Unit 3 · Kinematics

ANSWER KEY · FOR TEACHERS

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. displacement
2. velocity
3. acceleration
4. slope
5. area
6. projectile
7. parabola
8. 45°

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. u sin θ
2. g
3. H
4. R

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **c.** acceleration **K · 1**

Slope = change in velocity ÷ time = acceleration, $a = dv/dt$.

ii. **b.** not zero, because the direction of its velocity changes **U · 1**

Velocity is a vector: a change of direction alone is a change of velocity, so the car accelerates even at a steady speed.

iii. **b.** 5 m/s^2 **A · 1**

72 km/h = 20 m/s. a = (0 − 20) ÷ 4 = −5 m/s^2, a retardation of 5 m/s^2.

iv. **c.** 60° **A · 1**

$R = u^2 \sin 2\theta / g$, and sin 2θ is the same for θ and 90° − θ: sin 60° = sin 120°.

v. **c.** its velocity is horizontal and its acceleration is g, downward **U · 1**

Only the vertical part of the velocity is zero at the top; the horizontal part, u cos θ, stays. Gravity still pulls it down with g all the time.

4 Short answers

a. **MARKING SCHEME** **U · 2**

- ✓ Yes.
- ✓ An example, e.g. a ball at the top of its flight (v = 0, a = g).

b. **MARKING SCHEME** **U · 2**

- ✓ The rain's velocity relative to the walker is its own velocity minus the walker's.
- ✓ So it seems to slant towards the walker (tan $\theta = v_p/v_r$), and the umbrella is tilted forward to meet it.

c. **MARKING SCHEME** **A · 3**

- ✓ Relative velocity 15 km/h = 4.17 m/s.
- ✓ Distance to gain 24 m (both lengths).
- ✓ t ≈ 5.8 s.

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5 Long answer

ANSWER U · 4

The graph is a straight line from v = u at t = 0 to v = u + at at time t.
The displacement is the area under the line from 0 to t, a rectangle plus a triangle:
rectangle = u × t; triangle = ½ × t × (v − u) = ½ × t × at = ½at².

So $s = ut + \frac{1}{2}at^2$.

MARKING SCHEME

- ✓ A straight-line graph from u to v = u + at.
- ✓ The displacement is the area under the graph.
- ✓ The rectangle ut and the triangle ½t(v − u) = ½at².
- ✓ s = ut + ½at².

6 Numerical problems

a. **ANSWER** A · 4

While reacting he goes on at 15 m/s: 15 × 0.6 = 9.0 m.

While braking: $v^2 = u^2 - 2as$, so $s = \frac{15^2}{2 \times 5} = 22.5$ m.

Total = 9.0 + 22.5 = 31.5 m, less than 40 m: he stops **8.5 m** before the cow.

MARKING SCHEME

- ✓ Reaction distance 9.0 m.
- ✓ Braking distance from $v^2 = u^2 - 2as$: 22.5 m.
- ✓ Total 31.5 m.
- ✓ He stops in time, 8.5 m short.

b. **ANSWER** A · 4

i. Vertically it starts from rest: $45 = \frac{1}{2} \times 9.8 \times t^2$, so $t = \sqrt{90/9.8} = \mathbf{3.03\ s}$.

ii. Horizontally its speed stays 8 m/s: x = 8 × 3.03 = **24.2 m**.

iii. $v_x = 8$ m/s, $v_y = 9.8 \times 3.03 = 29.7$ m/s, so $v = \sqrt{8^2 + 29.7^2} = \mathbf{30.8\ m/s}$.

MARKING SCHEME

- ✓ $t = \sqrt{(2h/g)} = 3.03$ s.
- ✓ x = ut = 24.2 m.
- ✓ $v_y = gt = 29.7$ m/s.
- ✓ v = 30.8 m/s.

7 Think

ANSWER HA · 3

It lands back **in her hand**. When it leaves her hand the ball already has the bus's horizontal velocity, and nothing changes that while it is in the air (ignoring air), so it keeps up with her. Relative to her it moves only up and down.
Someone beside the road sees the ball move forward with the bus as it rises and falls: a parabola, like a projectile's.

MARKING SCHEME

- ✓ It lands in her hand.
- ✓ The ball keeps the bus's horizontal velocity, so it moves forward with her.
- ✓ From the road its path is a parabola (straight up and down only relative to the bus).

8 Activity: How fast do you react?

(not marked)

WHAT STUDENTS SHOULD FIND

Most people catch the ruler after it falls 10–25 cm: reaction times of about 0.14–0.23 s (t = √(2 × 0.15 ÷ 9.8) = 0.17 s for 15 cm). At 15 m/s a motorcycle goes 2–4 m in that time before the rider even starts to brake. The times vary from try to try, so the average is more reliable.

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See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Magnetic Braking** (exhibit): Drop the magnet through each tube: in plastic its velocity–time graph is a rising straight line; in copper it soon levels off: steady speed, zero acceleration.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	7	10	13	3	**33**

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