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

1 Spot the error

ANSWER U · 3

She has forgotten that velocity is a vector: the ball's direction reverses. Taking "away from the wall" as positive, u = −9 m/s and v = +6 m/s.
Change in momentum = 0.2 × 6 − 0.2 × (−9) = 1.2 + 1.8 = **3 kg m/s**, away from the wall.
F = 3 ÷ 0.03 = **100 N**, five times her answer.

MARKING SCHEME

- ✓ The mistake: the direction reverses, so the velocities have opposite signs.
- ✓ Change in momentum = 3 kg m/s.
- ✓ F = 100 N.

2 Reaching the opposite bank

ANSWER HA · 5

i. Across: 120 ÷ 5 = **24 s**. Downstream: 3 × 24 = **72 m**.
ii. **No, still 24 s.** The crossing depends only on the velocity across the river, 5 m/s, and the river's flow is at right angles to it. He only lands farther down: 4 × 24 = 96 m.
iii. The boat must point partly upstream, so that its own velocity (5 m/s, the longest side) added to the river's (3 m/s downstream) gives a resultant straight across. The triangle is right-angled with 5 as its hypotenuse: across speed = $\sqrt{(5^2 - 3^2)} = \sqrt{16}$ = **4 m/s**. Time = 120 ÷ 4 = **30 s**, longer than steering straight across.

MARKING SCHEME

- ✓ 24 s and 72 m.
- ✓ Still 24 s, because only the velocity across the river sets the time.
- ✓ The triangle: 5 m/s is the hypotenuse, the river's 3 m/s and the resultant across are its other sides.
- ✓ Across speed = $\sqrt{(5^2 - 3^2)}$ = 4 m/s.
- ✓ Time = 30 s.

3 Three walks

ANSWER A · 3

East and west on one line: 8 − 4 = 4 km, west. This and the 6 km north are at right angles:
R = $\sqrt{(4^2 + 6^2)} = \sqrt{52}$ = **7.2 km**; tan θ = 4/6 = 0.667, so θ = **33.7° west of north**.
Distance walked: 4 + 6 + 8 = **18 km**.

MARKING SCHEME

- ✓ 4 km west and 6 km north, at right angles.
- ✓ R = 7.2 km, at 33.7° west of north.
- ✓ Distance 18 km.

4 An elevator goes up and down

ANSWER

i. Up from 0 to 3 m/s, flat to 10 s, down to 0 at 12 s; flat on the axis to 14 s; down to −2 m/s at 16 s, flat to 26 s, back to 0 at 28 s.
ii. It is at rest (at a floor, with zero velocity).
iii. Above the axis: ½ × 2 × 3 + 8 × 3 + ½ × 2 × 3 = 3 + 24 + 3 = **30 m up**. Below the axis: ½ × 2 × 2 + 10 × 2 + ½ × 2 × 2 = 2 + 20 + 2 = **24 m down**.
iv. Distance = 30 + 24 = **54 m**. Displacement = 30 − 24 = **6 m upward**. Average velocity = 6 ÷ 28 = **0.21 m/s upward**.
v. 6 ÷ 3 = **2 floors** above where it started.

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MARKING SCHEME A · 5

- ✓ The graph, with the part below the time axis for going down.
- ✓ At rest between 12 s and 14 s.
- ✓ 30 m up and 24 m down.
- ✓ Distance 54 m, displacement 6 m upward, average velocity 0.21 m/s upward.
- ✓ 2 floors above the start.

5 Work backwards

ANSWER A · 4

The graph is a trapezium with parallel sides 120 s and 120 − 20 − 10 = 90 s, and height v.
Area: ½ × (120 + 90) × v = 105v = 1,050, so v = **10 m/s**.
Acceleration = 10 ÷ 20 = **0.5 m/s^2**. Retardation = 10 ÷ 10 = **1 m/s^2**.
Average velocity = 1,050 ÷ 120 = **8.75 m/s**.

MARKING SCHEME

- ✓ Trapezium with parallel sides 120 s and 90 s: 105v = 1,050.
- ✓ Top speed 10 m/s.
- ✓ Acceleration 0.5 m/s^2 and retardation 1 m/s^2.
- ✓ Average velocity 8.75 m/s.

6 Who carries more?

ANSWER HA · 4

i. Karma, who is nearer the sack.
ii. About Karma's shoulder, the force on Karma has no moment. 600 × 0.5 = F × 2, so F = **150 N** on Jeevan.
iii. The pole doesn't move up or down, so the two upward forces add up to the load: 600 − 150 = **450 N** on Karma.

Check about Jeevan's shoulder: 600 × 1.5 = 900 N m and 450 × 2 = 900 N m. They are equal.

MARKING SCHEME

- ✓ Karma, nearer the sack.
- ✓ 600 × 0.5 = F × 2, so 150 N on Jeevan.
- ✓ 450 N on Karma.
- ✓ The check: 900 N m each way about Jeevan's shoulder.

7 Show that

ANSWER U · 3

About the middle: 30 × 0.2 + 30 × 0.2 = **12 N m**, both turning the same way.
About P: the far force is 0.5 m away and the near force 0.1 m. They turn opposite ways, so 30 × 0.5 − 30 × 0.1 = 15 − 3 = **12 N m**, the same.
A single force's moment depends on the point it is taken about; with a couple, moving the point adds to one force's moment and takes the same from the other's, because the two forces are equal.

MARKING SCHEME

- ✓ About the middle: 12 N m.
- ✓ About P: 30 × 0.5 − 30 × 0.1 = 12 N m.
- ✓ A single force has no equal and opposite partner, so its moment changes with the point.

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8 Is the report possible?

ANSWER A · 4

Total momentum before = $2 \times 3 + 1 \times 0 = 6$ kg m/s.

i. Anju's: $2 \times 1 + 1 \times 5 = 7$ kg m/s. Rizwan's: $2 \times 1 + 1 \times 4 = 6$ kg m/s. Sneha's: $2 \times 2 + 1 \times 3 = 7$ kg m/s. **Anju's and Sneha's cannot be right**: with no external force, the total must stay 6 kg m/s.

ii. $2 \times 1.5 + 1 \times v = 6$, so $v =$ **3 m/s**.

MARKING SCHEME

- ✓ Total before = 6 kg m/s.
- ✓ The three totals after: 7, 6 and 7 kg m/s.
- ✓ Anju's and Sneha's cannot be right.
- ✓ 3 m/s in the fourth run.

9 Rubber or clay?

ANSWER HA · 3

The rubber ball. The clay's momentum goes from mv to zero, a change of mv. The ball's goes from mv toward the door to some momentum away from it, so its change is mv plus that, larger. For the same time, force = change in momentum ÷ time is larger for the ball, and by Newton's third law the ball pushes the door with the same force as the door pushes it.

A bounce changes the momentum more than a dead stop does.

MARKING SCHEME

- ✓ The rubber ball pushes harder.
- ✓ Its change in momentum is larger than the clay's, since it also gains momentum back the other way.
- ✓ Same time, so a larger force on the ball, and by the third law on the door.

10 How much gas?

ANSWER A · 3

Momentum given each second = (mass per second) × speed, so mass per second = 7,000,000 ÷ 2,800 = **2,500 kg each second**, about two and a half tonnes.

The hose gives the water $20 \times 15 = 300$ kg m/s of forward momentum each second, so the water pushes back with a force of **300 N**.

(The Falcon figures are the unit's, in the photo's caption.)

MARKING SCHEME

- ✓ Mass per second = force ÷ speed, with the speed in m/s (2,800 m/s).
- ✓ About 2,500 kg each second.
- ✓ The hose gains backward momentum equal to the water's forward momentum each second: 300 N.

11 Design a fair test

ANSWER A · 4

i. She changes the number of coins taped to the balloon, and measures how far along the thread it travels.

ii. Any three: the same balloon; the same amount of air (the same size each time, measured round the middle); the same thread, tight and level; the same way of letting go.

iii. Repeat each load several times and take the average.

iv. The more coins, the shorter the distance. The air thrown out gives the same momentum backward, so the balloon gains the same forward momentum; with more mass, its velocity is smaller.

MARKING SCHEME

- ✓ Changes the number of coins; measures the distance traveled.
- ✓ Any three things kept the same.
- ✓ Repeats and takes averages.
- ✓ A shorter distance with more coins: the same momentum in a larger mass means a smaller velocity.

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12 Correct the misconceptions

ANSWER U · 3

1. A body at rest has **no momentum**, however heavy: p = mv = 0. (It has a lot of inertia.)
2. The ball's acceleration at the top is still about 10 m/s^2 downward. Its velocity is zero for an instant, but it is still changing.
3. The moment is 6 **N m**, not joules: the distance is at right angles to the force, not moved along it.

MARKING SCHEME

✓ A body at rest has zero momentum.
✓ The acceleration at the top is still g, downward.
✓ A moment is in N m, not joules.

13 Which explanation fits the evidence?

ANSWER HA · 3

Sujata's. A single force on the north pole would pull the needle along as well as turn it, and the compass would slide. Two equal, opposite, parallel forces add up to zero, so they don't move the needle from its place; they only turn it: a couple.
Once the needle lies along the field, both forces act along the same line, so the moment is zero and it stops turning.

MARKING SCHEME

✓ Sujata's explanation.
✓ Equal and opposite forces add up to zero, so there is turning but no sliding (a single force would move it along).
✓ Along the field, the two forces are in the same line and the moment is zero.

14 Think

ANSWER HA · 4

i. Taking the truck's direction as positive: 3,000 × 10 − 1,000 × 10 = 20,000 kg m/s = 4,000 v, so v = **5 m/s**, in the truck's direction.
ii. Truck: from 10 to 5 m/s, a change of **5 m/s**. Car: from −10 to +5 m/s, a change of **15 m/s**.
iii. Truck: 3,000 × 5 ÷ 0.1 = **150,000 N**. Car: 1,000 × 15 ÷ 0.1 = **150,000 N**. They are equal.
iv. **No.** The forces are equal and opposite (Newton's third law), as the numbers show. The car's passengers suffer more because the same force on a smaller mass gives a change in velocity three times as great.

MARKING SCHEME

✓ v = 5 m/s in the truck's direction.
✓ Changes in velocity of 5 m/s and 15 m/s.
✓ 150,000 N on each.
✓ He is wrong: equal forces, but the lighter car has the larger change in velocity.

15 Make your own

ANSWER HA · 2

For example: speeding up for 10 s to 8 m/s, steady for 5 s, braking for 5 s. Area = ½ × (20 + 5) × 8 = **100 m**. Any trapezium works whose top side T and height v obey ½ × (20 + T) × v = 100.

MARKING SCHEME

✓ A graph with three straight parts from rest to rest over 20 s.
✓ The area shown to be 100 m.

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.

- **The Wind Sock** (exhibit): The wind sock shows both how strong the wind is and which way it blows: the wind's velocity is a vector quantity.

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- **Walk Your Weight** (exhibit): The plank tips when the moment of your weight about the pivot matches the moment on the other side: the principle of moments.
- **Newton's Cradle** (exhibit): Lift one ball and let go: it stops dead and the ball at the far end swings out, carrying on the momentum, mass × velocity.
- **Saturn V - LEGO Model** (exhibit): A rocket pushes hot gas down hard and gains an equal momentum upward: the Saturn V rose toward the Moon by conservation of momentum.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	23	21	**53**

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