

Exercise walk-through

1.5

Motion in Two or Three Dimensions

AP Physics C: Mechanics

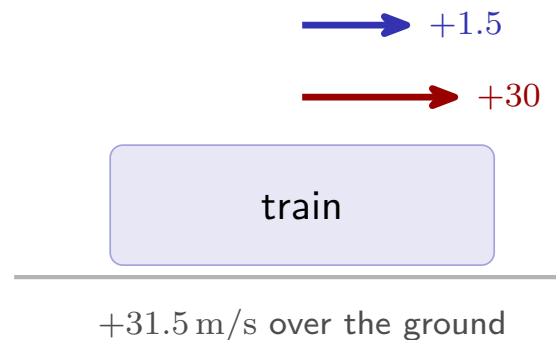
Reference frames and relative motion

Velocities add as vectors between frames:

Frame conversion

$$\vec{v}_{A/C} = \vec{v}_{A/B} + \vec{v}_{B/C}$$

Frames moving at **constant** relative velocity share the same acceleration – they are **inertial**, and Newton's laws hold identically.



Relative motion is vector addition

the rule

$$\vec{v}_{A/C} = \vec{v}_{A/B} + \vec{v}_{B/C} - \text{the inner subscripts cancel}$$

reversing

$$\vec{v}_{B/A} = -\vec{v}_{A/B}$$

a boat crossing

add the boat's velocity through the water to the water's velocity over the ground

**reference
frame**

all motion is measured relative to one; there is no absolute rest

Write the subscripts before the numbers. If the inner pair does not cancel, you have chained the frames the wrong way round.

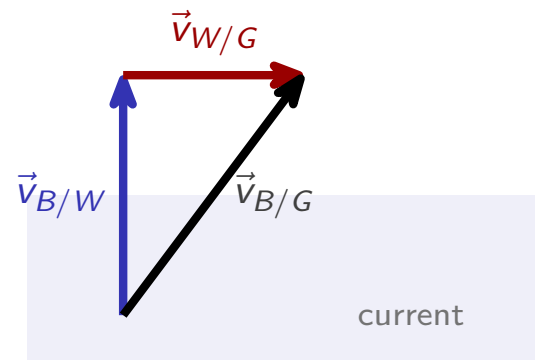
A boat crossing a river

The boat's ground velocity is the **vector sum** of its velocity through the water and the current:

$$\vec{v}_{B/G} = \vec{v}_{B/W} + \vec{v}_{W/G}$$

Across 3.0, downstream 2.0

$$|\vec{v}_{B/G}| = \sqrt{3.0^2 + 2.0^2} \approx 3.6 \text{ m/s}$$



Exercises 2.1·2.3

2.1 State what the horizontal and vertical motions of a projectile share in common. [1]

2.2 A ball is thrown horizontally at 8 m s^{-1} . State its horizontal acceleration (ignore air resistance). [1]

2.3 A stone falls from rest for 2 s. Find its vertical velocity (use $g = 10 \text{ m s}^{-2}$). [2]

Exercises 2.1·2.3

2.1 State what the horizontal and vertical motions of a projectile share in common. [1]

2.1

- The time of flight (both motions happen over the same time)

2.2 A ball is thrown horizontally at 8 m s^{-1} . State its horizontal acceleration (ignore air resistance). [1]

2.2

- Zero – there is no horizontal force

2.3 A stone falls from rest for 2 s. Find its vertical velocity (use $g = 10 \text{ m s}^{-2}$). [2]

2.3

- $v = gt = 10 \times 2 = 20 \text{ m s}^{-1}$

Exercises 2.4·3.1

2.4 A projectile has $v_x = 6 \text{ m s}^{-1}$ and $v_y = 8 \text{ m s}^{-1}$ at some instant. Find its speed. [2]

3.1 For a projectile (no air resistance), the horizontal velocity [1]

☐

A increases

B decreases

C stays constant

D becomes zero at the top

Exercises 2.4·3.1

2.4 A projectile has $v_x = 6 \text{ m s}^{-1}$ and $v_y = 8 \text{ m s}^{-1}$ at some instant. Find its speed. [2]

2.4

- $\sqrt{6^2 + 8^2} = 10 \text{ m s}^{-1}$

3.1 For a projectile (no air resistance), the horizontal velocity [1]

☐

A increases

B decreases

C stays constant

D becomes zero at the top

3.1 C

- with no horizontal force, the horizontal velocity is constant

Exercise 3.2

3.2 Two balls leave a table at the same instant; one is dropped and one is thrown horizontally. They [1]

☐

A land at the same time

B the dropped one lands first

C the thrown one lands first

D never land

Exercise 3.2

3.2 Two balls leave a table at the same instant; one is dropped and one is thrown horizontally. They [1]

☐

A land at the same time

B the dropped one lands first

C the thrown one lands first

D never land

3.2 A

- the vertical motions are identical, so they land together

Exercise 3.3 (a)

3.3 A ball is launched horizontally at 10 m s^{-1} from a height of 5 m ($g = 10 \text{ m s}^{-2}$).

(a) Find the time to reach the ground.

[2]

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3.3 A ball is launched horizontally at 10 m s^{-1} from a height of 5 m ($g = 10 \text{ m s}^{-2}$).

(a) Find the time to reach the ground.

[2]

(a)

- $t = \sqrt{2h/g} = \sqrt{2(5)/10} = 1 \text{ s}$

Exercise 3.3 (b)

3.3 A ball is launched horizontally at 10 m s^{-1} from a height of 5 m ($g = 10 \text{ m s}^{-2}$).

(b) Find the horizontal range.

[2]

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3.3 A ball is launched horizontally at 10 m s^{-1} from a height of 5 m ($g = 10 \text{ m s}^{-2}$).

(b) Find the horizontal range.

[2]

(b)

- $x = v_x t = 10 \times 1 = 10 \text{ m}$

Exercise 3.4 (a)

3.4 A projectile's velocity components are $v_x = 12 \text{ m s}^{-1}$ and $v_y = -5 \text{ m s}^{-1}$.

(a) Find the speed.

[2]

Exercise 3.4 (a)

3.4 A projectile's velocity components are $v_x = 12 \text{ m s}^{-1}$ and $v_y = -5 \text{ m s}^{-1}$.

(a) Find the speed.

[2]

(a)

- $\sqrt{12^2 + 5^2} = 13 \text{ m s}^{-1}$

Exercise 3.4 (b)

3.4 A projectile's velocity components are $v_x = 12 \text{ m s}^{-1}$ and $v_y = -5 \text{ m s}^{-1}$.

(b) Find the angle below the horizontal.

[1]

Exercise 3.4 (b)

3.4 A projectile's velocity components are $v_x = 12 \text{ m s}^{-1}$ and $v_y = -5 \text{ m s}^{-1}$.

(b) Find the angle below the horizontal.

[1]

(b)

- $\tan^{-1}(5/12) = 23^\circ$ below the horizontal