



Unit 7 • Force and Motion: describing motion

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. distance
2. scalar
3. displacement
4. acceleration
5. retardation
6. 9.8 m/s
7. velocity
8. at rest

K • 4

Each carries 0.5 mark.

2 Label the diagram

1. straight, up: uniform velocity
2. straight, down: uniform velocity back
3. curving up: speeding up
4. curving over: slowing down

U • 2

Each carries 0.5 mark.

3 Multiple choice

- i. c. acceleration

K • 1

Slope = change in velocity ÷ change in time = acceleration. (The slope of a displacement–time graph is the velocity.)

- ii. c. 5 m, roughly north-east

A • 1

The distance is $3 + 4 = 7$ m, but displacement is the straight line from start to end. The two walks make a right-angled triangle, so the straight line is $\sqrt{3^2 + 4^2} = \sqrt{25} = 5$ m, pointing roughly north-east (a little more north than east). “7 m” is the distance, the tempting wrong answer.

- iii. b. 3 m/s^2

A • 1

$a = (v-u)/t = (25-10)/5 = 15/5 = 3 \text{ m/s}^2$. “15” forgets to divide by the time; “7” is $(25 + 10)/5$, adding instead of subtracting; “2” is $10 \div 5$.

- iv. b. the object is moving back towards the start with uniform velocity

U • 1

The displacement is getting smaller at a steady rate: the object is coming **back** with a **uniform** (negative) velocity, like segment CD of the motorcycle. Slowing down would be a curve that flattens out.

- v. b. starting from rest with uniform acceleration

U • 1

On a v - t graph, a straight rising line means the velocity grows by equal amounts in equal times: **uniform acceleration**, starting from $v = 0$. (On an s - t graph the same shape would mean uniform velocity: always check which graph it is!)

4 Very short answers

- a. MARKING SCHEME

K • 1

✓ m/s^2 written.

- b. MARKING SCHEME

U • 1

✓ It is moving in the opposite (negative) direction from the reference point.



- c. MARKING SCHEME K · 1
✓ $v^2 = u^2 + 2as$ written.

5 Short answers

- a. MARKING SCHEME K · 2
✓ Average velocity: total displacement ÷ total time taken (in the direction of the displacement).
✓ Acceleration: the rate of change of velocity, $a = (v - u)/t$.
- b. MARKING SCHEME U · 2
✓ Any one difference, e.g. the slope of a displacement–time graph gives the velocity; the slope of a velocity–time graph gives the acceleration.
✓ Any second difference, e.g. a flat line on a displacement–time graph means the body is at rest; on a velocity–time graph it means uniform velocity.
- c. MARKING SCHEME U · 2
✓ Velocity has both size and direction (it is a vector).
✓ On the bend the direction keeps changing, so the velocity changes even though the speed stays the same.

6 Long answer

ANSWER

U · 4

- i. By definition, acceleration = change in velocity ÷ time, $a = (v - u)/t$. So $at = v - u$, and $v = u + at$.
- ii. For uniform acceleration, average velocity = $(u + v)/2$, so $s = \text{average velocity} \times \text{time} = [(u + v)/2] \times t$. Put $v = u + at$: $s = [(u + u + at)/2] \times t = (u + \frac{1}{2}at) \times t$, so $s = ut + \frac{1}{2}at^2$.

MARKING SCHEME

- ✓ i. $a = (v - u)/t$ from the definition of acceleration.
✓ $at = v - u$, so $v = u + at$.
✓ ii. $s = \text{average velocity} \times \text{time} = [(u + v)/2] \times t$.
✓ Putting $v = u + at$: $s = (u + \frac{1}{2}at)t = ut + \frac{1}{2}at^2$.

7 Numerical problems

- a. ANSWER A · 4
 $u = 0$, $a = 1.5 \text{ m/s}^2$, $t = 30 \text{ s}$.
 $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 1.5 \times 30^2 = 0.75 \times 900 = 675 \text{ m}$.
 $v = u + at = 0 + 1.5 \times 30 = 45 \text{ m/s towards the south}$.

MARKING SCHEME

- ✓ $s = ut + \frac{1}{2}at^2$ with $u = 0$, $a = 1.5 \text{ m/s}^2$ and $t = 30 \text{ s}$ put in.
✓ $s = 675 \text{ m}$.
✓ $v = u + at = 0 + 1.5 \times 30$.
✓ $v = 45 \text{ m/s towards the south}$.



b. ANSWER

A · 4

- i. Uniform velocity: BC and DE (flat lines). Uniform acceleration: AB, CD and EF (straight lines sloping up).
- ii. CD: its velocity rises 15 m/s in 4 s (3.75 m/s^2), against 10 m/s in 4 s for AB (2.5 m/s^2) and 5 m/s in 4 s for EF (1.25 m/s^2).
- iii. $a = (v - u)/t = (25 - 10)/(10 - 6) = 15/4 = 3.75 \text{ m/s}^2$.
- iv. The displacement is the area under CD, a trapezium: $\frac{1}{2} \times (10 + 25) \times 4 = 70 \text{ m}$. (Check: $s = ut + \frac{1}{2}at^2 = 10 \times 4 + \frac{1}{2} \times 3.75 \times 16 = 70 \text{ m}$.)

MARKING SCHEME

- ✓ i. Uniform velocity: BC and DE; uniform acceleration: AB, CD and EF.
- ✓ ii. CD (the steepest: 3.75 m/s^2 , against 2.5 m/s^2 for AB and 1.25 m/s^2 for EF).
- ✓ iii. $a = (25 - 10)/(10 - 6) = 3.75 \text{ m/s}^2$.
- ✓ iv. Area under CD = $\frac{1}{2} \times (10 + 25) \times 4 = 70 \text{ m}$.

8 Think**ANSWER**

HA · 2

Brakes can only stop the motorcycle, not drive it backwards. By $v = u + at$, it stops after $20 \div 6 = 3.3 \text{ s}$, before 4 s are over, so the equation with $t = 4 \text{ s}$ wrongly “reverses” it. In 4 s it goes only its stopping distance: $v^2 = u^2 + 2as$ with $v = 0$ gives $0 = 400 - 12s$, $s = 33.3 \text{ m}$.

MARKING SCHEME

- ✓ The motorcycle stops after $20 \div 6 \approx 3.3 \text{ s}$, before 4 s, so $t = 4 \text{ s}$ can’t be used.
- ✓ Stopping distance from $v^2 = u^2 + 2as$ with $v = 0$: $s = 400 \div 12 \approx 33.3 \text{ m}$.

9 Activity: A marble on a slope (Activities 7.2 and 7.3)

(not marked)

WHAT STUDENTS SHOULD FIND

The distance covered in each second grows (roughly in the ratio 1 : 3 : 5 : 7), so the velocity in each second increases by about the same amount each time: the marble has uniform acceleration. The displacement–time graph is a curve getting steeper (curving up), which means speeding up.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	13	10	2	34





Unit 7 • Force and Motion: inertia, Newton's laws and elasticity

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. inertia
2. mass
3. inertia of rest
4. unbalanced force
5. newton
6. reaction
7. elastic limit
8. plasticity

K • 4

Each carries 0.5 mark.

2 Label the diagram

- | | | |
|--------------|--------------------------------------|-------|
| 1. flick | 4. card | K • 3 |
| 2. coin | 5. the coin stays put, then falls in | |
| 3. glass mug | 6. card flies off | |
| | | |

Each carries 0.5 mark.

3 Multiple choice

- i. b. inertia of motion

U • 1

Your feet stop when they touch the ground, but the rest of your body keeps moving forward with the bus's speed (inertia of motion), so you fall forward.

- ii. d. they act on different bodies

K • 1

Action and reaction are equal and **opposite**, and act on **two different bodies**, which is exactly why they never cancel each other.

- iii. d. hitting a shuttlecock with a badminton racket

U • 1

The racket's strings stretch when the shuttlecock hits them and spring back, throwing it off: elasticity. The other three keep the new shape: plasticity.

- iv. b. the car covers less distance than the truck before stopping

A • 1

With the same force, $a = F/m$: the truck, with much more mass, gets a much smaller retardation, so it needs a **longer** distance to stop ($s = u^2/2a$). The car stops in a shorter distance.

- v. c. a loaded truck standing still

U • 1

Inertia depends on mass only, not on speed. The truck has by far the most mass, so it has the most inertia, even at rest. (How hard a moving thing is to stop depends on its speed as well as its mass; that is a different quantity, called **momentum**.)

4 Very short answers

- a. MARKING SCHEME

K • 1

✓ A body stays at rest, or moves in a straight line with uniform velocity, unless an unbalanced force acts on it.

- b. MARKING SCHEME

K • 1

✓ The force that gives 1 kg an acceleration of 1 m/s².



- c. MARKING SCHEME U · 1
✓ Steel.

5 Short answers

- a. MARKING SCHEME U · 2
✓ The shaking suddenly moves the branches, but the leaves and fruits tend to stay at rest (inertia of rest).
✓ Their stalks are pulled hard and break, so they fall.
- b. MARKING SCHEME U · 2
✓ By Newton's third law, the bullet pushes the gun backwards with a force equal to the gun's push on it, so the gun recoils.
✓ Held firmly, the recoil is shared with the much larger mass of the body, so the gun moves back only a little and does not hurt the shooter.
- c. MARKING SCHEME K · 2
✓ Any one difference, e.g. an elastic body regains its original shape when the deforming force is removed; a plastic body keeps its deformed shape.
✓ Any second difference, e.g. in elasticity the change is temporary and a restoring force develops; in plasticity the change is permanent and no restoring force develops.
- d. MARKING SCHEME A · 2
✓ Action: the feet push the boat backwards; reaction: the boat pushes the man forwards.
✓ The boat is free to move on the water, so the action pushes it back, away from the bank.

6 Long answer

ANSWER

U · 4

Second law: the acceleration produced in a body is directly proportional to the force acting on it and inversely proportional to its mass.

Proof: $a \propto F$ (mass constant) and $a \propto \frac{1}{m}$ (force constant). Combining them, $a \propto \frac{F}{m}$, so

$F \propto ma$ and $F = k ma$, where k is a constant.

One newton is defined as the force that gives a 1 kg mass an acceleration of 1 m/s².

Putting $F = 1$ N, $m = 1$ kg, $a = 1$ m/s²: $1 = k \times 1 \times 1$, so $k = 1$. Therefore $F = ma$.

MARKING SCHEME

- ✓ The acceleration of a body is directly proportional to the force on it and inversely proportional to its mass.
- ✓ $a \propto F$ (mass constant) and $a \propto 1/m$ (force constant), so $a \propto F/m$, $F \propto ma$.
- ✓ $F = k ma$, where k is a constant.
- ✓ 1 N gives 1 kg an acceleration of 1 m/s², so $1 = k \times 1 \times 1$, $k = 1$ and $F = ma$.

7 Numerical problems

- a. ANSWER A · 2
The total mass moving is $m = 50 + 12 = 62$ kg.
 $F = ma = 62 \times 2 = 124$ N (down the hill).
- MARKING SCHEME
✓ Total mass $m = 50 + 12 = 62$ kg.
✓ $F = ma = 62 \times 2 = 124$ N.



b. ANSWER

A · 4

$u = 72 \text{ km/h} = 72 \times 1000 \div 3600 = 20 \text{ m/s}$; $v = 10 \text{ km/h} = 10 \times 1000 \div 3600 = 2.78 \text{ m/s}$; $s = 50 \text{ m}$.

$$v^2 = u^2 + 2as \Rightarrow 2.78^2 = 20^2 + 2 \times a \times 50 \Rightarrow 7.72 = 400 + 100a \Rightarrow a = -3.92 \text{ m/s}^2$$

$F = ma = 1500 \times (-3.92) = -5880 \text{ N}$: a braking force of about **5900 N**, opposite to the motion.

(If you round the retardation to 3.9 m/s^2 , you get $1500 \times 3.9 = 5850 \text{ N}$. Either is right with the working shown.)

MARKING SCHEME

✓ $u = 72 \text{ km/h} = 20 \text{ m/s}$ and $v = 10 \text{ km/h} = 2.78 \text{ m/s}$.

✓ $v^2 = u^2 + 2as$ with $s = 50 \text{ m}$: $7.72 = 400 + 100a$.

✓ $a = -3.92 \text{ m/s}^2$ (a retardation of 3.92 m/s^2).

✓ $F = ma = 1500 \times 3.92 \approx 5880 \text{ N}$, opposite to the motion.

8 Think

ANSWER

HA · 2

Action and reaction act on different bodies, so they never cancel each other. To find whether the horse moves, look only at the forces on the horse: it pushes the ground backwards with its hooves, and the ground pushes it forwards. When that forward push is bigger than the cart's backward pull on the horse, the horse, and the cart with it, accelerates forwards.

MARKING SCHEME

✓ The horse's pull and the cart's pull act on different bodies, so they do not cancel.

✓ The ground pushes the horse forwards (reaction to its hooves pushing the ground back); when this is more than the cart's pull, they move forwards.

9 Activity: What force does to shape (Activity 7.17)

(not marked)

WHAT STUDENTS SHOULD FIND

The rubber band, the balloon and the steel spring change shape and go back when you stop: they are elastic. The toothpaste tube stays squeezed and the piece of plastic bag stays stretched: they are plastic, deformed for good. The spring goes back only if it is not pulled beyond its elastic limit.

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.

- **Newton's Cradle** (exhibit): Release one ball, then two: the same number fly off the far end, pushed by equal forces.
- **Saturn V - LEGO Model** (exhibit): A rocket pushes hot gas down and the gas pushes it up: find the Saturn V's engines.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	12	12	9	2	35

