

Exercise walk-through

1.4

Reference Frames and Relative Motion

AP Physics C: Mechanics

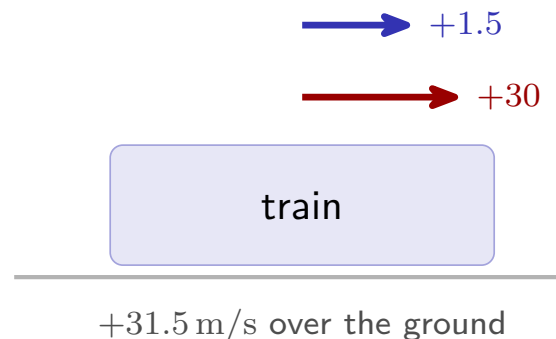
Reference frames and relative motion

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.

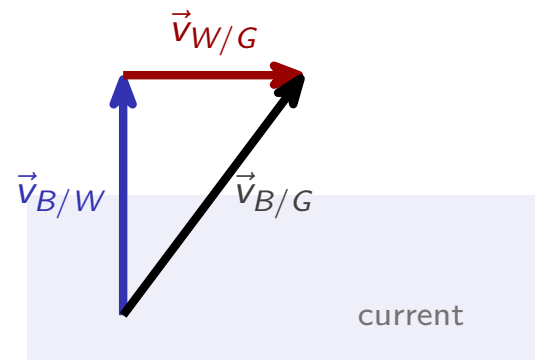
A boat crossing a river

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 A passenger walks forward at 1.5 m s^{-1} on a bus moving 12 m s^{-1} . Find the passenger's velocity relative to the ground. [2]

2.2 Car A moves at $+25 \text{ m s}^{-1}$ and car B at $+18 \text{ m s}^{-1}$ (same direction). Find the velocity of A relative to B. [2]

2.3 Two cars approach head-on, each at 20 m s^{-1} relative to the ground. Find the speed of one relative to the other. [2]

Exercises 2.1-2.3

2.1 A passenger walks forward at 1.5 m s^{-1} on a bus moving 12 m s^{-1} . Find the passenger's velocity relative to the ground. [2]

2.1

- $12 + 1.5 = 13.5 \text{ m s}^{-1}$ relative to the ground

2.2 Car A moves at $+25 \text{ m s}^{-1}$ and car B at $+18 \text{ m s}^{-1}$ (same direction). Find the velocity of A relative to B. [2]

2.2

- $25 - 18 = +7 \text{ m s}^{-1}$ (A ahead of B)

2.3 Two cars approach head-on, each at 20 m s^{-1} relative to the ground. Find the speed of one relative to the other. [2]

2.3

- Take one direction positive: $20 - (-20) = 40 \text{ m s}^{-1}$

Exercises 2.4·3.1

2.4 A boat heads directly across a river at 6 m s^{-1} while the current flows at 8 m s^{-1} . Find the boat's speed relative to the ground. [2]

3.1 The velocity of an object depends on [1]

☐

A its mass

B the reference frame chosen

C its colour

D nothing – it is absolute

Exercises 2.4-3.1

2.4 A boat heads directly across a river at 6 m s^{-1} while the current flows at 8 m s^{-1} . Find the boat's speed relative to the ground. [2]

2.4

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

3.1 The velocity of an object depends on [1]

☐

A its mass

B the reference frame chosen

C its colour

D nothing – it is absolute

3.1 B

- velocity is defined relative to a reference frame

Exercise 3.2

3.2 Two cars move in the same direction at 30 m s^{-1} and 22 m s^{-1} . The faster car's velocity relative to the slower is [1]

☐

A 52 m s^{-1}

B 8 m s^{-1}

C 0

D 22 m s^{-1}

Exercise 3.2

3.2 Two cars move in the same direction at 30 m s^{-1} and 22 m s^{-1} . The faster car's velocity relative to the slower is [1]

☐

A 52 m s^{-1}

B 8 m s^{-1}

C 0

D 22 m s^{-1}

3.2 B

- $30 - 22 = 8 \text{ m s}^{-1}$

Exercise 3.3 (a)

3.3 A swimmer heads straight across a river at 2 m s^{-1} ; the current is 1.5 m s^{-1} downstream.

(a) Find the swimmer's speed relative to the ground.

[2]

Exercise 3.3 (a)

3.3 A swimmer heads straight across a river at 2 m s^{-1} ; the current is 1.5 m s^{-1} downstream.

(a) Find the swimmer's speed relative to the ground.

[2]

(a)

- $\sqrt{2^2 + 1.5^2} = 2.5 \text{ m s}^{-1}$

Exercise 3.3 (b)

3.3 A swimmer heads straight across a river at 2 m s^{-1} ; the current is 1.5 m s^{-1} downstream.

(b) State why the swimmer does not land directly opposite the start.

[1]

Exercise 3.3 (b)

3.3 A swimmer heads straight across a river at 2 m s^{-1} ; the current is 1.5 m s^{-1} downstream.

(b) State why the swimmer does not land directly opposite the start. [1]

(b)

- The current carries the swimmer downstream while crossing

Exercise 3.4 (a)

3.4 A ball is dropped inside a train moving at constant velocity.

(a) Describe its path as seen by a passenger on the train.

[1]

Exercise 3.4 (a)

3.4 A ball is dropped inside a train moving at constant velocity.

(a) Describe its path as seen by a passenger on the train.

[1]

(a)

- Straight down

Exercise 3.4 (b)

3.4 A ball is dropped inside a train moving at constant velocity.

(b) Describe its path as seen by someone standing on the ground.

[1]

Exercise 3.4 (b)

3.4 A ball is dropped inside a train moving at constant velocity.

(b) Describe its path as seen by someone standing on the ground.

[1]

(b)

- A parabola – it keeps the train's forward velocity