

Exercise walk-through

4.2

Change in Momentum and Impulse

AP Physics C: Mechanics

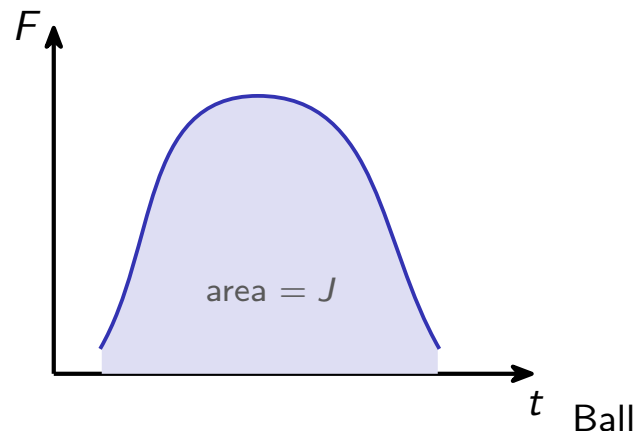
Impulse and Newton's law

Impulse – and the deepest form of
 $F = ma$

$$\vec{J} = \int \vec{F} dt = \Delta \vec{p}$$

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

For a fixed Δp , a longer **contact time** means a **smaller** force – cushioning.



bounces: $\Delta p = -6$; in 0.01 s, $F = 600$ N.

The impulse–momentum theorem, and reading it off a graph

The theorem

The **impulse–momentum theorem**: $\vec{J} = \int \vec{F} dt = \Delta \vec{p}$.
Impulse is what a force *does over time*, and it equals the change in momentum.

On a force–time graph

The impulse is the **area** under the curve – so a small force for a long time can match a large force for a short one.

On a momentum–time graph

The net force is the **slope** at each instant. Same two quantities, the other way round.

$\vec{F}_{\text{net}} = d\vec{p}/dt$ reduces to $m\vec{a}$ only when the mass is constant. When mass changes, go back to the momentum form.

Why impulse explains airbags

the theorem

$$\vec{J} = \int \vec{F} dt = \Delta \vec{p} - \text{the impulse-momentum theorem} \quad -$$

the general law

$$\sum \vec{F} = \frac{d\vec{p}}{dt}, \text{ which reduces to } m\vec{a} \text{ only when the mass is constant}$$

changing mass

the extra $\frac{dm}{dt}\vec{v}$ term appears for rockets and conveyor belts – one of AP's favourite twists

the design idea

the same Δp spread over a longer time means a smaller force

Airbags, crumple zones, catching gloves and bending your knees are all one physics: they stretch Δt , and $F = \Delta p / \Delta t$ falls in proportion.

Exercises 2.1-2.3

2.1 A 20 N force acts for 3 s. Find the impulse. [2]

2.2 State what impulse equals (the theorem). [1]

2.3 A 4 kg object receives an impulse of 16 kg m s^{-1} . Find its change in velocity. [2]

Exercises 2.1-2.3

2.1 A 20 N force acts for 3 s. Find the impulse. [2]

2.1

- $J = F\Delta t = 20 \times 3 = 60 \text{ kg m s}^{-1}$

2.2 State what impulse equals (the theorem). [1]

2.2

- The change in momentum, Δp

2.3 A 4 kg object receives an impulse of 16 kg m s^{-1} . Find its change in velocity. [2]

2.3

- $\Delta v = J/m = 16/4 = 4 \text{ m s}^{-1}$

Exercises 2.4-3.1

2.4 Explain why a longer collision time reduces the force.

[2]

3.1 The impulse of a force equals the change in

[1]

☐

A kinetic energy

B momentum

C mass

D acceleration

Exercises 2.4-3.1

2.4 Explain why a longer collision time reduces the force. [2]

2.4

- For a fixed Δp , $F = \Delta p / \Delta t$; a larger Δt gives a smaller F

3.1 The impulse of a force equals the change in [1]

- ☐ **A** kinetic energy
B momentum
C mass
D acceleration

3.1 B

- impulse equals the change in momentum

Exercise 3.2

3.2 For a fixed change in momentum, increasing the contact time

[1]

☐

A increases the force

B decreases the force

C leaves the force unchanged

D reverses the force

Exercise 3.2

3.2 For a fixed change in momentum, increasing the contact time

[1]

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A increases the force

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3.2 B

- a longer time reduces the force

Exercise 3.3 (a)

3.3 A 0.15 kg ball hits a wall at 10 m s^{-1} and bounces back at 8 m s^{-1} (opposite direction).

(a) Find the change in momentum.

[2]

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3.3 A 0.15 kg ball hits a wall at 10 m s^{-1} and bounces back at 8 m s^{-1} (opposite direction).

(a) Find the change in momentum. [2]

(a)

- Taking the incoming direction positive: $\Delta p = m(v_f - v_i) = 0.15(-8 - 10) = -2.7 \text{ kg m s}$
(magnitude 2.7)

Exercise 3.3 (b)

3.3 A 0.15 kg ball hits a wall at 10 m s^{-1} and bounces back at 8 m s^{-1} (opposite direction).

(b) If the contact lasts 0.02 s, find the average force. [2]

Exercise 3.3 (b)

3.3 A 0.15 kg ball hits a wall at 10 m s^{-1} and bounces back at 8 m s^{-1} (opposite direction).

(b) If the contact lasts 0.02 s, find the average force. [2]

(b)

- $F = \Delta p / \Delta t = 2.7 / 0.02 = 135 \text{ N}$

Exercise 3.4 (a)

3.4 A 60 kg person jumps down and lands, changing momentum by 300 kg m s^{-1} .

(a) Find the force if they stop in 0.1 s (stiff legs).

[1]

Exercise 3.4 (a)

3.4 A 60 kg person jumps down and lands, changing momentum by 300 kg m s^{-1} .

(a) Find the force if they stop in 0.1 s (stiff legs). [1]

(a)

- $F = 300/0.1 = 3000 \text{ N}$

Exercise 3.4 (b)

3.4 A 60 kg person jumps down and lands, changing momentum by 300 kg m s^{-1} .

(b) Find the force if they stop in 0.5 s (bent knees).

[2]

Exercise 3.4 (b)

3.4 A 60 kg person jumps down and lands, changing momentum by 300 kg m s^{-1} .

(b) Find the force if they stop in 0.5 s (bent knees). [2]

(b)

- $F = 300/0.5 = 600 \text{ N}$