1 Equations of motion, free fall, and 2D motion – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
air resistance	空气阻力			
acceleration due to gravity	重力加速度			
free fall	自由落体			
components	分量			
projectile	抛体			

Recall

In Part A you learned to describe motion and read graphs. Now bring two more tools:

- When velocity is constant, velocity = displacement ÷ time.
- When something speeds up steadily, you need equations that include **acceleration** – that is this sheet.
- From maths you know right-angled triangles (Pythagoras, sine, cosine). You will use them to split motion into two directions.

Take it slowly. Each idea has a worked example before the Practice.

New ideas

■ 1 The constant-acceleration equations

When acceleration is **constant** (steady), four equations link five quantities: start velocity v_0, final velocity v, acceleration a, time t, and displacement Δx.

$$v = v_0 + at, \qquad \Delta x = v_0 t + \tfrac{1}{2}at^2, \qquad v^2 = v_0^2 + 2a\,\Delta x, \qquad \Delta x = \tfrac{1}{2}(v_0 + v)t.$$

The trick: list what you know, then pick the equation that holds your three knowns plus the one you want, so only one unknown is left.

Worked example. A car starts from rest ($v_0 = 0$) and accelerates at 2.0 m/s^2 for 6.0 s. Final velocity: $v = v_0 + at = 0 + 2.0 \times 6.0 = 12$ m/s. Distance: $\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 2.0 \times 6.0^2 = 36$ m.

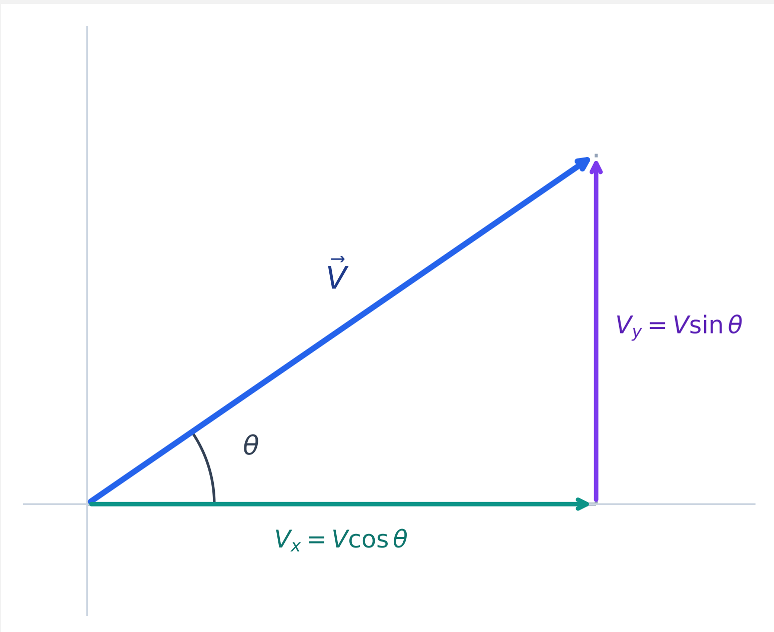
■ 2 Free fall

Near Earth, if we ignore **air resistance** 空气阻力, everything falls with the same **acceleration due to gravity** 重力加速度 $g = 9.8$ m/s^2, pointing down. This is **free fall** 自由落体.

Worked example. A stone is dropped ($v_0 = 0$) and falls for 2.0 s. Taking down as positive: speed $v = gt = 9.8 \times 2.0 = 20$ m/s, and distance $\Delta x = \frac{1}{2}gt^2 = \frac{1}{2} \times 9.8 \times 2.0^2 = 20$ m.

■ 3 Motion in two directions –components

A vector at an angle splits into two **components** 分量 at right angles: a horizontal part and a vertical part.



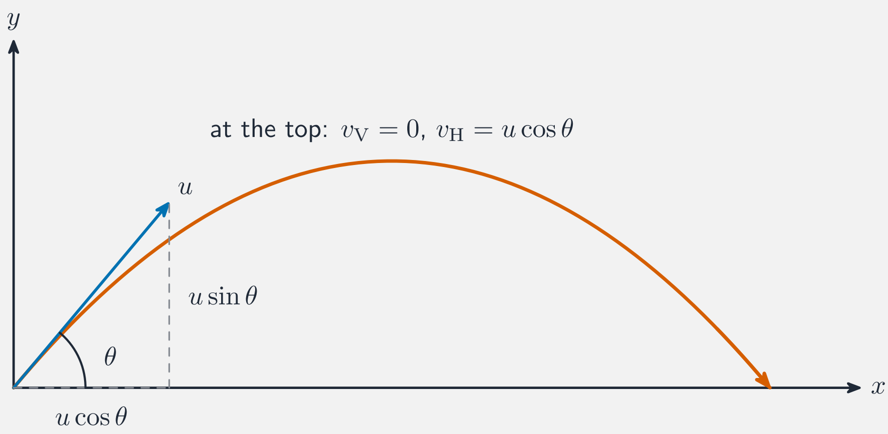
For a velocity v at angle θ above the horizontal:

$$v_x = v\cos\theta, \qquad v_y = v\sin\theta.$$

Worked example. A ball leaves at 10 m/s, 30° above the horizontal: $v_x = 10\cos 30° = 8.7$ m/s, and $v_y = 10\sin 30° = 5.0$ m/s.

■ 4 Projectile motion

A **projectile** 抛体 moves under gravity alone. The big idea: its horizontal and vertical motions are **independent** and share only the **time**.



- Horizontal: no acceleration, so the horizontal velocity stays constant.
- Vertical: acceleration g downward, exactly like free fall.

So a ball dropped and a ball thrown sideways from the same height reach the ground **at the same moment** –their vertical motions are identical.

Watch out: the two directions share only the time. Never mix a horizontal distance with a vertical velocity in one equation –solve each direction on its own, then join them through t.

Practice

Try these in order. The methods are all above.

2.1 A car accelerates from rest at 3.0 $\mathrm{m/s^2}$ for 5.0 s. Find its final velocity. [2]

2.2 Using the same car, find the distance it travels in those 5.0 s. [2]

2.3 A ball is dropped from rest. Taking $g = 9.8$ m/s^2 and down as positive, find its speed after 1.5 s. [2]

2.4 A velocity of 12 m/s points 60° above the horizontal. Find its horizontal and vertical components. [2]

2.5 A stone is thrown horizontally from a cliff at the same moment another is dropped. Explain why they hit the ground at the same time. [2]

2.6 A motorbike slows from 20 m/s to 8 m/s while covering 42 m. Use $v^2 = v_0^2 + 2a\,\Delta x$ to find its acceleration. [3]