Exercise walk-through

Reference Frames and Relative Motion ▪ 1.4

eXercise

You must be able to

- describe motion relative to a chosen **reference frame 参考系**
- combine velocities: $\vec{v}_{AC} = \vec{v}_{AB} + \vec{v}_{BC}$
- find a **relative velocity 相对速度** by subtracting: $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$
- apply this to boats in a current and objects on a moving vehicle

Method — Velocity is relative to a frame

A person walking 2 m s^{-1} forward on a train moving 30 m s^{-1} has a velocity relative to the ground of

$$v_{\text{ground}} = 30 + 2 = 32 \text{ m s}^{-1}.$$

Method — Adding velocities in 1-D

Use signs for direction. Walking backward at 2 m s^{-1} on the same train:
$30 + (-2) = 28$ m s^{-1} relative to the ground.

Method — Relative velocity by subtraction

The velocity of A relative to B is $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$. Two cars, both measured from the ground: $v_A = +20$, $v_B = +15$. Then A relative to B is $20 - 15 = +5$ m s^{-1} (A pulls ahead).

Method — Perpendicular velocities (a boat in a current)

A boat heads across a river at 3 m s^{-1}; the current carries it downstream at 4 m s^{-1}. The ground velocity combines by Pythagoras: $\sqrt{3^2 + 4^2} = 5$ m s^{-1}.

Practice 2.1 ▪ 2 marks

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.

Solution 2.1

Method: Velocity is relative to a frame

Worked steps

$12 + 1.5 = 13.5$ m s^{-1} relative to the ground M1 A1.

Practice 2.2 ▪ 2 marks

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

Solution 2.2

Method: Adding velocities in 1-D

Worked steps

$25 - 18 = +7$ m s^{-1} (A ahead of B) M1 A1.

Practice 2.3 ▪ 2 marks

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

Solution 2.3

Method: Relative velocity by subtraction

Worked steps

Take one direction positive: $20 - (-20) = 40$ m s^{-1} M1 A1.

Practice 2.4 ▪ 2 marks

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.

Solution 2.4

Method: Perpendicular velocities (a boat in a current)

Worked steps

$\sqrt{6^2 + 8^2} = 10$ m s^{-1} M1 A1.

Exam-style 3.1 ▪ 1 mark

The velocity of an object depends on

A its mass

B the reference frame chosen

C its colour

D nothing — it is absolute

Solution 3.1

A its mass

B the reference frame chosen ✓

C its colour

D nothing — it is absolute

Worked steps

B — velocity is defined relative to a reference frame.

Exam-style 3.2 ▪ 1 mark

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

A 52 m s^{-1}

B 8 m s^{-1}

C 0

D 22 m s^{-1}

Solution 3.2

A $52\ \text{m s}^{-1}$

B $8\ \text{m s}^{-1}$ ✓

C 0

D $22\ \text{m s}^{-1}$

Worked steps

B — $30 - 22 = 8\ \text{m s}^{-1}$.

Exam-style 3.3 ▪ 2 marks

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.

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

Solution 3.3

Method: Perpendicular velocities (a boat in a current)

Worked steps

(a) $\sqrt{2^2 + 1.5^2} = 2.5$ m s^{-1} M1 A1. (b) The current carries the swimmer downstream while crossing B1.

Exam-style 3.4 ▪ 1 mark

A ball is dropped inside a train moving at constant velocity.
(a) Describe its path as seen by a passenger on the train.
(b) Describe its path as seen by someone standing on the ground.

Solution 3.4

Method: Velocity is relative to a frame

Worked steps

(a) Straight down B1. (b) A parabola — it keeps the train's forward velocity B1.