

1/10/16

Write on board -

◦ Does a stopped or moving car have momentum?  
Does either have inertia?

◦ Describe some objects that would be difficult to stop

ex. speeding train or charging elephant  
→ what do these objects have in common?

◦ Momentum is a property of an object in motion. Momentum is a quantity that describes the tendency for an object in motion to remain in motion.

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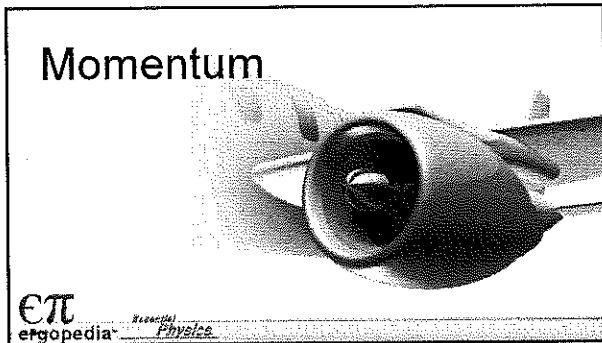
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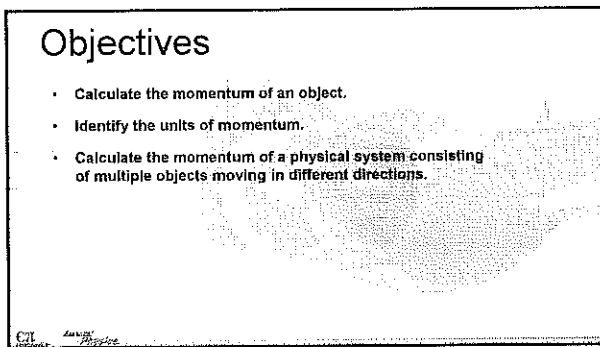
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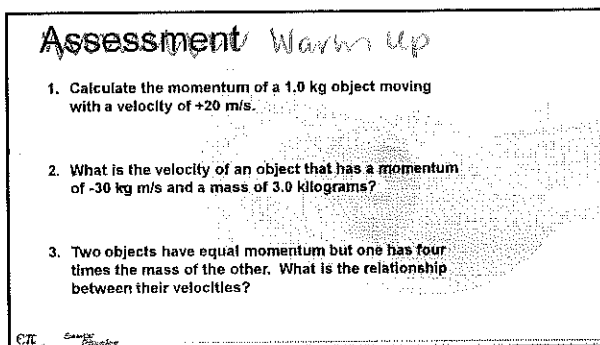
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①  $p = mv = 1\text{kg}(20\text{m/s}) = 20\text{kg m/s}$

② if  $p = mv$  then  $v = p/m$

$= \frac{-30\text{kg m/s}}{3\text{kg}} = -10\text{ m/s}$

$3\cancel{\text{kg}}$

③ lighter object will be moving 4x faster

3

**Assessment**

4. Which answer below shows the correct units for momentum? A.  $\text{kg m/s}^2$  B.  $\text{kg m}^2/\text{s}^2$  C.  $\text{kg m/s}$  D.  $\text{kg s/m}$

5. Two bowling balls each have a mass of 4.0 kg. The red ball is moving east at 2.0 m/s. The blue ball is moving west at 1.0 m/s. Calculate the total momentum of the system.

4) Answer C  $\text{kg m/s}$  or  $\text{N s}$  discuss

5) Red  $2 \text{ m/s} (4 \text{ kg}) = 8 \text{ kg m/s}$   
 Blue  $4 \text{ kg} (1 \text{ m/s}) = -4 \text{ kg m/s}$   
 $T_p = 8 \text{ kg m/s} - 4 \text{ kg m/s} = 4 \text{ kg m/s}$

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**Physics terms**

- momentum

• Vector equal to the product of velocity and mass.

Ex. truck & car going same speed truck has more momentum because it has more mass

10

**Equations**

$p = mv$

The momentum of an object is its mass multiplied by its velocity.  
 Momentum is a vector.

$\text{kg m/s}$   
 or  
 $\text{N s}$   
 $= \text{kg m/s}^2 \cdot \cancel{s}$   
 $\Rightarrow \text{kg m/s}$

• vector - shows magnitude & direction

• + & - signs show direction

Historically, momentum was identified with the persistence of an object to continue its original speed & direction of motion. Today we call it "momentum", however Newton called it "impetus" in 1687. Impetus comes from the Latin term petere which means go toward

11 What does momentum mean?

How is the word *momentum* used in everyday life? Discuss!

Can you think of an example?

How is the physics definition of the word different from the everyday usage?

ex. "our team got great momentum in the semifinal!"  
"candidate has a lot of momentum"

Ask - Can different objects have the same momentum?

→ lead to next slide

• write answer on board

\* everyday use momentum synonym with inertia.

\* If physics, momentum depends on mass & velocity, while inertia depends on mass only. Inertia is resistance to motion.

12 Consider these two objects

A one kilogram sphere is moving at 100 meters per second.

A 100 kilogram sphere is moving at one meter per second.

$$p = mv$$

$$1 \text{ kg} (100 \text{ m/s}) = 100 \text{ kg m/s}$$

$$100 \text{ kg} (1 \text{ m/s}) = 100 \text{ kg m/s}$$

\* objects with different masses can have the same momentum

13 Test your knowledge - which has more momentum, a 4000 lb car traveling at 60 mph or a 30,000 kg truck traveling at 1.5 m/s?

$$1 \text{ lb} = 0.454 \text{ kg}$$

$$4000 \text{ lb} (0.454 \text{ kg/lb}) = 1814 \text{ kg} (26.8 \text{ m/s}) = 48615 \text{ kg m/s}$$

$$60 \text{ mph} (1609 \text{ m/mi}) (1/3600 \text{ s}) = 26.8 \text{ m/s}$$

$$30000 \text{ kg} (1.5 \text{ m/s}) = 45000 \text{ kg m/s}$$

→ car has more momentum.

14 Consider these two objects

If the same stopping force is applied to each, which sphere will stop first?

15

Consider these two objects

If the same stopping force is applied to each, which sphere will stop first?

A. The 100 kg sphere  
 B. The 1 kg sphere  
 C. It's a tie.  
 D. More information is needed.

1 kg 100 m/s

100 kg 1 m/s

CTL Example Physics

Class thoughts

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16

Consider these two objects

If the same stopping force is applied to each, which sphere will stop first?

A. The 100 kg sphere  
 B. The 1 kg sphere  
 C. It's a tie!  
 D. More information is needed.

1 kg 100 m/s

100 kg 1 m/s

CTL Example Physics

Show answer

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17

Consider these two objects

If the same stopping force is applied to each, which sphere will stop first?

A. The 100 kg sphere  
 B. The 1 kg sphere  
 C. It's a tie!  
 D. More information is needed.

1 kg 100 m/s

100 kg 1 m/s

**Why?**

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Why might the balls be equally difficult to stop?

→ something equal to the ball  
 ⇒ same momentum

calculate momentum of each sphere using  $p = mv$

Ans. 100 kg m/s for both

**Momentum**

Momentum is the product of mass and velocity.

$$p = mv$$

Momentum was originally identified with a moving object's persistence of motion.

The diagram shows two spheres. The top sphere is small and labeled '1 kg' with an arrow pointing right labeled '100 m/s'. The bottom sphere is larger and labeled '100 kg' with an arrow pointing right labeled '1 m/s'.

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18

**Momentum**

Momentum is the product of mass and velocity.

$$p = mv$$

The spheres have the same momentum.

The diagram shows two spheres. The top sphere is small and labeled '1 kg' with an arrow pointing right labeled '100 m/s' and 'p = 100 kg m/s'. The bottom sphere is larger and labeled '100 kg' with an arrow pointing right labeled '1 m/s' and 'p = 100 kg m/s'.

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**Test your knowledge**

A red truck and a blue truck have the same mass. The red truck is parked, and the blue truck is traveling along the highway at 60 mph.

- Do both trucks have inertia?
- Do both trucks have momentum?

Class thoughts

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### Test your knowledge

A red truck and a blue truck have the same mass. The red truck is parked, and the blue truck is traveling along the highway at 60 mph.

a) Do both trucks have inertia?  
 Yes. All objects with mass have inertia. They resist having their motion changed.

b) Do both trucks have momentum?

CTL Energy Project

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### Test your knowledge

A red truck and a blue truck have the same mass. The red truck is parked, and the blue truck is traveling along the highway at 60 mph.

a) Do both trucks have inertia?  
 Yes. All objects with mass have inertia. They resist having their motion changed.

b) Do both trucks have momentum?  
 No. The blue truck has momentum. The red truck has NO momentum because it has zero velocity. Momentum is sometimes referred to as "Inertia in motion".

CTL Energy Project

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### Units of momentum

Momentum has units of mass multiplied by velocity.

$$p = mv$$

mass in kg      velocity in m/s

units of momentum =  $\frac{\text{kg m}}{\text{s}}$  or N·s

CTL Energy Project

◦ Combination of base units  
 kg·m/s do not have a name like newton or joule

◦ Update flip books w/ formula card

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### Exploring the ideas

Click on the interactive calculator on page 306

**11.1 - Momentum and Impulse**

Momentum is a property of an object in motion, whether it is a person, car, truck, or spaceship. A car traveling down the road has momentum. It requires force between the tires and road to change its velocity. A big truck traveling at the same velocity has much more momentum, because it is more difficult to change its velocity. Momentum is a quantity that describes the tendency for an object in motion to remain in motion. 42

**Calculating momentum**

The momentum of a moving object is its mass multiplied by its velocity. The higher an object's mass or velocity, the more momentum it has. A truck has more momentum than a car traveling at the same speed because the truck has more mass. A car has more momentum when traveling on the highway than when moving slowly in heavy traffic. 43

**Momentum is a vector quantity**

Momentum is the product of mass and velocity, and velocity is a vector quantity. Momentum is also a vector quantity. Momentum is not direction can take on either positive or negative signs to indicate its direction. For example, a 10 kg ball traveling at 7 m/s to the right has a momentum of 70 kg·m/s, and the same ball moving to the left has a momentum of -70 kg·m/s. Momentum has units of mass multiplied by speed—or kilogram meters per second (kg·m/s). 44

**Momentum is mass multiplied by velocity and has a direction.**

-2 m/s
10 kg
2 m/s

Momentum = -20 kg·m/s
Momentum = 20 kg·m/s

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### Engaging with the concepts

What is the momentum of a 60 kg sprinter running at 7.0 m/s?

**Momentum calculator**

$p = mv$

Momentum
Mass
Velocity

p
m
v

(kg·m/s)
(kg)
(m/s)

Solve for: **Momentum**

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### Engaging with the concepts

What is the momentum of a 60 kg sprinter running at 7.0 m/s? 420 kg m/s

What is the velocity of the sprinter if her momentum is 270 kg m/s?

**Momentum calculator**

$p = mv$

Momentum
Mass
Velocity

p
m
v

(kg·m/s)
(kg)
(m/s)

Solve for: **Momentum**

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### Engaging with the concepts

What is the momentum of a 60 kg sprinter running at 7.0 m/s? 420 kg m/s

What is the velocity of the sprinter if her momentum is 270 kg m/s? 4.5 m/s

If she wanted to double her momentum, how fast would she have to run?

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### Engaging with the concepts

What is the momentum of a 60 kg sprinter running at 7.0 m/s? 420 kg m/s

What is the velocity of the sprinter if her momentum is 270 kg m/s? 4.5 m/s

If she wanted to double her momentum, how fast would she have to run?  
twice as fast (9.0 m/s)

Momentum is directly proportional to velocity

- Doubling  $v \Rightarrow$  doubled momentum

what will happen to the sprinter's momentum if we double the velocity? Triple it?

What type of relationship is this?

27

### Engaging with the concepts

A 2,000 kg car and a 4,000 kg truck are both traveling at 10 m/s when they hit a wall.

Which has more momentum before impact?

What is the ratio of their momenta?

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18

### Engaging with the concepts

A 2,000 kg car and a 4,000 kg truck are both traveling at 10 m/s when they hit a wall.

Which has more momentum before impact? the truck

What is the ratio of their momenta?

$P_{truck} : P_{car}$  is 2:1

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### Engaging with the concepts

A boulder is dropped from rest and hits the ground at a speed of 15 m/s, transferring 1,200 kg m/s of momentum to the Earth.

What is its mass?

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### Engaging with the concepts

A boulder is dropped from rest and hits the ground at a speed of 15 m/s, transferring 1,200 kg m/s of momentum to the Earth.

What is its mass? 80 kg

$$m = \frac{p}{v} = \frac{1,200 \text{ kg m/s}}{15 \text{ m/s}} = 80 \text{ kg}$$

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### Engaging with the concepts

Create two objects with a momentum of 100 kg m/s, but with masses of 1.0 kg and 4.0 kg.

If the mass is four times greater, how does the velocity change?

*Example: Physics*

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### Engaging with the concepts

Create two objects with a momentum of 100 kg m/s, but with masses of 1.0 kg and 4.0 kg.

$p_1 = (1 \text{ kg})(100 \text{ m/s}) = 100 \text{ kg m/s}$   
 $p_2 = (4 \text{ kg})(25 \text{ m/s}) = 100 \text{ kg m/s}$

If the mass is four times greater, how does the velocity change?  
 The velocity is one-fourth as much.

*Example: Physics*

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33

### Engaging with the concepts

What do you think will happen if you enter a negative momentum?  
 Why?  
 Try it!

*Example: Physics*

\* Ask

Test - moves to left

Why does the car move to the left?

=> vector

**Momentum**

Momentum is a vector.  $p = mv$

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34

**Momentum**

Momentum is a vector.  $p = mv$

For one-dimensional motion, this means the *direction* of motion determines the *sign* of an object's momentum.

$p = -100 \text{ kg m/s}$      $10 \text{ kg}$      $10 \text{ kg}$      $p = +100 \text{ kg m/s}$

CIT Example Physics

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**Momentum of a system**

What is the total momentum of this system of two balls?

A. Zero  
B. +100 kg m/s  
A. +200 kg m/s

$p = -100 \text{ kg m/s}$      $10 \text{ kg}$      $10 \text{ kg}$      $p = +100 \text{ kg m/s}$

CIT Example Physics

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31

### Momentum of a system

What is the total momentum of this system of two balls?

A. Zero  $100 \text{ kg m/s} + -100 \text{ kg m/s} = 0 \text{ kg m/s}$

A.  $+100 \text{ kg m/s}$

A.  $+200 \text{ kg m/s}$

$p = -100 \text{ kg m/s}$      $10 \text{ kg}$      $10 \text{ kg}$      $p = +100 \text{ kg m/s}$

CTT Physics

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### Assessment

1. Calculate the momentum of a 1.0 kg object moving with a velocity of  $+20 \text{ m/s}$ .
2. What is the velocity of an object that has a momentum of  $-30 \text{ kg m/s}$  and a mass of 3.0 kilograms?
3. Two objects have equal momentum but one has four times the mass of the other. What is the relationship between their velocities?

CTT Physics

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### Assessment

1. Calculate the momentum of a 1.0 kg object moving with a velocity of  $+20 \text{ m/s}$ .  
 $p = mv = (1.0 \text{ kg})(20 \text{ m/s}) = +20 \text{ kg m/s}$
2. What is the velocity of an object that has a momentum of  $-30 \text{ kg m/s}$  and a mass of 3.0 kilograms?
3. Two objects have equal momentum but one has four times the mass of the other. What is the relationship between their velocities?

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### Assessment

1. Calculate the momentum of a 1.0 kg object moving with a velocity of +20 m/s.

$$p = mv = (1.0 \text{ kg})(20 \text{ m/s}) = +20 \text{ kg m/s}$$

2. What is the velocity of an object that has a momentum of -30 kg m/s and a mass of 3.0 kilograms?

$$\text{If } p = mv, \text{ then } v = p/m = (-30 \text{ kg m/s})/(3.0 \text{ kg}) = -10 \text{ m/s}$$

3. Two objects have equal momentum but one has four times the mass of the other. What is the relationship between their velocities?

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### Assessment

1. Calculate the momentum of a 1.0 kg object moving with a velocity of +20 m/s.

$$p = mv = (1.0 \text{ kg})(20 \text{ m/s}) = +20 \text{ kg m/s}$$

2. What is the velocity of an object that has a momentum of -30 kg m/s and a mass of 3.0 kilograms?

$$\text{If } p = mv, \text{ then } v = p/m = (-30 \text{ kg m/s})/(3.0 \text{ kg}) = -10 \text{ m/s}$$

3. Two objects have equal momentum but one has four times the mass of the other. What is the relationship between their velocities?

The lighter object is moving 4 times faster.

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### Assessment

4. Which answer below shows the correct units for momentum?

A. kg m/s<sup>2</sup>

B. kg m<sup>2</sup>/s<sup>2</sup>

C. kg m/s

D. kg s/m

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### Assessment

4. Which answer below shows the correct units for momentum?
- A.  $\text{kg m/s}^2$
  - B.  $\text{kg m}^2/\text{s}^2$
  - C.  $\text{kg m/s}$
  - D.  $\text{kg s/m}$

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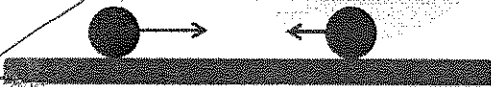
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### Assessment

5. Two bowling balls each have a mass of 4.0 kg.  
The red ball is moving east at 2.0 m/s. The blue ball is moving west at 1.0 m/s. Calculate the total momentum of the system.




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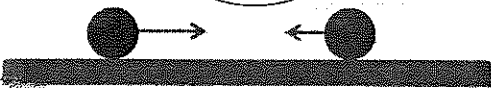
### Assessment

5. Two bowling balls each have a mass of 4.0 kg.  
The red ball is moving east at 2.0 m/s. The blue ball is moving west at 1.0 m/s. Calculate the total momentum of the system.

$$mv_{red} = (4.0 \text{ kg})(+2.0 \text{ m/s}) = +8.0 \text{ kg m/s}$$

$$mv_{blue} = (4.0 \text{ kg})(-1.0 \text{ m/s}) = -4.0 \text{ kg m/s}$$

The total momentum is +4.0 kg m/s




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