AP PHYSICS 1 • EXERCISE SHEET

1.4 Reference Frames and Relative Motion

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS reference frame 参考系 • inertial reference frame 惯性参考系 • relative motion 相对运动 • velocity 速度 • acceleration 加速度

Objective

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

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

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ 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}.

■ 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.

■ 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.

2 Practice

2.1 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. [1]

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

2.3 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. [2]

2.4 Explain why two observers in different inertial frames measure the same acceleration for one object. [2]

3 Exam-style questions

3.1 Quantities that depend on the reference frame include [1]

- **A** velocity but not acceleration
- **B** acceleration but not velocity
- **C** both velocity and acceleration
- **D** neither velocity nor acceleration

3.2 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 [1]

- **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

3.3 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. [1]

(b) State its ground velocity if the wind instead blows 30 m s^{-1} west. [1]

Solutions

2.1 $+4.0 + 1.0 = +5.0$ m s^{-1}.

2.2 -20 m s^{-1}.

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

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

3.1 A.

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

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