

1.5 Motion in Two or Three Dimensions

Name: _____ Class: _____ Date: _____

Total: 15 marks

KEY WORDS time of flight 飞行时间 • independent 独立 • components 分量 • free fall 自由落体
• projectile motion 抛体运动

Objective

Build the skills to answer exam questions on **motion in two dimensions** — especially projectiles.

You must be able to:

- treat the horizontal and vertical motions as **independent** 独立
- use constant velocity horizontally and free-fall acceleration g vertically
- find the **time of flight** 飞行时间 from the vertical motion, then the range from the horizontal
- combine perpendicular velocity components into a resultant

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.

■ Independent axes

In projectile motion the two axes do not affect each other:

- horizontal: constant velocity, $x = v_x t$;
- vertical: free fall, $a_y = -g$.

They share only the **time** t .

■ Horizontal launch

A ball rolls off a table at $v_x = 5 \text{ m s}^{-1}$ from height $h = 1.25 \text{ m}$. Vertical: $h = \frac{1}{2}gt^2$, so

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(1.25)}{10}} = 0.5 \text{ s.}$$

Horizontal range: $x = v_x t = 5 \times 0.5 = 2.5 \text{ m}$.

■ Combining velocity components

At any instant the speed is $\sqrt{v_x^2 + v_y^2}$. If $v_x = 5$ and $v_y = 5$, speed = $\sqrt{50} \approx 7.1 \text{ m s}^{-1}$.

2 Practice

Now apply the methods above.

2.1 State what the horizontal and vertical motions of a projectile share in common. [1]

2.2 A ball is thrown horizontally at 8 m s^{-1} . State its horizontal acceleration (ignore air resistance). [1]

2.3 A stone falls from rest for 2 s. Find its vertical velocity (use $g = 10 \text{ m s}^{-2}$). [2]

2.4 A projectile has $v_x = 6 \text{ m s}^{-1}$ and $v_y = 8 \text{ m s}^{-1}$ at some instant. Find its speed. [2]

3 Exam-style questions

3.1 For a projectile (no air resistance), the horizontal velocity [1]

- **A** increases
- **B** decreases
- **C** stays constant
- **D** becomes zero at the top

3.2 Two balls leave a table at the same instant; one is dropped and one is thrown horizontally. They [1]

- **A** land at the same time
- **B** the dropped one lands first

- **C** the thrown one lands first
 - **D** never land
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3.3 A ball is launched horizontally at 10 m s^{-1} from a height of 5 m ($g = 10 \text{ m s}^{-2}$).

(a) Find the time to reach the ground. [2]

(b) Find the horizontal range. [2]

3.4 A projectile's velocity components are $v_x = 12 \text{ m s}^{-1}$ and $v_y = -5 \text{ m s}^{-1}$.

(a) Find the speed. [2]

(b) Find the angle below the horizontal. [1]

Solutions

2.1 The time of flight (both motions happen over the same time).

2.2 Zero — there is no horizontal force.

2.3 $v = gt = 10 \times 2 = 20 \text{ m s}^{-1}$.

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

3.1 C — with no horizontal force, the horizontal velocity is constant.

3.2 A — the vertical motions are identical, so they land together.

3.3 (a) $t = \sqrt{2h/g} = \sqrt{2(5)/10} = 1 \text{ s}$. (b) $x = v_x t = 10 \times 1 = 10 \text{ m}$.

3.4 (a) $\sqrt{12^2 + 5^2} = 13 \text{ m s}^{-1}$. (b) $\tan^{-1}(5/12) = 23^\circ$ below the horizontal.