

Exercise walk-through

4.3

Conservation of Linear Momentum

AP Physics 1

Linear momentum

Mass in motion

$$\vec{p} = m\vec{v}$$

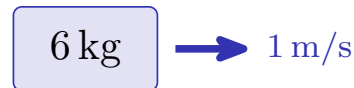
A **vector** – points the way the velocity does. Total momentum = the **vector sum**.

Momentum grows with **both** mass and speed – a slow truck and a fast bullet can match.



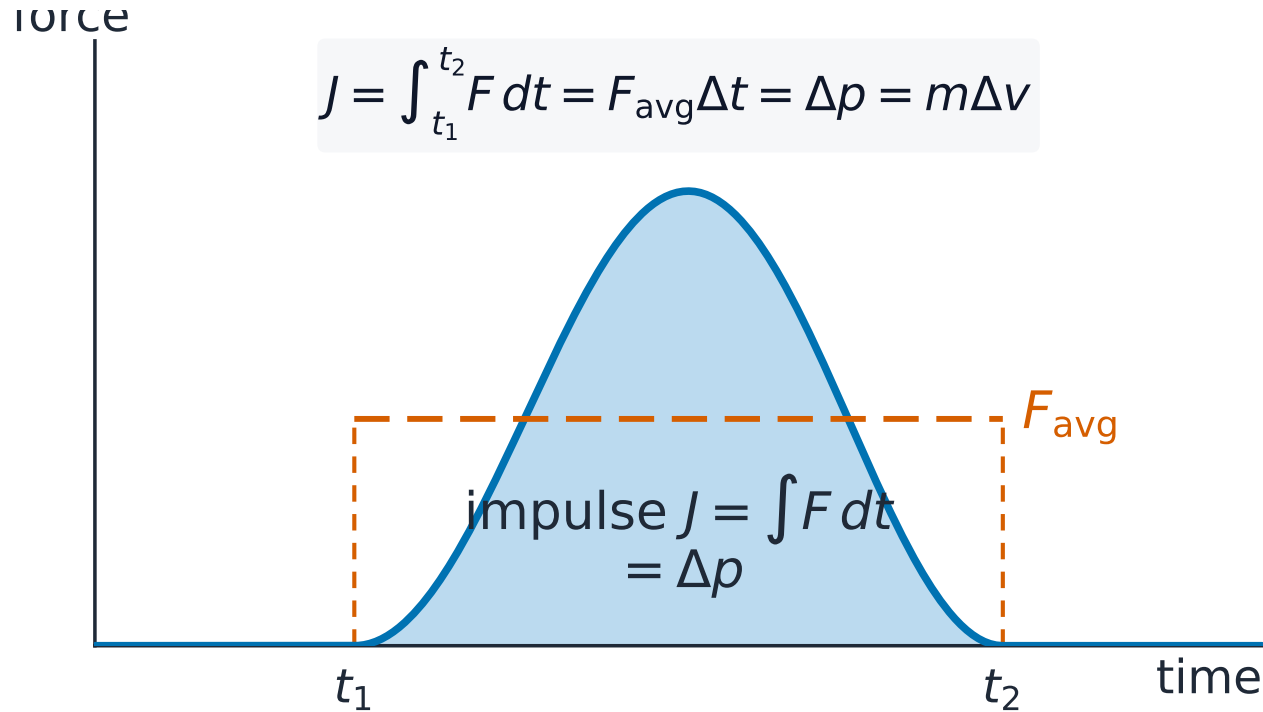
A light blue rounded rectangle containing the text "2 kg" is followed by a thick blue arrow pointing to the right, which then points to the text "3 m/s".

same $p = 6 \text{ kg m/s}$



A light blue rounded rectangle containing the text "6 kg" is followed by a thick blue arrow pointing to the right, which then points to the text "1 m/s".

Impulse is the area under the force-time curve



Impulse is the area under the force-time curve, equal to the average force times the contact time

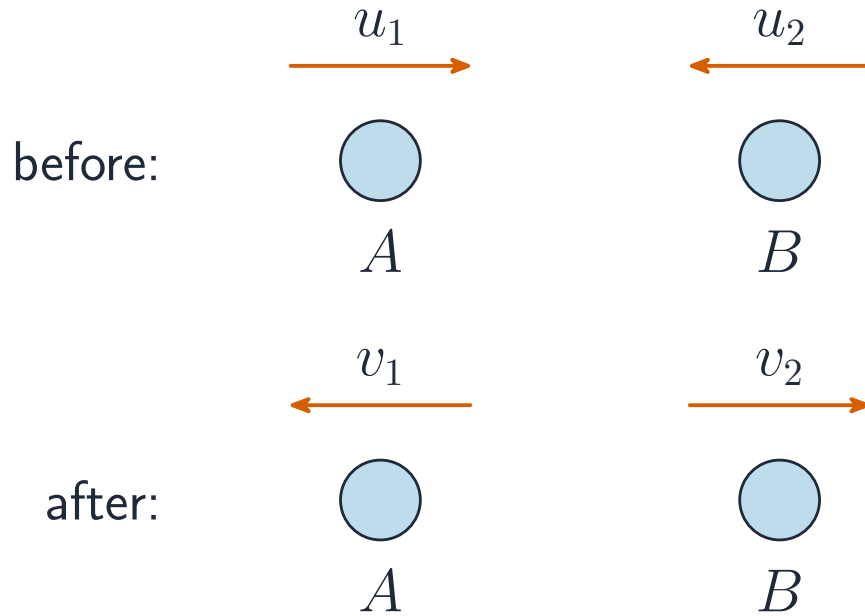
Worked example – a ball bouncing off a wall

A 0.15 kg ball hits a wall at 20 m/s and bounces straight back at 15 m/s. The contact lasts 0.020 s. Find the average force.

- take **toward the wall** as positive:
 $\Delta p = m(v_f - v_i) = 0.15(-15 - 20)$
- $= -5.25 \text{ kg m/s}$
- $F = \frac{\Delta p}{\Delta t} = \frac{-5.25}{0.020} = -260 \text{ N}$, i.e. 260 N away from the wall

The rebound makes v_f **negative**, so Δp is larger than either speed alone would suggest. Forgetting that sign halves the answer.

A head-on collision



A head-on collision: total momentum before equals total momentum after

Exercises 2.1-2.3

2.1 State the condition for the total momentum of a system to be conserved. [1]

2.2 A 3.0 kg cart at 4.0 m s^{-1} hits a stationary 1.0 kg cart and they couple together. Find their common speed. [2]

2.3 A stationary 5.0 kg object explodes into two pieces; a 2.0 kg piece flies off at $+6.0 \text{ m s}^{-1}$. Find the velocity of the 3.0 kg piece. [2]

Exercises 2.1-2.3

2.1 State the condition for the total momentum of a system to be conserved. [1]

2.1

- the net external force on the system must be zero
-

2.2 A 3.0 kg cart at 4.0 m s^{-1} hits a stationary 1.0 kg cart and they couple together. Find their common speed. [2]

2.2

- $3.0(4.0) = (3.0 + 1.0)v \Rightarrow v = \frac{12}{4.0} = 3.0 \text{ m s}^{-1}$
-

2.3 A stationary 5.0 kg object explodes into two pieces; a 2.0 kg piece flies off at $+6.0 \text{ m s}^{-1}$. Find the velocity of the 3.0 kg piece. [2]

2.3

- $0 = 2.0(+6.0) + 3.0 v \Rightarrow v = \frac{-12}{3.0} = -4.0 \text{ m s}^{-1}$

Exercises 3.1-3.2

3.1 The total momentum of a system is conserved when

[1]

☐

- A kinetic energy is conserved
- B the net external force is zero
- C there is no friction anywhere
- D the velocity is constant

3.2 A 2.0 kg rifle fires a 0.010 kg bullet at 400 m s^{-1} . The rifle recoils at

[1]

☐

- A 2.0 m s^{-1}
- B 4.0 m s^{-1}
- C 0.5 m s^{-1}
- D 8.0 m s^{-1}

Exercises 3.1·3.2

3.1 The total momentum of a system is conserved when

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3.1 B

- the net external force is zero.

3.2 A 2.0 kg rifle fires a 0.010 kg bullet at 400 m s^{-1} . The rifle recoils at

[1]

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- A 2.0 m s^{-1}
- B 4.0 m s^{-1}
- C 0.5 m s^{-1}
- D 8.0 m s^{-1}

3.2 A

- $0 = 0.010(400) + 2.0 v \Rightarrow v = -2.0 \text{ m s}^{-1}$

Exercise 3.3 (a)

3.3 A 60 kg astronaut, initially at rest in space, throws a 2.0 kg tool at 5.0 m s^{-1} .

(a) Find the astronaut's recoil speed.

[2]

Exercise 3.3 (a)

3.3 A 60 kg astronaut, initially at rest in space, throws a 2.0 kg tool at 5.0 m s^{-1} .

(a) Find the astronaut's recoil speed.

[2]

(a)

- $$0 = 2.0(5.0) + 60 v \Rightarrow v = \frac{-10}{60} = -0.17 \text{ m s}^{-1}, \text{ i.e. } 0.17 \text{ m s}^{-1}$$

Exercise 3.3 (b)

3.3 A 60 kg astronaut, initially at rest in space, throws a 2.0 kg tool at 5.0 m s^{-1} .

(b) State the direction of the recoil relative to the tool.

[1]

Exercise 3.3 (b)

3.3 A 60 kg astronaut, initially at rest in space, throws a 2.0 kg tool at 5.0 m s^{-1} .

(b) State the direction of the recoil relative to the tool. [1]

(b)

- opposite to the tool's direction