Exercise walk-through

Reference Frames and Relative Motion ▪ 1.4

eXercise

You must be able to

- define a **reference frame 参考系** as the coordinate system an observer measures from
- explain that **displacement** and **velocity** depend on the observer's reference frame
- use **vector addition** to find a velocity relative to a different frame
- explain that **acceleration** is the same in all **inertial reference frames 惯性参考系**

Method — Relative velocity in one dimension

The velocity of A relative to C is $v_{A/C} = v_{A/B} + v_{B/C}$. A passenger walks at $+2$ m s^{-1} on a train moving at $+30$ m s^{-1}: relative to the ground the passenger moves at $+32$ m s^{-1}.

Method — Reversing a subscript

$v_{A/B} = -\, v_{B/A}$. If the train moves at $+30$ m s^{-1} relative to the ground, the ground moves at -30 m s^{-1} relative to the train.

Method — The same acceleration in every inertial frame

Two observers moving at constant velocity relative to each other measure **different velocities** but the **same acceleration** — a constant relative velocity adds a constant, and the rate of change of a constant is zero.

Practice 2.1 ▪ 1 mark

A boat moves at $+4.0$ m s^{-1} relative to the water; the water flows at $+1.0$ m s^{-1} relative to the bank. Find the boat's velocity relative to the bank.

Solution 2.1

Method: Relative velocity in one dimension

Worked steps

$+4.0 + 1.0 = +5.0$ m s^{-1} **B1**.

Practice 2.2 ▪ 1 mark

A car moves at $+20$ m s^{-1} relative to the road. Find the road's velocity relative to the car.

Solution 2.2

Method: Relative velocity in one dimension

Worked steps

-20 m s^{-1} **B1**.

Practice 2.3 ▪ 2 marks

Two cars drive directly toward each other, each at 15 m s^{-1} relative to the road. Find the velocity of one car relative to the other.

Solution 2.3

Worked steps

Take one car as $+15$ and the other as -15; relative velocity $= (+15) - (-15) = 30$ m s^{-1}, closing **M1** **A1**.

Practice 2.4 ▪ 2 marks

Explain why two observers in different inertial frames measure the same acceleration for one object.

Solution 2.4

Method: The same acceleration in every inertial frame

Worked steps

Their relative velocity is constant, so their measured velocities differ by a constant amount **B1**; the rate of change of velocity — the acceleration — is therefore the same **B1**.

Exam-style 3.1 ▪ 1 mark

Quantities that depend on the reference frame include

A velocity but not acceleration

B acceleration but not velocity

C both velocity and acceleration

D neither velocity nor acceleration

Solution 3.1

A velocity but not acceleration ✓

B acceleration but not velocity

C both velocity and acceleration

D neither velocity nor acceleration

Worked steps

A.

Exam-style 3.2 ▪ 1 mark

A person walks at 1.5 m s^{-1} toward the back of a bus moving forward at 12 m s^{-1}. The person's velocity relative to the ground is

A 13.5 m s^{-1} forward

B 10.5 m s^{-1} forward

C 1.5 m s^{-1} backward

D 12 m s^{-1} forward

Solution 3.2

Method: Relative velocity in one dimension

A 13.5 m s^{-1} forward

B 10.5 m s^{-1} forward ✓

C 1.5 m s^{-1} backward

D 12 m s^{-1} forward

Worked steps

B — $12 + (-1.5) = 10.5$ m s^{-1} forward.

Exam-style 3.3 ▪ 1 mark

A plane flies at 200 m s^{-1} east relative to the air. A wind blows relative to the ground.
(a) Find the plane's ground velocity if the wind blows at 30 m s^{-1} east.
(b) State its ground velocity if the wind instead blows 30 m s^{-1} west.

Solution 3.3

Method: Relative velocity in one dimension

Worked steps

(a) $200 + 30 = 230$ m s^{-1} east **B1**. (b) $200 - 30 = 170$ m s^{-1} east **B1**.