Unit 11 · Force

ANSWER KEY · FOR TEACHERS

Full marks 40

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. scalar quantity → **c.** has magnitude only
2. vector quantity → **f.** has both magnitude and direction, and adds by the triangle law
3. resultant → **g.** the single vector with the same effect as two or more vectors together
4. moment of a force → **e.** force × perpendicular distance from the pivot to the line of action
5. couple → **d.** two equal, opposite, parallel forces not in the same line
6. linear momentum → **b.** mass × velocity

K · 3

Each carries 0.5 mark.

2 Label the diagram

1. slope = a
2. area = ½at^2
3. area = ut

K · 3

Each carries 1 mark.

3 Multiple choice

i. **b.** displacement, acceleration, weight — K · 1

Displacement, acceleration and weight all have a direction. Each of the other groups has a scalar in it: mass, speed and time, work and electric current.

ii. **c.** 13 N — A · 1

At right angles, $R = \sqrt{5^2 + 12^2} = \sqrt{169} = 13$ N. 17 N would be the resultant if they acted in the same direction, 7 N if they acted in opposite directions.

iii. **b.** N m — K · 1

Moment = force × perpendicular distance, so its unit is newton × meter, N m. It is not the joule, the unit of work, even though both are a newton times a meter.

iv. **b.** turns it without moving it from its place — U · 1

The two forces of a couple are equal and opposite, so their resultant is zero: no movement from place to place. Because they don't act along the same line, they do have a moment, and turn the body.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ Currents add as numbers (they don't follow vector addition).

b. MARKING SCHEME — U · 1

✓ A displacement in the negative direction.

c. MARKING SCHEME — U · 1

✓ 10 m/s^2 downward (not zero).

d. MARKING SCHEME — U · 1

✓ The distance in a moment is at right angles to the force, not moved along it as in work.

5 Short answers

a. MARKING SCHEME — U · 2

✓ Moment = force × perpendicular distance, and the nut needs a certain moment.

✓ A longer wrench has a larger distance, so a smaller force gives the same moment.

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b. MARKING SCHEME U · 2

✓ The total momentum before firing is zero, and it must stay zero.

✓ The bullet gains forward momentum, so the gun gains an equal backward momentum.

c. MARKING SCHEME A · 2

✓ The largest is 10 N and the smallest 2 N.

✓ So 12 N cannot be, and 3 N can.

6 Long answer

ANSWER U · 4

For a body with uniform acceleration a, its velocity–time graph is a straight line from u at time 0 to v at time t.

First equation. The slope is the acceleration: $a = \dfrac{v-u}{t}$, so $v = u + at$.

Second equation. The distance s is the area under the line. It is a rectangle of height u and width t, area ut, with a triangle on top of base t and height $v - u = at$, area $\dfrac{1}{2} \times t \times at = \dfrac{1}{2}at^2$. So

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

MARKING SCHEME

✓ The graph is a straight line from u at time 0 to v at time t, and its slope is a = (v − u)/t.

✓ So v = u + at.

✓ The area under the line is a rectangle of area ut and a triangle of base t and height at.

✓ So s = ut + ½ × t × at = ut + ½at².

7 Numerical problems

a. ANSWER A · 4

The graph rises from 0 to 20 m/s (0 to 8 s), stays at 20 m/s (8 to 20 s), and falls to 0 (20 to 24 s).

i. $a = \dfrac{20-0}{8} = 2.5$ m/s²

ii. $a = \dfrac{0-20}{4} = -5$ m/s², a retardation of **5 m/s²**.

iii. Distance $= \dfrac{1}{2} \times 8 \times 20 + 12 \times 20 + \dfrac{1}{2} \times 4 \times 20 = 80 + 240 + 40 =$ **360 m**.

iv. Average velocity $= 360 \div 24 =$ **15 m/s**.

MARKING SCHEME

✓ i. Acceleration 2.5 m/s².

✓ ii. Retardation 5 m/s².

✓ iii. Distance = 80 + 240 + 40 = 360 m.

✓ iv. Average velocity = 360 ÷ 24 = 15 m/s.

b. ANSWER A · 3

$$v = \sqrt{240^2 + 70^2} = \sqrt{57{,}600 + 4{,}900} = \sqrt{62{,}500} = 250 \text{ km/h}$$

$$\tan\theta = \frac{70}{240} = 0.292 \quad \Rightarrow \quad \theta = 16.3^\circ$$

250 km/h, at 16.3° east of north.

MARKING SCHEME

✓ v = √(240² + 70²).

✓ v = 250 km/h.

✓ tan θ = 70/240, so θ = 16.3° east of north.

c. ANSWER

$u = 72$ km/h $= \dfrac{72 \times 1000}{3600} = 20$ m/s, $v = 0$.

Change in momentum $= mv - mu = 0 - 1500 \times 20 = -30{,}000$ kg m/s (a decrease of 30,000 kg m/s).

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$$F = \frac{mv - mu}{t} = \frac{-30{,}000}{4} = -7{,}500 \text{ N}$$ A · 3

The momentum falls by 30,000 kg m/s, and the braking force is 7,500 N, against the motion.

MARKING SCHEME

✓ u = 72 km/h = 20 m/s.
✓ Change in momentum = 1500 × 20 = 30,000 kg m/s (a decrease).
✓ F = 30,000 ÷ 4 = 7,500 N, against the motion.

d. ANSWER A · 3

Total momentum before = 2 × 3 + 1 × (−2) = 6 − 2 = 4 kg m/s.
After: (2 + 1) v = 4, so v = 1.33 m/s.
They move together at 1.33 m/s, in the direction the 2 kg trolley was moving.

MARKING SCHEME

✓ Taking one direction as positive: total momentum before = 2 × 3 + 1 × (−2) = 4 kg m/s.
✓ (2 + 1) v = 4.
✓ v = 1.33 m/s, in the 2 kg trolley's direction.

8 Think

ANSWER HA · 3

Total momentum before = 0. After: 2 × 5 + 100 × v = 0, so v = −0.1 m/s: she moves toward the station at 0.1 m/s. Time = 10 ÷ 0.1 = **100 s**.
Waving her arms moves parts of her body, but the total momentum of her and her suit stays zero, since nothing is thrown away and there is no air to push against. When her arms stop, she stops.

MARKING SCHEME

✓ Her speed: 2 × 5 = 100 × v, so v = 0.1 m/s toward the station.
✓ Time = 10 ÷ 0.1 = 100 s.
✓ Waving her arms throws nothing away and there is no air to push against, so her total momentum stays zero.

9 Activity: Finding a resultant by drawing

(not marked)

WHAT STUDENTS SHOULD FIND

About 70 N at 0°, 61 N at 60°, 50 N at 90°, 36 N at 120° and 10 N at 180°. The resultant is largest when the forces point the same way (30 + 40) and smallest when they point opposite ways (40 − 30), and at every other angle it lies between the two.

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.
- **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	9	12	16	3	**40**

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