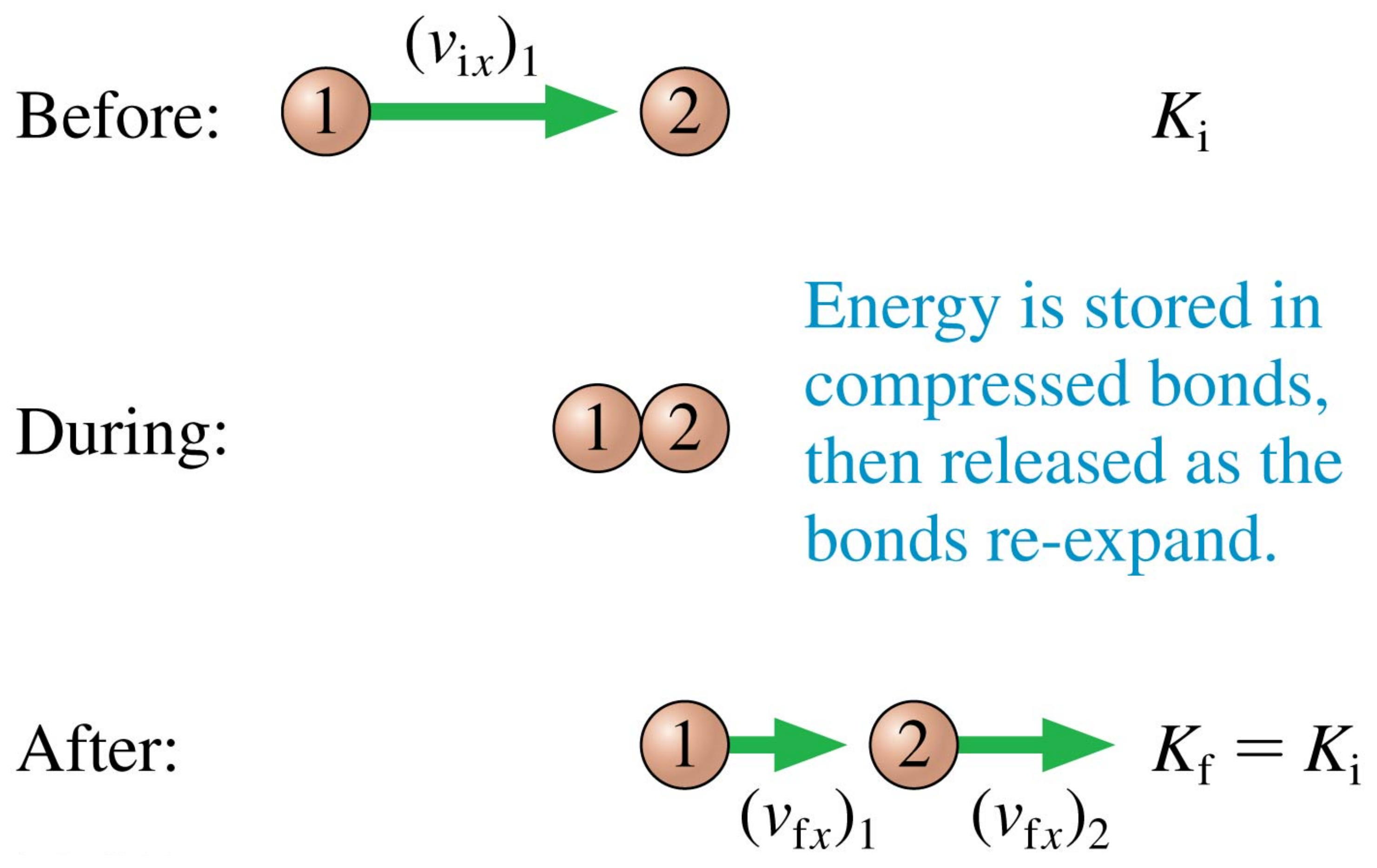
# A Perfectly Elastic Collision

- Consider a head-on, perfectly elastic collision of a ball of mass $m_1$ and initial velocity $(v_{ix})_1$, with a ball of mass $m_2$ initially at rest.
- The balls' velocities after the collision are $(v_{fx})_1$ and $(v_{fx})_2$.




- Momentum is conserved in all isolated collisions.
- In a perfectly elastic collision in which potential energy is not changing, the kinetic energy must also be conserved.

momentum conservation: $$m_1(v_{fx})_1 + m_2(v_{fx})_2 = m_1(v_{ix})_1$$

energy conservation: $$\frac{1}{2}m_1(v_{fx})_1^2 + \frac{1}{2}m_2(v_{fx})_2^2 = \frac{1}{2}m_1(v_{ix})_1^2$$





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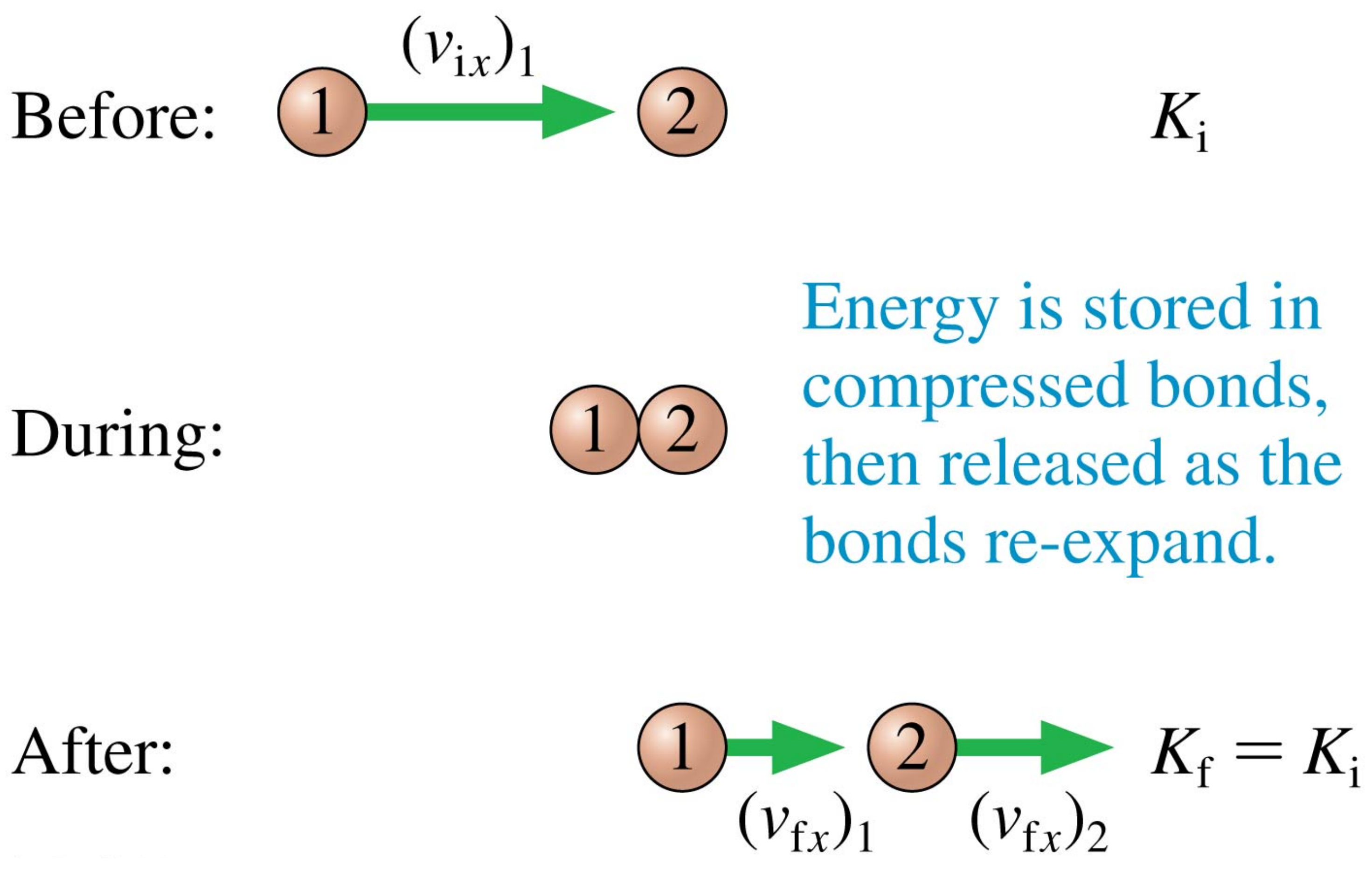
# A Perfectly Elastic Collision

- Simultaneously solving the conservation of momentum equation and the conservation of kinetic energy equations allows us to find the two unknown final velocities.
- The result is




$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1 \qquad (v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$

(perfectly elastic collision with ball 2 initially at rest)





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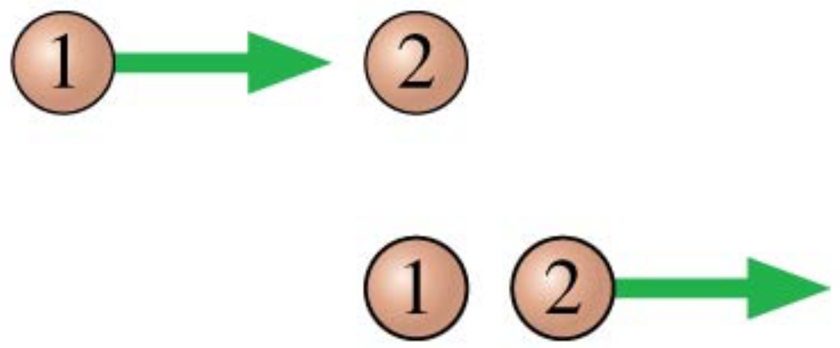
# A Perfectly Elastic Collision: Special Case a

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1 \qquad (v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$

(perfectly elastic collision with ball 2 initially at rest)

- Consider a head-on, perfectly elastic collision of a ball of mass $m_1$ and initial velocity $(v_{ix})_1$, with a ball of mass $m_2$ initially at rest.
- Case a: $m_1 = m_2$

Case a: $m_1 = m_2$




Ball 1 stops. Ball 2 goes forward with $v_{f2} = v_{i1}$.

- Equations 11.29 give $v_{f1} = 0$ and $v_{f2} = v_{i1}$
- The first ball stops and transfers all its momentum to the second ball.





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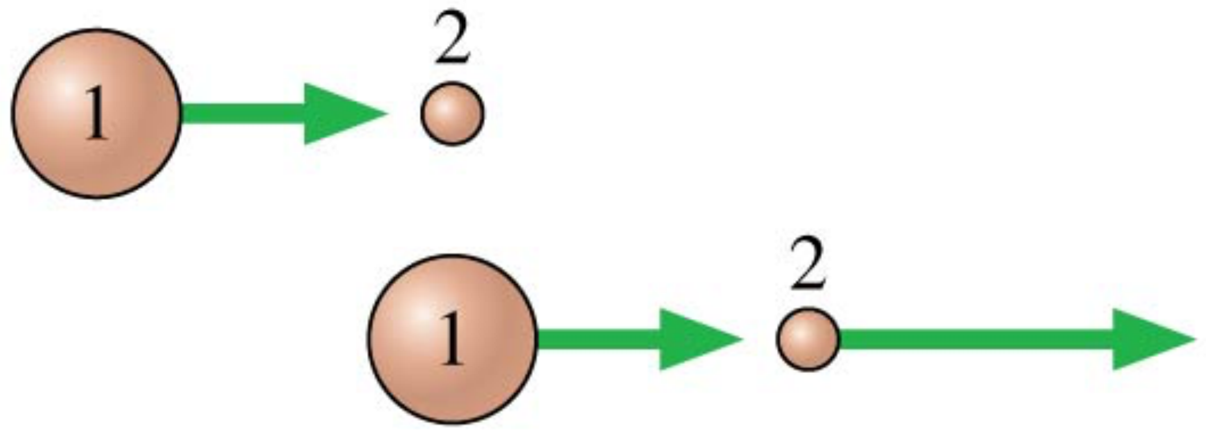
# A Perfectly Elastic Collision: Special Case b

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1 \qquad (v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$

(perfectly elastic collision with ball 2 initially at rest)

- Consider a head-on, perfectly elastic collision of a ball of mass $m_1$ and initial velocity $(v_{ix})_1$, with a ball of mass $m_2$ initially at rest.
- Case b: $m_1 >> m_2$
- Equations 11.29 give $v_{f1} \approx v_{i1}$ and $v_{f2} \approx 2v_{i1}$
- The big first ball keeps going with about the same speed, and the little second ball flies off with about twice the speed of the first ball.

Case b: $m_1 \gg m_2$




Ball 1 hardly slows down. Ball 2 is knocked forward at $v_{f2} \approx 2v_{i1}$.





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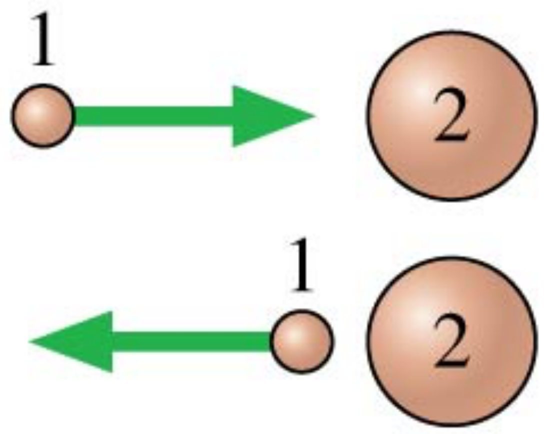
# A Perfectly Elastic Collision: Special Case c

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1 \qquad (v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$

(perfectly elastic collision with ball 2 initially at rest)

- Consider a head-on, perfectly elastic collision of a ball of mass $m_1$ and initial velocity $(v_{ix})_1$, with a ball of mass $m_2$ initially at rest.
- Case c: $m_1 << m_2$

Case c: $m_1 \ll m_2$




Ball 1 bounces off ball 2 with almost no loss of speed. Ball 2 hardly moves.

- Equations 11.29 give $v_{f1} \approx -v_{i1}$ and $v_{f2} \approx 0$
- The little first ball rebounds with about the same speed, and the big second ball hardly moves at all.





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# Course Evaluations!

Please do them -
I would like to target 80% response rate

Canvas >> Course Evaluation

*Reminder*: Labs are not being evaluated this term

# Chapter 11
# Clicker Questions

# Chapter 11
# Clicker Questions

A B C D E

New: Put a Zoom stamp in the box to lock in your choice (trying this rather than Slido)


Bullet Block Experiment
Will the spinning block
higher
the same height
not as high
Or will it go higher?

# Reading Question 11.4

The total momentum of a system is conserved

A. Always.
B. If the system is isolated.
C. If the forces are conservative.
D. Never; it's just an approximation.





A B C D E

# Reading Question 11.4

The total momentum of a system is conserved

A. Always.
✔ **B. If the system is isolated.**
C. If the forces are conservative.
D. Never; it's just an approximation.





A B C D E

# Reading Question 11.5

In an *inelastic collision*,

A. Impulse is conserved.
B. Momentum is conserved.
C. Force is conserved.
D. Energy is conserved.
E. Elasticity is conserved.





A B C D E

# Reading Question 11.5

In an *inelastic collision*,

A. Impulse is conserved.
**B. Momentum is conserved.**
C. Force is conserved.
D. Energy is conserved.
E. Elasticity is conserved.




A B C D E

# Reading Question 11.6

A *perfectly elastic collision* is a collision

A. Between two springs.
B. That conserves thermal energy.
C. That conserves kinetic energy.
D. That conserves potential energy.
E. That conserves mechanical energy.





A B C D E

# Reading Question 11.6

A *perfectly elastic collision* is a collision

A. Between two springs.

B. That conserves thermal energy.

C. That conserves kinetic energy.

D. That conserves potential energy.

✔ **E. That conserves mechanical energy.**





A

B

C

D

E

# QuickCheck 11.8

A mosquito and a truck have a head-on collision. Splat! Which has a larger change of momentum?

A. The mosquito
B. The truck
C. They have the same change of momentum.
D. Can’t say without knowing their initial velocities.




A B C D E

# QuickCheck 11.8

A mosquito and a truck have a head-on collision. Splat! Which has a larger change of momentum?

A. The mosquito.

B. The truck.

✔ **C. They have the same change of momentum.**

D. Can't say without knowing their initial velocities.

Momentum is conserved, so $\Delta p_{\text{mosquito}} + \Delta p_{\text{truck}} = 0$.
Equal magnitude (but opposite sign) changes in momentum.



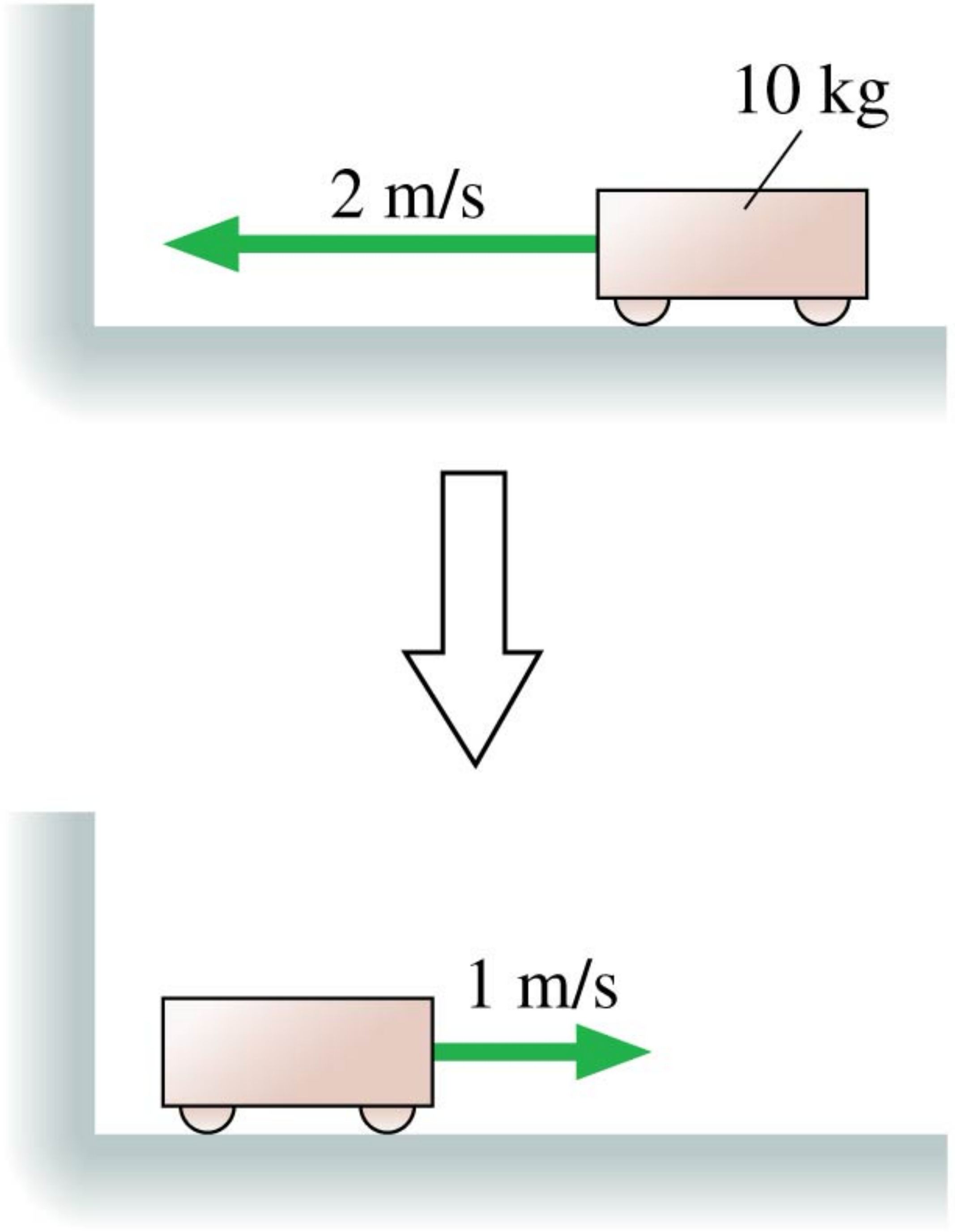


A B C D E

# QuickCheck 11.1

The cart's change of momentum $\Delta p_x$ is

A. –20 kg m/s
B. –10 kg m/s
C. 0 kg m/s
D. 10 kg m/s
E. 30 kg m/s



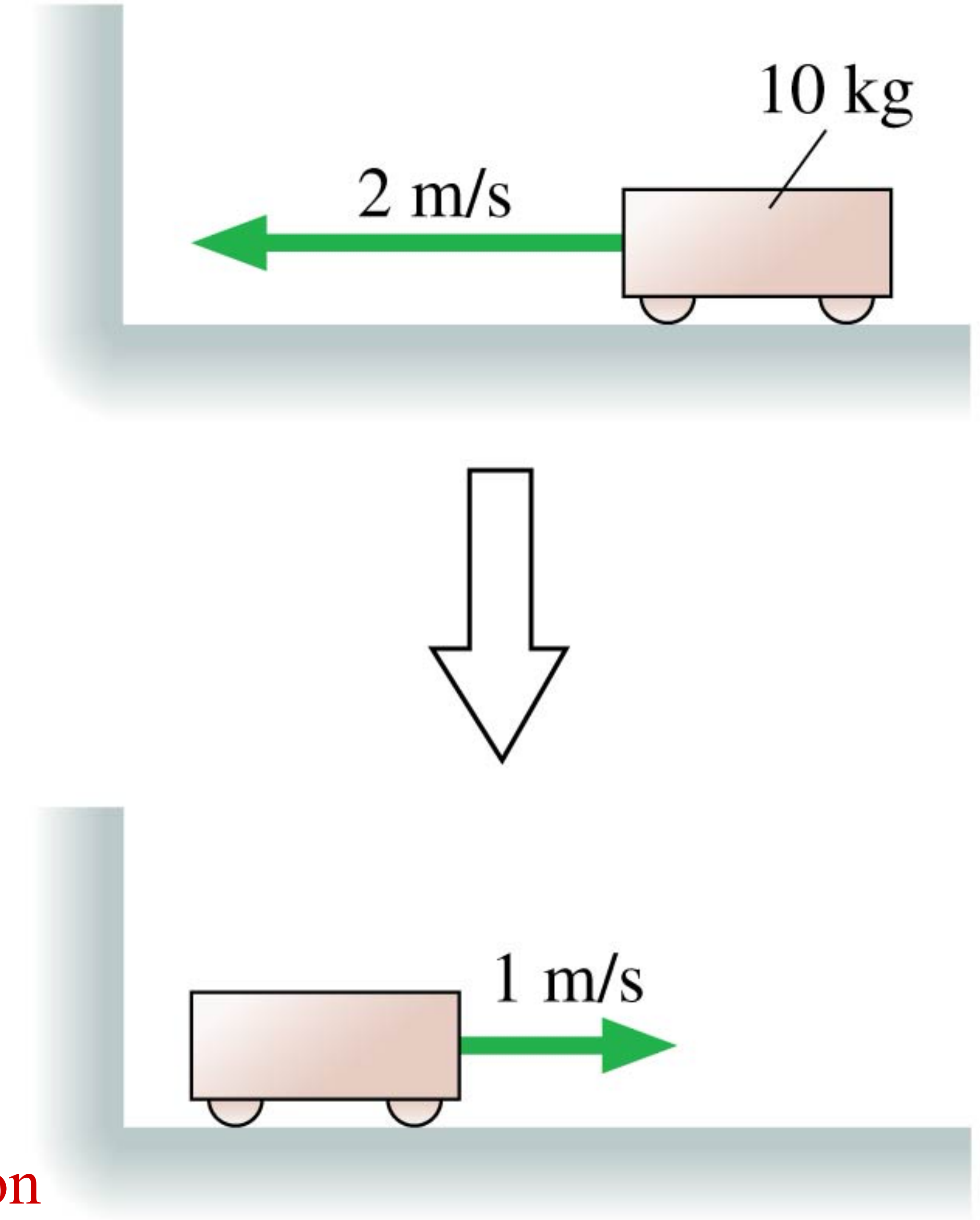





A B C D E

# QuickCheck 11.1

The cart's change of momentum $\Delta p_x$ is




A. –20 kg m/s
B. –10 kg m/s
C. 0 kg m/s
D. 10 kg m/s
✔ E. **30 kg m/s**

$\Delta p_x = 10 \text{ kg m/s} - (-20 \text{ kg m/s}) = 30 \text{ kg m/s}$

<u>Negative</u> initial momentum because motion is to the left and $v_x < 0$.

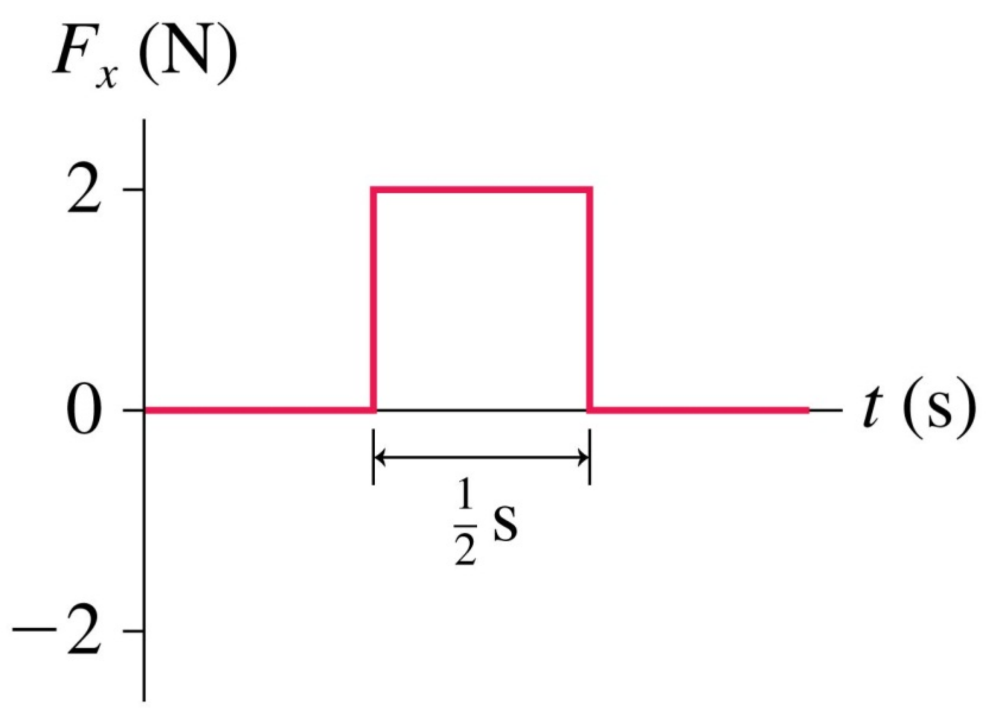




A B C D E

# QuickCheck 11.2

A 2.0 kg object moving to the right with speed 0.50 m/s experiences the force shown. What are the object's speed and direction after the force ends?




A. 0.50 m/s left

B. At rest

C. 0.50 m/s right

D. 1.0 m/s right

E. 2.0 m/s right

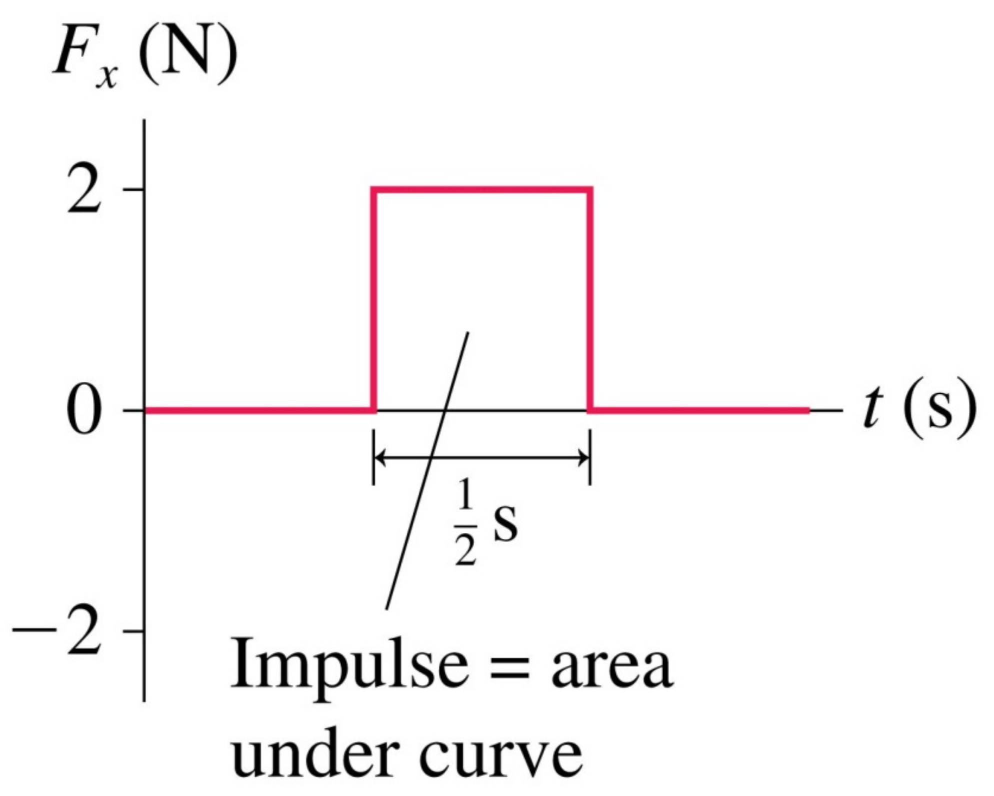




A B C D E

# QuickCheck 11.2

A $2.0\ \mathrm{kg}$ object moving to the right with speed $0.50\ \mathrm{m/s}$ experiences the force shown. What are the object's speed and direction after the force ends?




A. $0.50\ \mathrm{m/s}$ left

B. At rest

C. $0.50\ \mathrm{m/s}$ right

✔ **D. $\mathbf{1.0\ m/s}$ right**

E. $2.0\ \mathrm{m/s}$ right

$\Delta p_x = J_x$ or $p_{fx} = p_{ix} + J_x$



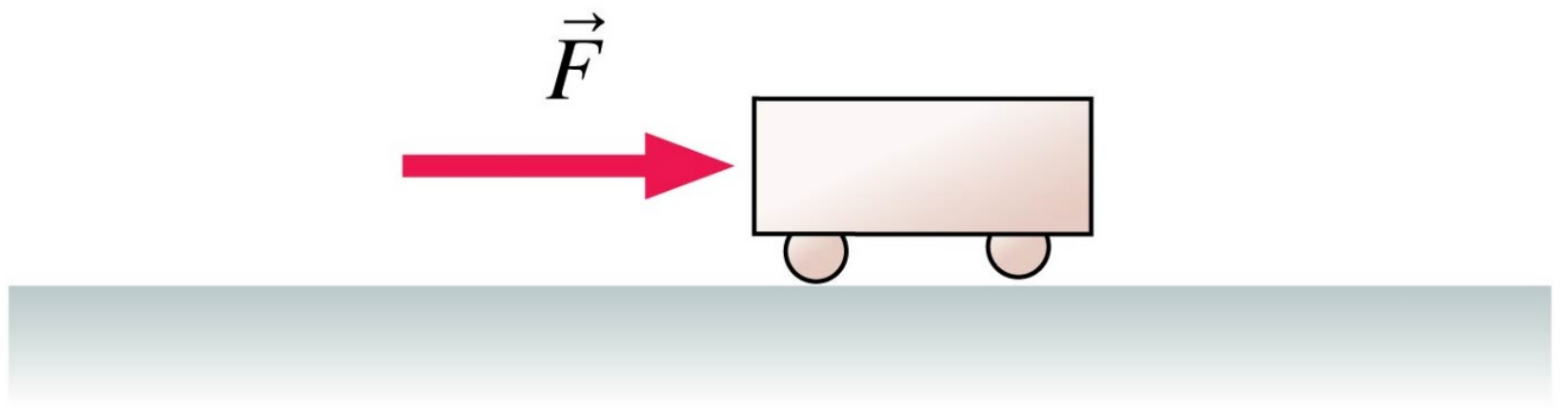


A B C D E

# QuickCheck 11.4

A force pushes the cart for $1\ \mathrm{s}$, starting from rest. To achieve the same speed with a force half as big, the force would need to push for

A. $\frac{1}{4}\ \mathrm{s}$
B. $\frac{1}{2}\ \mathrm{s}$
C. $1\ \mathrm{s}$
D. $2\ \mathrm{s}$
E. $4\ \mathrm{s}$








A B C D E

# QuickCheck 11.4

A force pushes the cart for $1\ \mathrm{s}$, starting from rest. To achieve the same speed with a force half as big, the force would need to push for

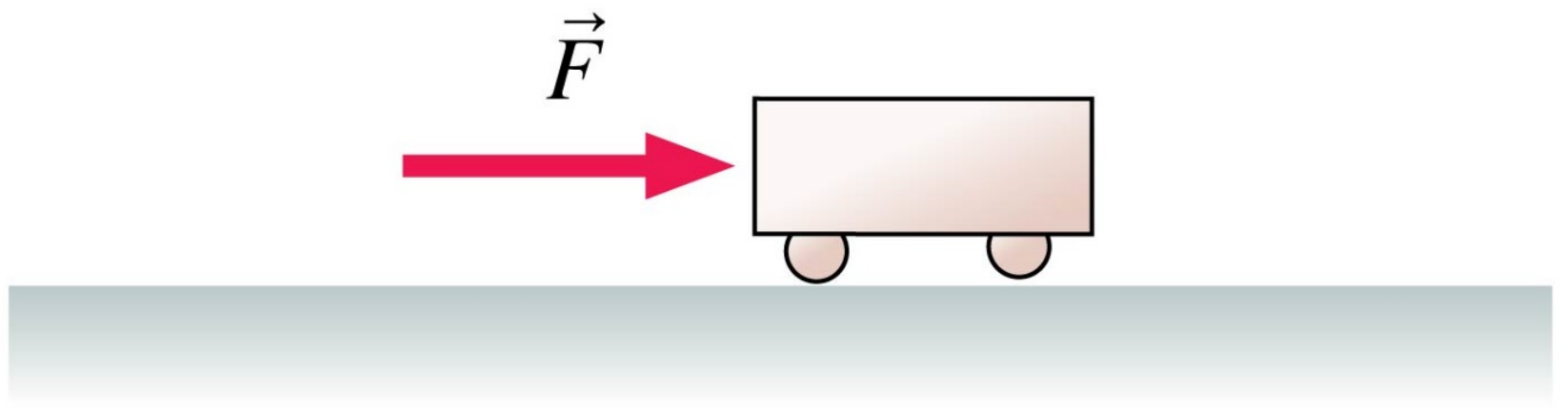
A. $\frac{1}{4}\ \mathrm{s}$

B. $\frac{1}{2}\ \mathrm{s}$

C. $1\ \mathrm{s}$

**D. $2\ \mathrm{s}$**

E. $4\ \mathrm{s}$








A

B

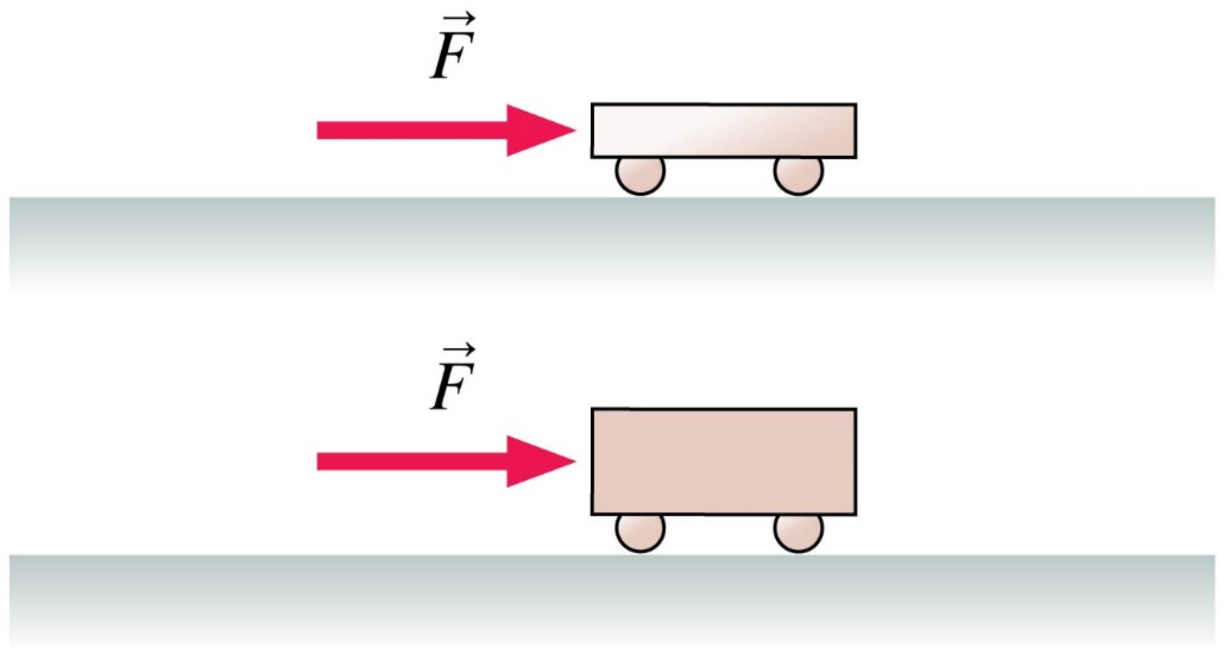
C

D

E

# QuickCheck 11.5

A light plastic cart and a heavy steel cart are both pushed with the same force for $1.0\ \text{s}$, starting from rest. After the force is removed, the momentum of the light plastic cart is ________ that of the heavy steel cart.




A. greater than

B. equal to

C. less than

D. Can’t say. It depends on how big the force is.

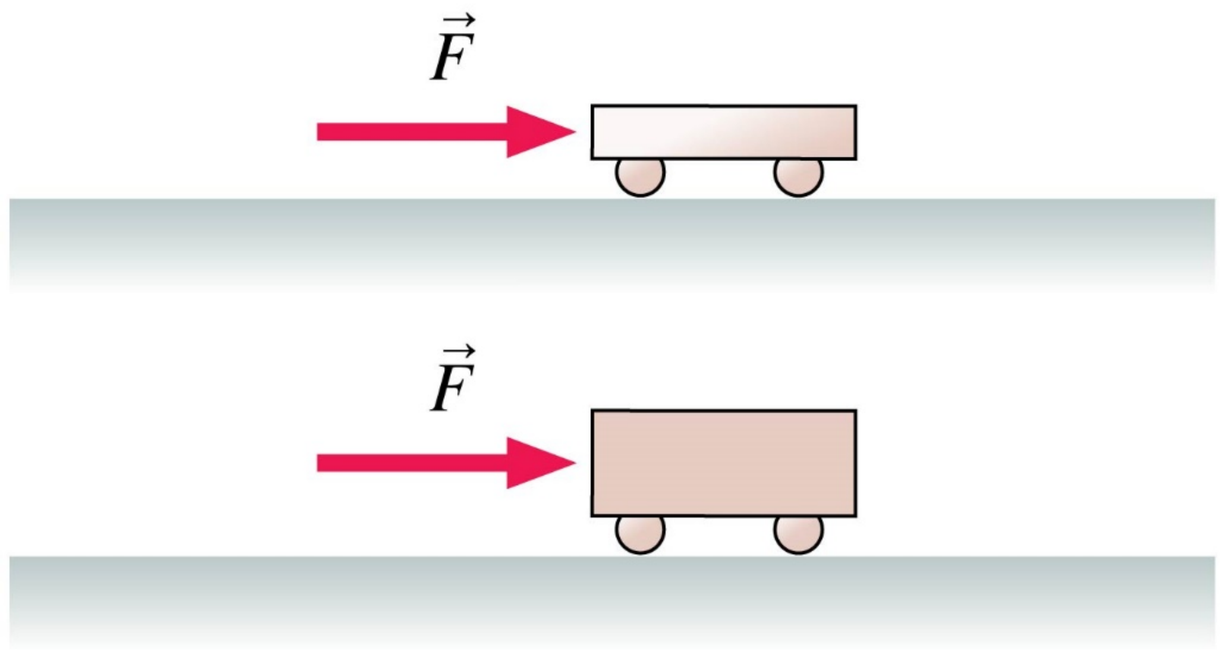




A B C D E

# QuickCheck 11.5

A light plastic cart and a heavy steel cart are both pushed with the same force for $1.0$ s, starting from rest. After the force is removed, the momentum of the light plastic cart is ________ that of the heavy steel cart.




A. greater than

✔ **B. equal to**

C. less than

D. Can't say. It depends on how big the force is.

Same force, same time → same impulse
Same impulse → same change of momentum

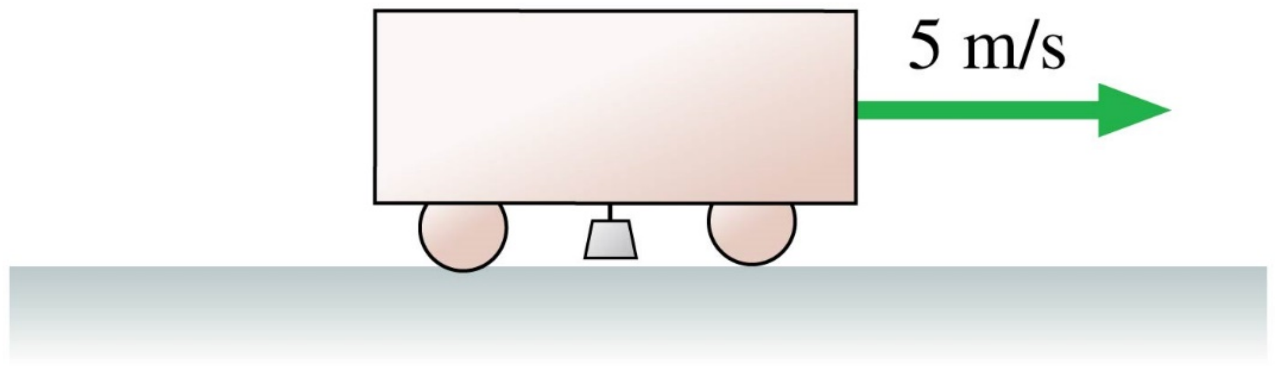




A B C D E

# QuickCheck 11.12

A cart is rolling at 5 m/s. A heavy lead weight is suspended by a thread beneath the cart. Suddenly the thread breaks and the weight falls. Immediately afterward, the speed of the cart is




A. Less than 5 m/s

B. Still 5 m/s

C. More than 5 m/s





A

B

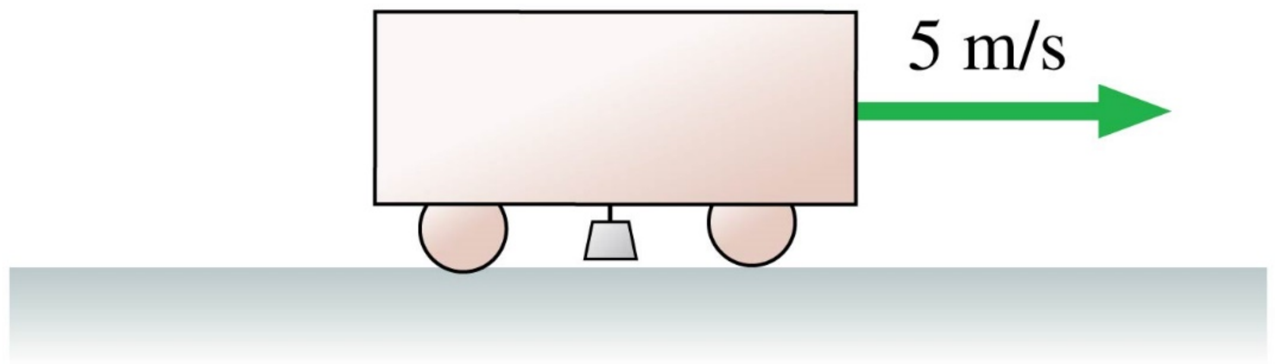
C

D

E

# QuickCheck 11.12

A cart is rolling at 5 m/s. A heavy lead weight is suspended by a thread beneath the cart. Suddenly the thread breaks and the weight falls. Immediately afterward, the speed of the cart is




A. Less than 5 m/s

**B. Still 5 m/s**

C. More than 5 m/s

No external forces to exert an impulse. The falling weight still has forward momentum.





A B C D E

## EXAMPLE 11.6 | Recoil

A 10 g bullet is fired from a 3.0 kg rifle with a speed of 500 m/s. What is the recoil speed of the rifle?

**MODEL** The rifle causes a small mass of gunpowder to explode, and the expanding gas then exerts forces on *both* the bullet and the rifle. Let's define the system to be bullet + gas + rifle. The forces due to the expanding gas during the explosion are internal forces, within the system. Any friction forces between the bullet and the rifle as the bullet travels down the barrel are also internal forces. Gravity is balanced by the upward force of the person holding the rifle, so $\vec{F}_{net} = \vec{0}$. This is an isolated system and the law of conservation of momentum applies.

## EXAMPLE 11.6 Recoil

A 10 g bullet is fired from a 3.0 kg rifle with a speed of 500 m/s. What is the recoil speed of the rifle?

**MODEL** The rifle causes a small mass of gunpowder to explode, and the expanding gas then exerts forces on *both* the bullet and the rifle. Let's define the system to be bullet + gas + rifle. The forces due to the expanding gas during the explosion are internal forces, within the system. Any friction forces between the bullet and the rifle as the bullet travels down the barrel are also internal forces. Gravity is balanced by the upward force of the person holding the rifle, so $\vec{F}_{net} = \vec{0}$. This is an isolated system and the law of conservation of momentum applies.

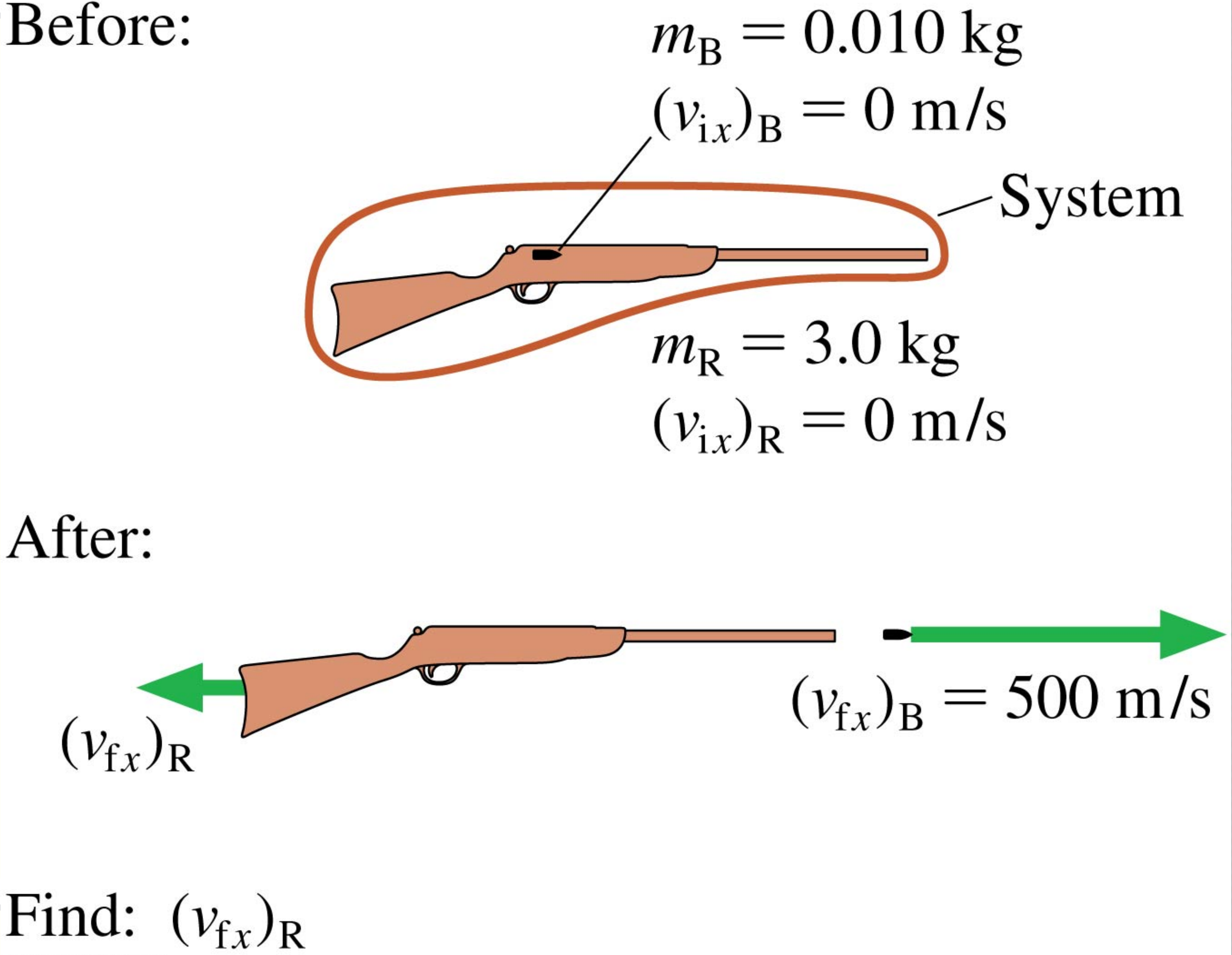
## EXAMPLE 11.6 Recoil

**VISUALIZE** **FIGURE 11.24** shows a pictorial representation before and after the bullet is fired.

## EXAMPLE 11.6 Recoil

A 10 g bullet is fired from a 3.0 kg rifle with a speed of 500 m/s. What is the recoil speed of the rifle?

**MODEL** The rifle causes a small mass of gunpowder to explode, and the expanding gas then exerts forces on *both* the bullet and the rifle. Let's define the system to be bullet + gas + rifle. The forces due to the expanding gas during the explosion are internal forces, within the system. Any friction forces between the bullet and the rifle as the bullet travels down the barrel are also internal forces. Gravity is balanced by the upward force of the person holding the rifle, so $\vec{F}_{net} = \vec{0}$. This is an isolated system and the law of conservation of momentum applies.

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**VISUALIZE** **FIGURE 11.24** shows a pictorial representation before and after the bullet is fired.

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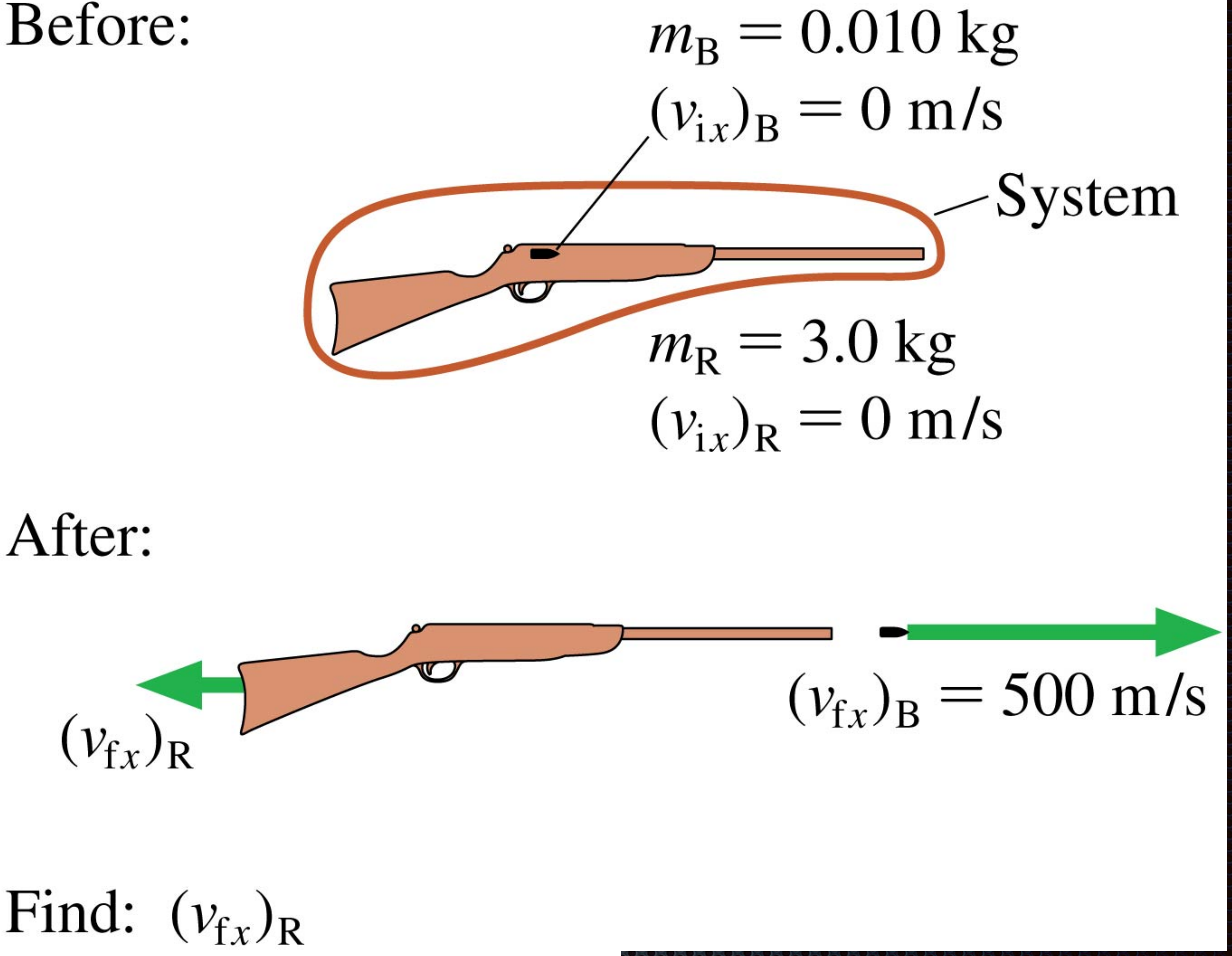



## EXAMPLE 11.6 | Recoil


**SOLVE** The $x$-component of the total momentum is $P_x = (p_x)_B + (p_x)_R + (p_x)_{gas}$. Everything is at rest before the trigger is pulled, so the initial momentum is zero. After the trigger is pulled, the momentum of the expanding gas is the sum of the momenta of all the molecules in the gas. For every molecule moving in the forward direction with velocity $v$ and momentum $mv$ there is, on average, another molecule moving in the opposite direction with velocity $-v$ and thus momentum $-mv$. When the values are summed over the enormous number of molecules in the gas, we will be left with $p_{gas} \approx 0$. In addition, the mass of the gas is much less than that of the rifle or bullet. For both reasons, we can reasonably neglect the momentum of the gas. The law of conservation of momentum is thus

$$P_{fx} = m_B (v_{fx})_B + m_R (v_{fx})_R = P_{ix} = 0$$

Solving for the rifle's velocity, we find

$$(v_{fx})_R = -\frac{m_B}{m_R}(v_{fx})_B = -\frac{0.010 \text{ kg}}{3.0 \text{ kg}} \times 500 \text{ m/s} = -1.7 \text{ m/s}$$

The minus sign indicates that the rifle's recoil is to the left. The recoil *speed* is 1.7 m/s.