

# Momentum & Newton's 3 Laws

• **Mass** - The amount of matter (stuff) in something.

• Symbol: **m**

• Example: **the mass of a rock is 2 kg.**

• **Velocity** – How fast (speed) and which direction something is moving.

• Symbol: **v**

• Example: **the rock is falling down with a speed of 2 m/s.**

• **Momentum** – Mass in motion

• Symbol: **p**

• Momentum equals mass times velocity, i.e.,  **$p = mv$** .

• Example: **the rock is falling down with momentum  
(2 kg) x (2 m/s) = 4 kg m/s**

• **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

# Momentum & Newton's 3 Laws

## •Vocabulary:

•**Mass** - The amount of matter (stuff) in something.

•**Velocity** – How fast (speed) and which direction something is moving.

•**Momentum** – Mass in motion

•**Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

# Momentum & Newton's 3 Laws

• **Mass** - The amount of matter (stuff) in something.

• Symbol: **m**

• Example: **the mass of a rock is 2 kg.**



$$m = 1$$



$$m = 10$$

# Momentum & Newton's 3 Laws

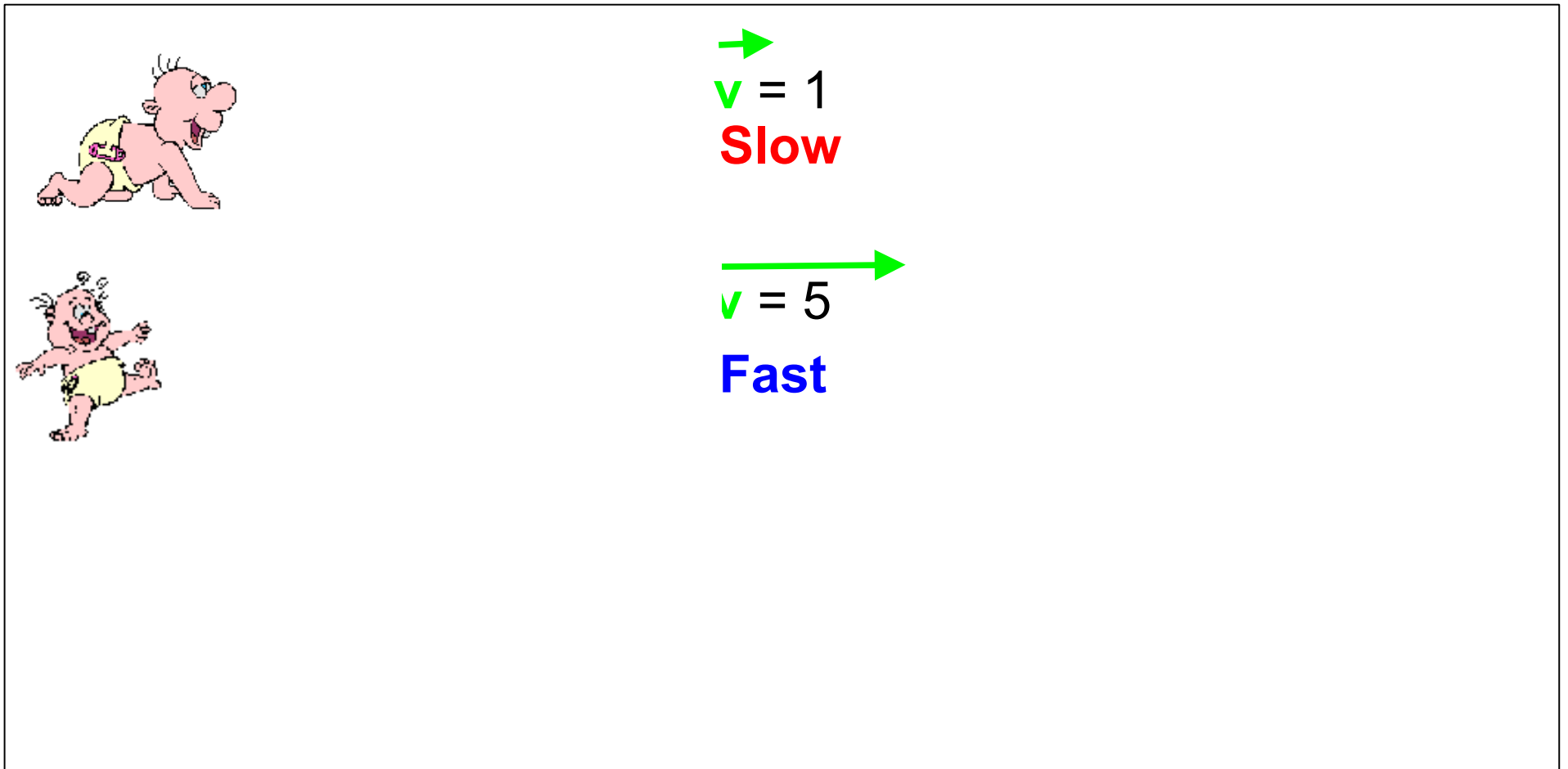
- **Velocity** – How fast (speed) and which direction something is moving.
- Symbol: **v**
- Example: **the rock is falling down with a speed of 2 m/s.**



→  
**v** = 1  
**Slow**

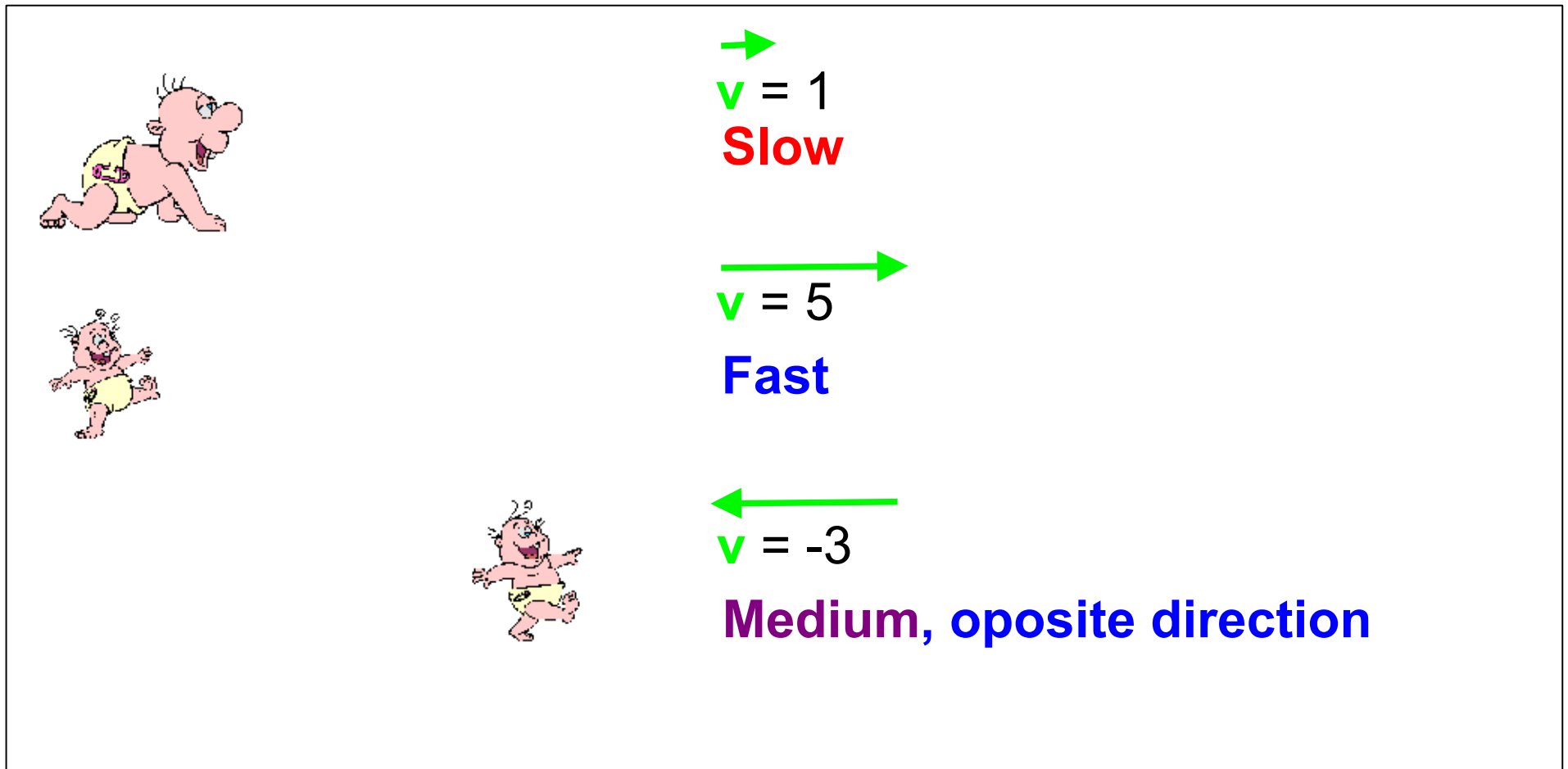
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- Symbol:  $v$
- Example: **the rock is falling down with a speed of 2 m/s.**



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# Momentum & Newton's 3 Laws

• **Momentum** – Mass in motion

• Symbol: **p**

• Momentum equals mass times velocity, i.e., **p = mv**.



$$\vec{v} = 2 \quad m = 1$$

$$p = ?$$

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$$\begin{aligned} \vec{v} = 2 \quad m = 1 \\ \mathbf{p} = m \mathbf{v} = 1 \times 2 = 2 \end{aligned}$$



# Momentum & Newton's 3 Laws

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$$\vec{v} = 2 \quad m = 1$$

$$p = m v = 1 \times 2 = 2$$



$$\vec{v} = 5 \quad m = 1$$

$$p = ?$$

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$$\vec{v} = 2 \quad m = 1$$

$$\mathbf{p} = m \mathbf{v} = 1 \times 2 = 2$$



$$\vec{v} = 5 \quad m = 1$$




$$\mathbf{p} = m \mathbf{v} = 1 \times 5 = 5$$

# Momentum & Newton's 3 Laws

• **Momentum** – Mass in motion

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• Momentum equals mass times velocity, i.e., **p = mv**.

	$\vec{v} = 2$ $m = 1$
	$p = m v = 1 \times 2 = 2$
	$\vec{v} = 5$ $m = 1$
	$p = m v = 1 \times 5 = 5$
	$\vec{v} = 2$ $m = 10$
	$p = ?$

# Momentum & Newton's 3 Laws

• **Momentum** – Mass in motion

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$$\vec{v} = 2 \quad m = 1$$

$$\mathbf{p} = m \mathbf{v} = 1 \times 2 = 2$$



$$\vec{v} = 5 \quad m = 1$$

$$\mathbf{p} = m \mathbf{v} = 1 \times 5 = 5$$



$$\vec{v} = 2 \quad m = 10$$

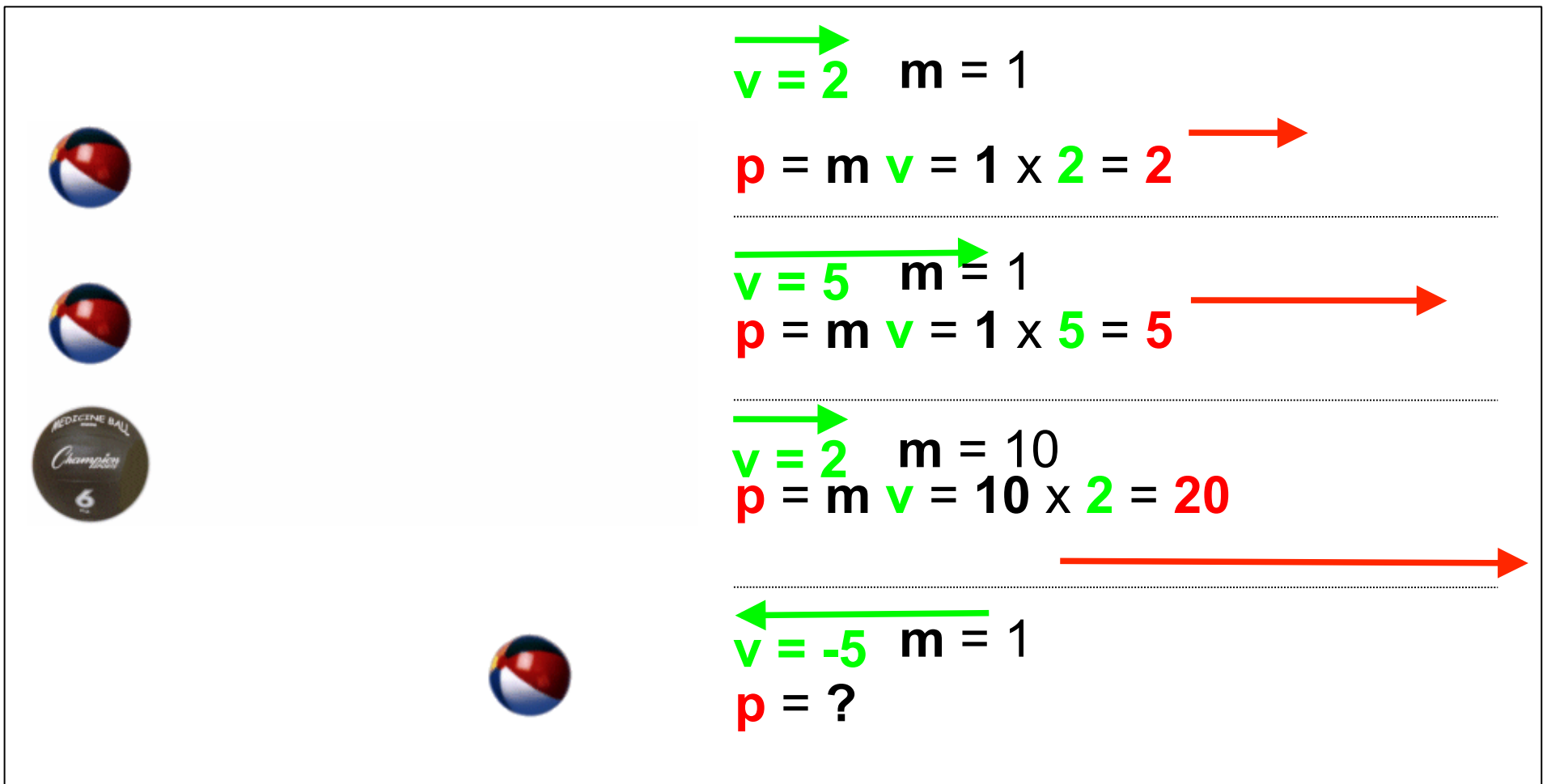
$$\mathbf{p} = m \mathbf{v} = 10 \times 2 = 20$$

# Momentum & Newton's 3 Laws

• **Momentum** – Mass in motion

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The diagram illustrates the calculation of momentum for four different scenarios. Each scenario is represented by a ball and its corresponding velocity and mass values, followed by the momentum calculation. The balls are arranged vertically on the left side of the diagram. The first three balls are small, and the fourth is larger. The fourth ball is a medicine ball with the text 'MEDICINE BALL' and 'Champion Sports' and the number '6' on it. The velocity and mass values are given in green and red, and the momentum calculation is shown in red. The momentum values are 2, 5, 20, and a question mark. The momentum values are also represented by red arrows of increasing length.

$\vec{v} = 2$     $m = 1$   
 $p = m v = 1 \times 2 = 2$

$\vec{v} = 5$     $m = 1$   
 $p = m v = 1 \times 5 = 5$

$\vec{v} = 2$     $m = 10$   
 $p = m v = 10 \times 2 = 20$

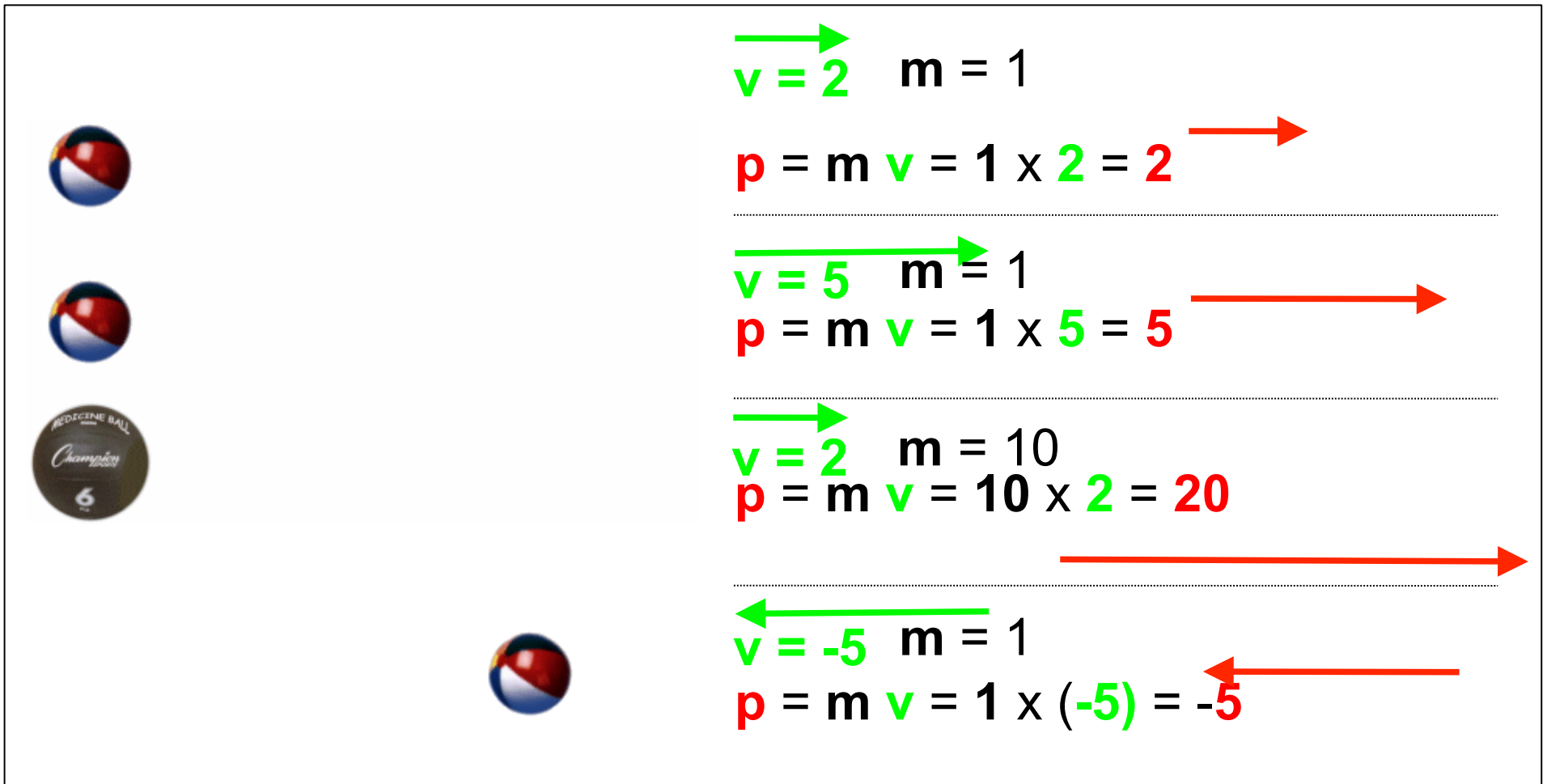
$\vec{v} = -5$     $m = 1$   
 $p = ?$

# Momentum & Newton's 3 Laws

• **Momentum** – Mass in motion

• Symbol: **p**

• Momentum equals mass times velocity, i.e., **p = mv**.



The diagram illustrates momentum calculations for four different balls. On the left, there are four images of balls: three small red and blue balls and one larger black medicine ball labeled 'Champion' and '6'. To the right of each ball, there are equations for velocity (v), mass (m), and momentum (p), along with a red arrow representing the direction and magnitude of the momentum.

Ball 1:  $v = 2$   $m = 1$   
 $p = m v = 1 \times 2 = 2$

Ball 2:  $v = 5$   $m = 1$   
 $p = m v = 1 \times 5 = 5$

Ball 3:  $v = 2$   $m = 10$   
 $p = m v = 10 \times 2 = 20$

Ball 4:  $v = -5$   $m = 1$   
 $p = m v = 1 \times (-5) = -5$

# Momentum & Newton's 3 Laws

- **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

## Elastic Collision



$$p = mv$$

# Momentum & Newton's 3 Laws

- **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Elastic Collision**

**Before**

$p = mv$

$p = (1 \times 2) + (1 \times 0) = 2$

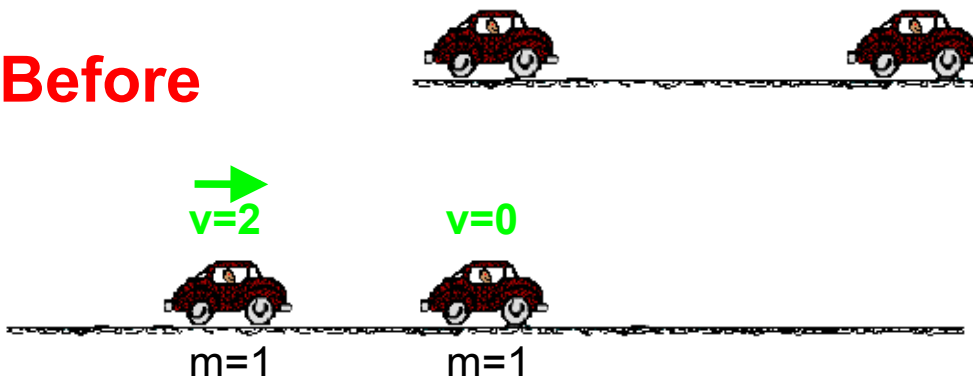


# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Elastic Collision**

**Before**




$v=2$   $v=0$

$m=1$   $m=1$

$p = mv$

$p = (1 \times 2) + (1 \times 0) = 2$

**After**



$v=?$   $v=?$

$m=1$   $m=1$

$p = (1 \times ?) + (1 \times ?) = 2$

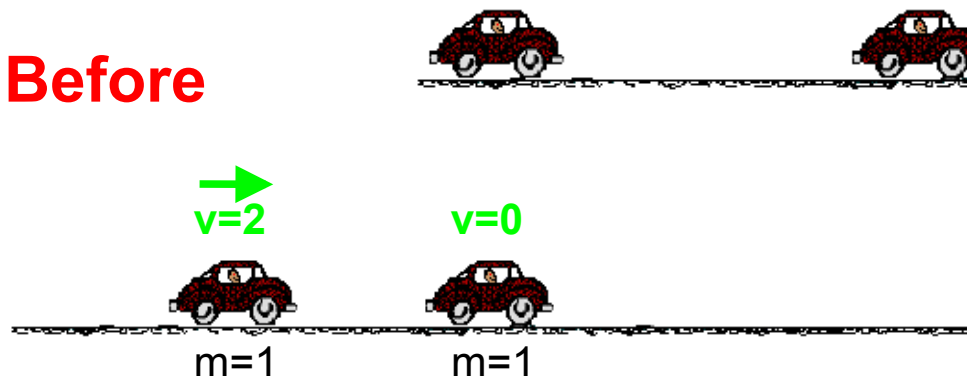
**EQUAL**

# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Elastic Collision**

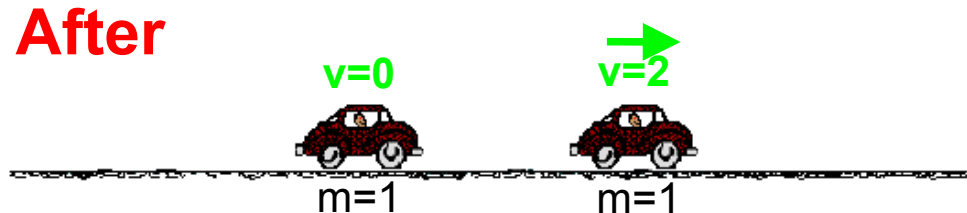
**Before**



$p = m v$

$p = (1 \times 2) + (1 \times 0) = 2$

**After**



$p = (1 \times 0) + (1 \times 2) = 2$

**EQUAL**

# Momentum & Newton's 3 Laws

- **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

## Inelastic Collision 1



$$p = mv$$

# Momentum & Newton's 3 Laws

- **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Inelastic Collision 1**

**Before**

$v=10$   $v=0$

$m=1$   $m=1$

$p = mv$

$p = (1 \times 10) + (1 \times 0) = 10$

# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Inelastic Collision 1**

**Before**

$v=10$   $v=0$

$m=1$   $m=1$

$p = mv$

$p = (1 \times 10) + (1 \times 0) = 10$

**After**

$v=?$

$m=2$

$p = (2 \times ?) = 10$

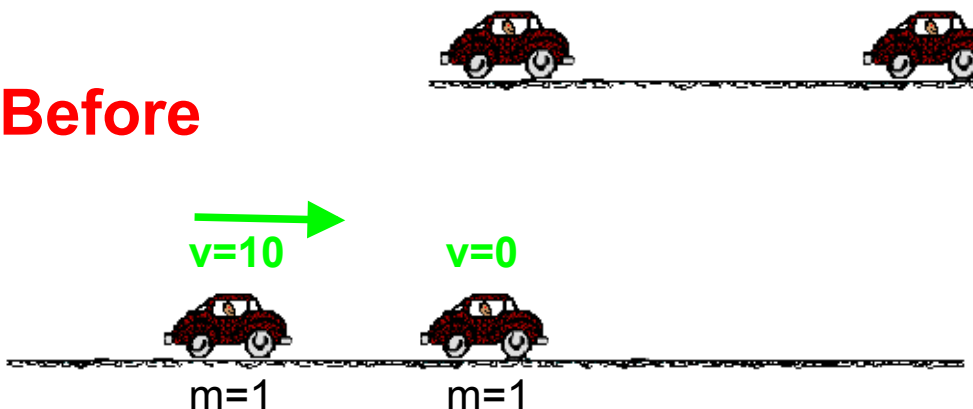
**EQUAL**

# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Inelastic Collision 1**

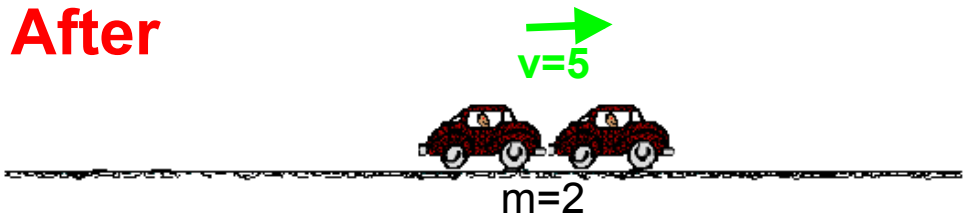
**Before**



$p = mv$

$$p = (1 \times 10) + (1 \times 0) = 10$$

**After**


$$p = (2 \times 5) = 10$$

**EQUAL**

# Momentum & Newton's 3 Laws

- **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

## Inelastic Collision 2



$$p = mv$$

# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Inelastic Collision 2**

**Before**

$v=2$

$v=-2$

$m=1$

$m=1$

$p = mv$

$p = (1 \times 2) + (2 \times -2) = 0$



# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Inelastic Collision 2**

**Before**

$v=2$

$v=-2$

$m=1$

$m=1$

$p = mv$

$p = (1 \times 2) + (2 \times -2) = 0$

**After**

**BANG!**

$m=2$

$p = (2 \times ?) = 0$

**EQUAL**

# Momentum & Newton's 3 Laws

- Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)

**Inelastic Collision 2**

**Before**

$v=2$

$v=-2$

$m=1$

$m=1$

$p = mv$

$p = (1 \times 2) + (2 \times -2) = 0$

**After**

**BANG!**

$m=2$

$p = (2 \times 0) = 0$

**EQUAL**

# The massive car moves less

$$\begin{array}{c} P \\ \longrightarrow \\ M v \end{array}$$



$$\begin{array}{c} P \\ \longleftarrow \\ m V \end{array}$$

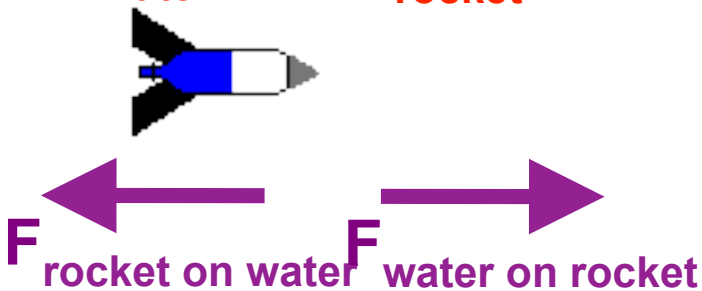
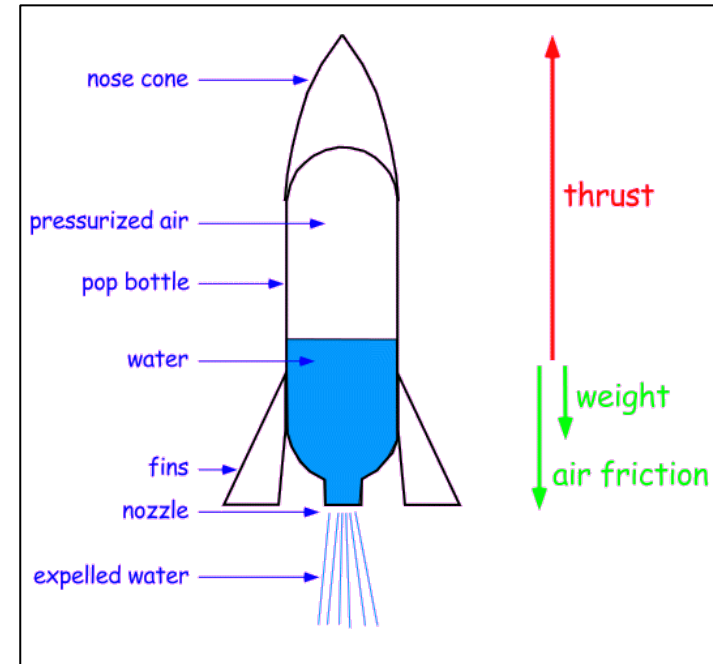


# Momentum & Newton's 3 Laws

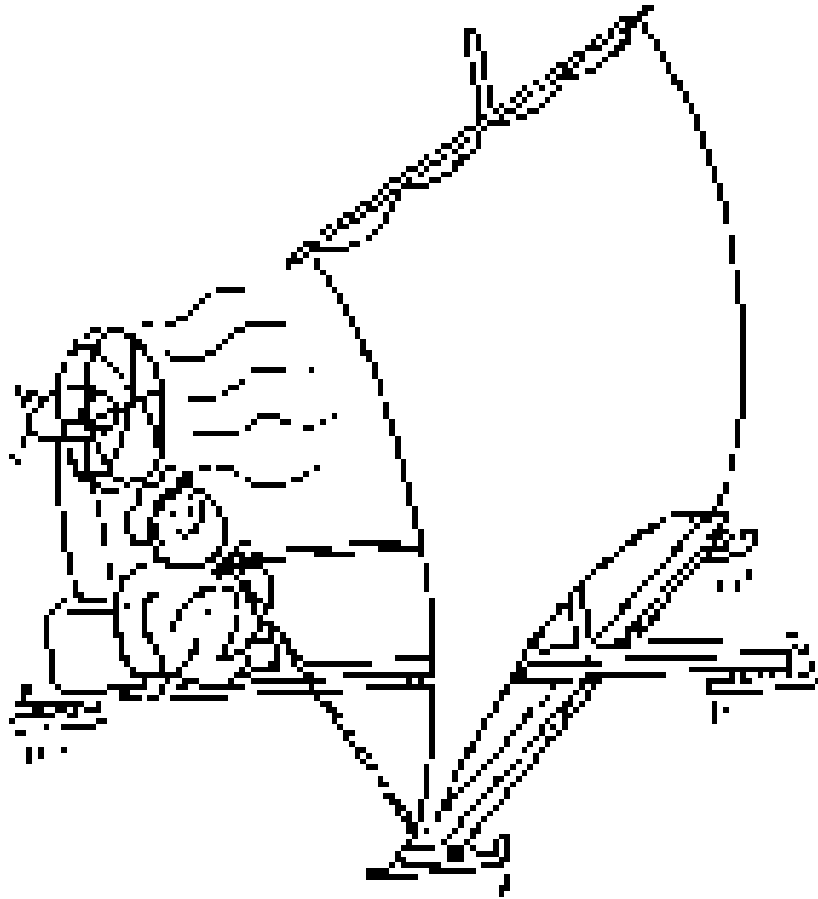
## Water Rocket:

**Forces:** Force of rocket on water is equal and opposite the force of water on rocket

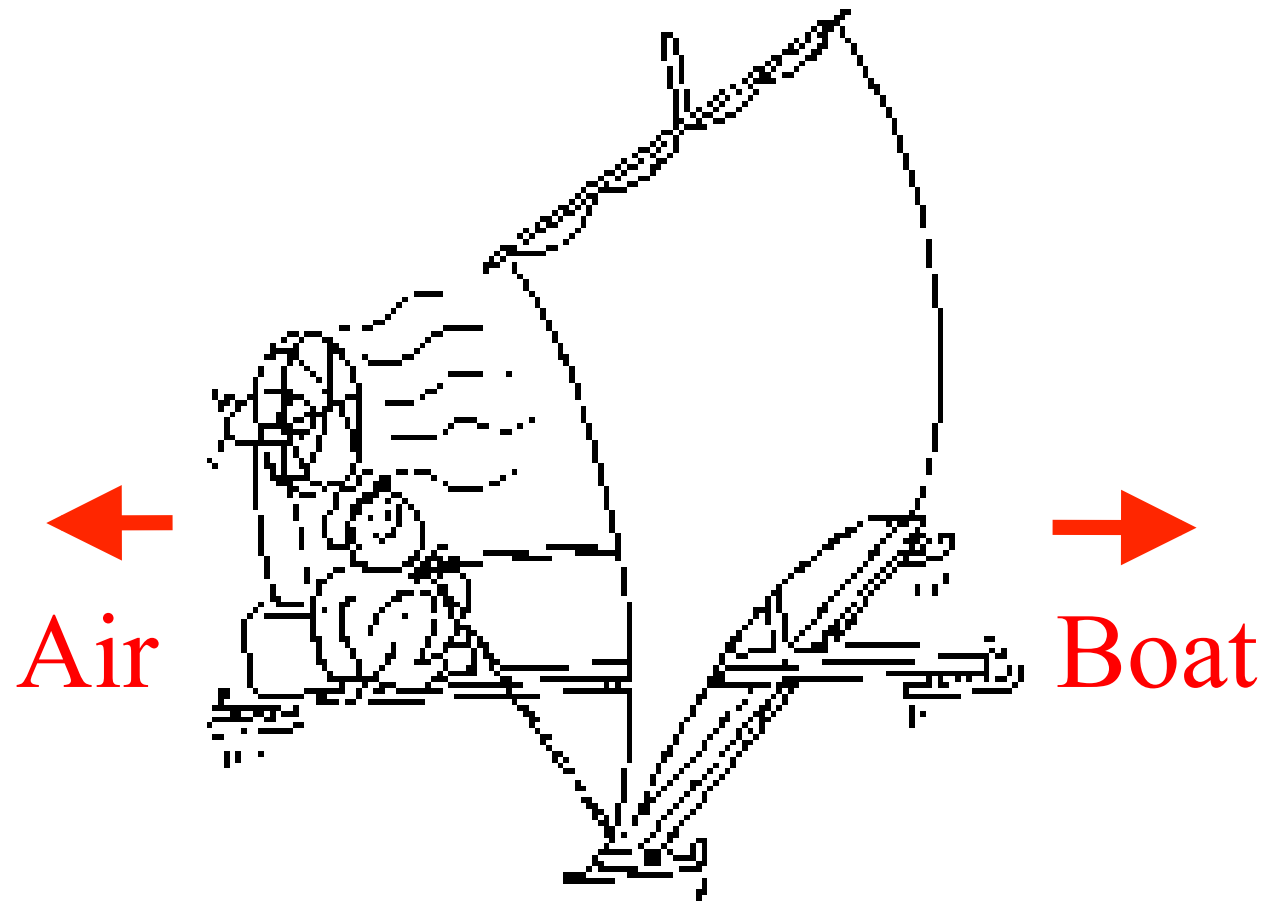
**Momentum:** Momentum before is equal to momentum after



# Which way does the sailboat go?



# Which way does the sailboat go?

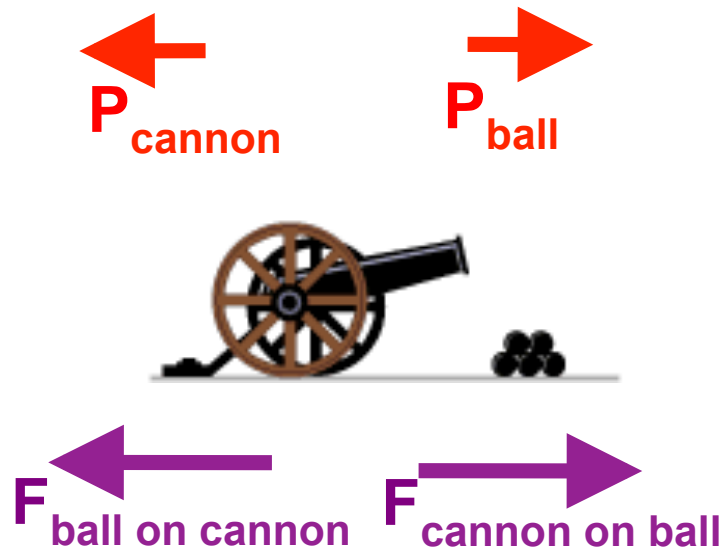


# Momentum & Newton's 3 Laws

Liquid Nitrogen Cannon:

• **Forces:** Force of ball on cannon is equal and opposite the force of cannon on ball

• **Momentum:** Momentum before shot is equal to momentum after shot



# Review: What is mass?

- (A) The amount of matter (stuff) in something.
- (B) How fast something is moving
- (C) Something heavy that is moving fast



# Review: What is mass?

- (A) The amount of matter (stuff) in something.
- (B) How fast something is moving
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# A rifle fires a bullet. What is the same afterwards?

- (A) The mass of the rifle and the mass of the bullet are the same
- (B) The speed of the rifle and the speed of the bullet are the same
- (C) The momentum of the rifle and the momentum of the bullet are the same (but in opposite directions)

# A rifle fires a bullet. What is the same afterwards?

- (A) The mass of the rifle and the mass of the bullet are the same
- (B) The speed of the rifle and the speed of the bullet are the same
- (C) The momentum of the rifle and the momentum of the bullet are the same (but in opposite directions)

