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

The 2 m/s is a velocity, not an acceleration. At a steady velocity a = 0, so the resultant force is zero and R = mg = 60 × 9.8 = **588 N**: the scale reads his true weight. R = m(g + a) applies only while the lift speeds up going up (or slows down going down).

MARKING SCHEME

- ✓ The mistake: 2 m/s is a velocity; the acceleration is zero.
- ✓ With a = 0, R = mg (first law).
- ✓ R = 588 N.

2 What if?

ANSWER A · 4

i. Friction μmg is the only horizontal force, so a = μg = 0.6 × 9.8 = **5.9 m/s²**. 54 km/h = 15 m/s: s = $u^2/(2\mu g)$ = 225 ÷ 11.76 = **19.1 m**.

ii. s ∝ 1/μ: halving μ doubles it, to **38.3 m**.

iii. **No** (in this simple model): the friction μmg and the mass to be stopped both grow with m, so a = μg doesn't depend on the mass.

MARKING SCHEME

- ✓ a = μg = 5.9 m/s².
- ✓ s = 19.1 m.
- ✓ 38.3 m on the wet road (twice as far).
- ✓ The mass cancels: a = μg, so the same distance.

3 Check the claim

ANSWER HA · 5

i. Run 1: before 1.0 × 0.80 = 0.80, after 2.0 × 0.40 = 0.80 kg m/s. Run 2: before 1.20, after 3.0 × 0.40 = 1.20 kg m/s. Run 3: before 1.20, after 4.0 × 0.24 = 0.96 kg m/s.

ii. **Run 3**: 20% of the momentum is missing. An outside force acted during the collision or the timing: most likely friction on a slow trolley (or a slope in the track, or a timing error).

iii. The speed halves, but the moving mass doubles (2.0 kg instead of 1.0 kg), so the momentum, mass × speed, stays 0.80 kg m/s. (Kinetic energy is what is lost: half of it.)

MARKING SCHEME

- ✓ Momenta before and after for all three runs.
- ✓ Run 3 is not conserved (0.96 against 1.20 kg m/s).
- ✓ A reason: friction or another external force (or a timing error).
- ✓ Diksha is wrong: the mass doubles as the speed halves.
- ✓ So the momentum is unchanged (it is the kinetic energy that halves).

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4 Predict, then explain

ANSWER A · 4

i. 3.0 V = 0.010 × 600 = 6 kg m/s, so V = **2 m/s**, backwards.

ii. F = Δp/Δt = 6 ÷ 0.05 = **120 N**.

iii. Held **loosely**, the rifle alone recoils at 2 m/s and hits her shoulder hard. Pressed **tightly**, the rifle and her body recoil together: a mass of, say, 60 kg more, so the recoil speed is about 6 ÷ 63 ≈ 0.1 m/s, much gentler (and the push is spread over a longer time).

MARKING SCHEME

✓ V = 2 m/s.

✓ Average force 120 N.

✓ Held tightly, the rifle and the body move together (much larger mass).

✓ So the recoil speed and the blow are much smaller.

5 Balance it

ANSWER A · 4

Take moments about the left end. Clockwise: the plank's weight 20 × 9.8 = 196 N at 2.0 m, and Mingma's 50 × 9.8 = 490 N at 1.0 m. Anticlockwise: the right support R_2 at 4.0 m.
4.0 R_2 = 196 × 2.0 + 490 × 1.0 = 882, so $\mathbf{R_2 = 220.5\ N}$.
Vertically: $R_1 + R_2$ = 196 + 490 = 686 N, so $\mathbf{R_1 = 465.5\ N}$. The support nearer to her carries more.

MARKING SCHEME

✓ Moments taken about one support (the plank's weight at its middle).

✓ R_2 = 220.5 N.

✓ Forces up = forces down: $R_1 + R_2$ = 686 N.

✓ R_1 = 465.5 N.

6 Design a fair test

ANSWER A · 4

i. She lays the brick on its large face, then its side, then its end (changing the area), and measures the force needed to pull it.

ii. Any two: the same brick (the same weight, so the same normal force); the same table surface; the same string held level; the same way of pulling.

iii. Pull horizontally and slowly, and read the balance just as the brick starts to move (the limiting friction), or while it slides at a steady speed (the kinetic friction); repeat each a few times.

iv. About the same reading on every face.

MARKING SCHEME

✓ Changes the face (area); measures the pulling force.

✓ Two things kept the same (weight, surface, string level…).

✓ Pull level; read at the start of sliding or at a steady speed; repeat.

✓ The same reading on every face.

7 Which explanation fits?

ANSWER U · 3

Alina's. By inertia (the first law), a body keeps moving at the same velocity unless a force changes it. The brakes act on the bus, and friction at the feet slows the passengers' feet with it, but nothing slows their upper bodies at once, so they carry on forward. No forward force acts on them: in the bus's frame they only seem pushed, because the bus is slowing down.

MARKING SCHEME

✓ Alina is right.

✓ Inertia of motion: the upper body keeps its velocity; only the feet slow with the bus.

✓ No forward force acts on the passengers (Swapnil is wrong).

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8 Correct the misconceptions

ANSWER U · 3

1. Friction does not depend on the area of contact (only on the surfaces and the normal reaction).
2. Friction opposes the slipping between surfaces, which can make it act forward: when we walk, the foot pushes the ground backward and friction pushes us forward.
3. Static friction adjusts itself to the applied force; $\mu_s R$ is only its greatest value, the limiting friction.

MARKING SCHEME

- ✓ Friction is independent of the area of contact.
- ✓ Friction opposes relative slipping and can act forward (walking, a car's driven wheels).
- ✓ Static friction is up to $\mu_s R$, not always equal to it.

9 Think

ANSWER HA · 3

In free fall $a = g$, so $R = m(g - a) = 0$: the scale reads **zero**; she is weightless.
If the lift were driven down faster than g, $R = m(g - a)$ would have to be negative, but a scale can't pull her down. So the scale reads zero and the floor drops away from her: she rises towards the ceiling (relative to the lift), until the ceiling pushes her down with it: she is pressed against the ceiling.

MARKING SCHEME

- ✓ Free fall: $R = m(g - g) = 0$, the scale reads zero.
- ✓ Faster than g: R would have to be negative, impossible for a floor.
- ✓ She leaves the floor and is pressed against the ceiling.

10 Make your own

ANSWER HA · 2

$a = (m_1 - m_2)g/(m_1 + m_2) = g/5$ needs $5(m_1 - m_2) = m_1 + m_2$, so $m_1 = 1.5\ m_2$. For example 3 kg and 2 kg: $a = (3 - 2) \times 9.8 \div 5 = 1.96\ m/s^2 = g/5$.

MARKING SCHEME

- ✓ A pair with $m_1 = 1.5\ m_2$ (e.g. 3 kg and 2 kg).
- ✓ Checked: $a = (m_1 - m_2)g/(m_1 + m_2) = g/5$.

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 swing out at the far end, carrying on the momentum, while the middle balls barely move.
- **Saturn V - LEGO Model** (exhibit): The real Saturn V rose by throwing its exhaust gas down at high speed: the gas's downward momentum is matched by the rocket's upward momentum, gravity aside.
- **Walk Your Weight** (exhibit): Walk out from the pivot until the plank tips: it turns once your weight's moment, force × perpendicular distance, exceeds the moment on the other side.
- **Tensegrity — Floating in Balance** (exhibit): Nothing here moves: on every part the strings' pulls, the rods' pushes and the weight give zero resultant force and zero torque, equilibrium's two conditions.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	16	10	**35**

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