1.4 Reference Frames and Relative Motion

Name: _____ Class: _____ Date: _____ **Total: 15 marks**

KEY WORDS reference frame 参考系 • relative velocity 相对速度 • relative motion 相对运动

Objective

Build the skills to answer exam questions on **reference frames and relative motion**.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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

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

■ 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.

■ 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).

■ 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}.

2 Practice

Now apply the methods above.

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 m s^{-1} and car B at +18 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]

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 Exam-style questions

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

3.2 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}

3.3 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]

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

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]

(b) Describe its path as seen by someone standing on the ground. [1]

Solutions

2.1 $12 + 1.5 = 13.5$ m s^{-1} relative to the ground.

2.2 $25 - 18 = +7$ m s^{-1} (A ahead of B).

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

2.4 $\sqrt{6^2 + 8^2} = 10$ m s^{-1}.

3.1 B — velocity is defined relative to a reference frame.

3.2 B — $30 - 22 = 8$ m s^{-1}.

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

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