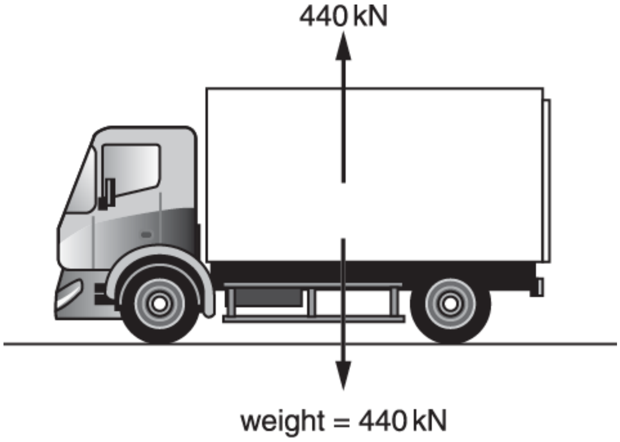
1. The diagram shows the forces acting on a stationary lorry.



(i) The downward force on the lorry is called weight. What is the name of the upward force?

----

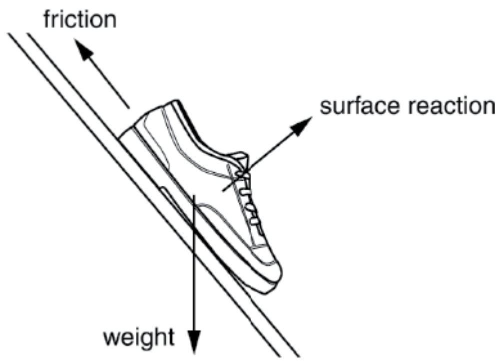
[1]

(ii) The lorry driver says that these two forces must be an interaction pair of forces as they are equal and opposite.

Explain why the driver is wrong.

-- **[2]**

2(a). The forces on a shoe as it starts to move down a slope are shown in the diagram.



(i) Each force is part of an interaction pair.

Complete the following sentences.

The pair force of the friction from the surface on the shoe is ____________________________________

____.

The pair force of the weight of the shoe is ____

____.

[2]

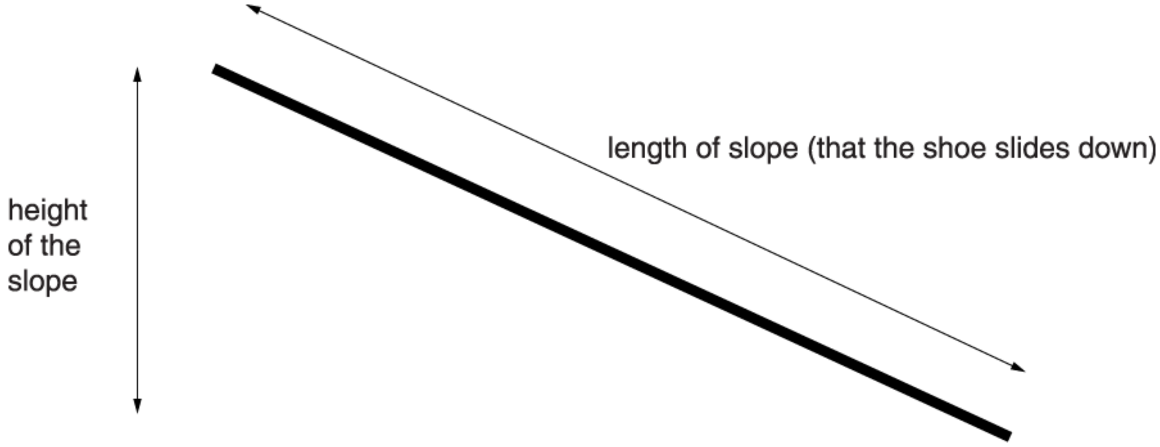
(ii) Describe the resultant force on the shoe as it starts to move down the slope.

____

____ **[1]**

(b). Ross measures the **time** it takes for the shoe to move down the slope, the **weight** of the shoe and the **mass** of the shoe.

He then measures the following distances:



He wants to calculate a number of different values using **only** his data.

Which **quantities** does he use to work out each **calculated value**?

Put ticks (✓) in the correct boxes in each row.

Calculated value	Quantity				
	Time	Mass of the shoe	Weight of the shoe	Height of slope	Length of slope
average speed along slope					
average vertical velocity					
change in gravitational potential energy when the shoe slides down the slope					
average momentum of the shoe down the slope					

[4]

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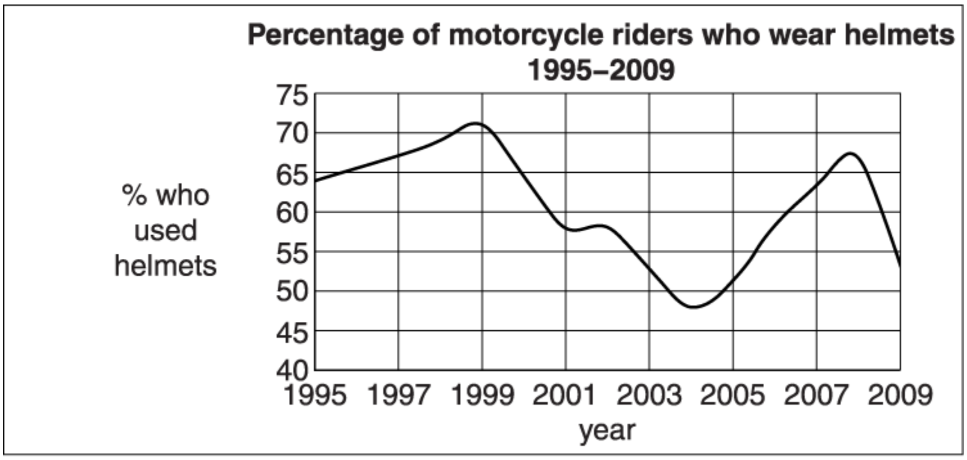
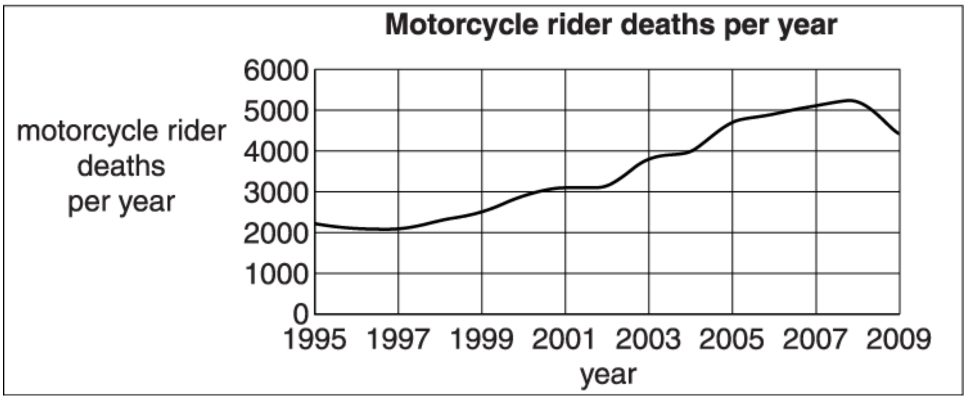
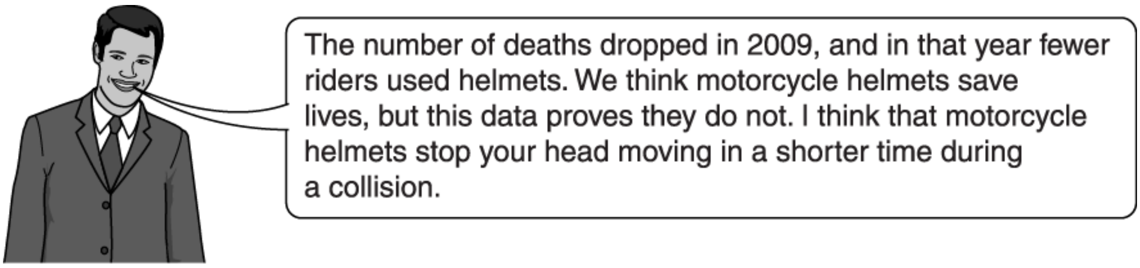
3. Look at the two graphs showing motorcycle rider deaths and helmet use.





A politician looks at the graphs.



The politician has misunderstood the ideas of correlation and cause, and does not understand how motorcycle helmets work.

Explain why he is **wrong**, using the data and your knowledge of physics.

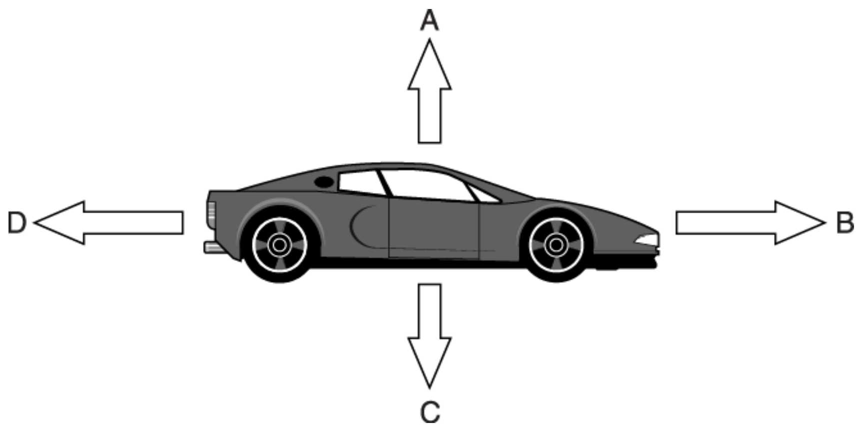
The quality of written communication will be assessed in your answer.

---

[6]

4. Racing car teams track the progress of cars to analyse their performance.

Some of the forces on a car are shown below.



(i) Draw lines to match each **arrow** to its **force** and each **force** with its **description**.

arrow	force	description
A	reaction force	push of the engine
B	driving force	force due to friction and air resistance
C	counter force	pull of gravity on the car
D	weight	force from the ground on the car

[2]

(ii) The team had force sensors on the car.

At one moment, the sensors measured the following forces:

A	B	C	D
6400 N	18000 N	6400 N	11500 N

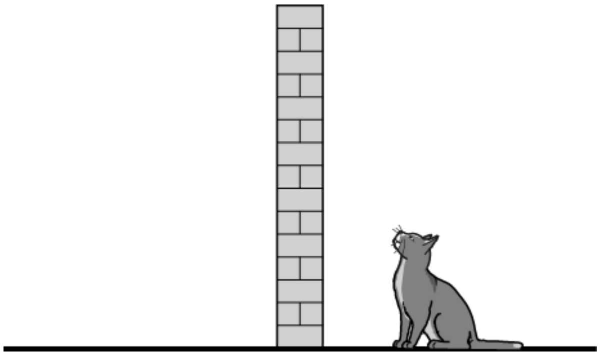
Calculate the resultant force on the car, including its direction.

resultant force ____________________ N

direction ____________________

[2]

5. Iggy the cat is sitting next to the bottom of a wall.



He jumps from the ground onto the wall.
The wall is 1.5 m high.

As Iggy walks along the wall he knocks a tin can off the wall and it falls to the ground.

The tin can weighs 0.2 kg and its velocity just before hitting the ground is 5.1 m / s.

(i) Calculate the momentum of the tin can just before it hits the ground.

momentum _____________________ kg m / s **[1]**

(ii) When the tin can hits the ground it takes 0.1 s to stop moving.

Calculate the resultant force acting on the can.

resultant force _____________________ N **[2]**

(iii) The tin can took 0.1 s to stop moving because the ground was **soft**.

Explain what effect **hard** ground would have had on the resultant force.

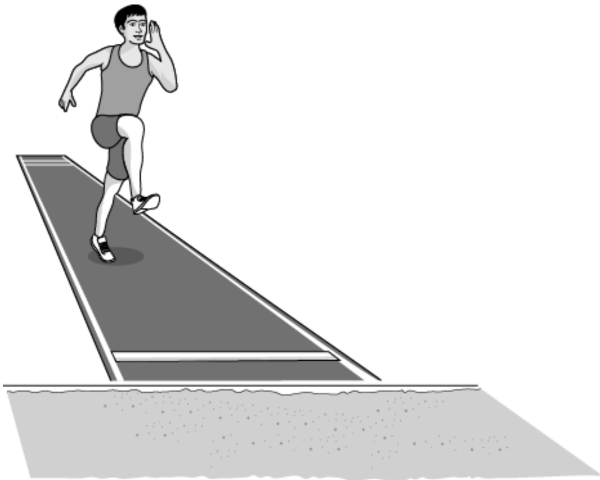
____

____

____ **[2]**

6. Amir is a long jumper. He runs as fast as he can before he jumps.

This lets Amir jump much further than if he had jumped without running.

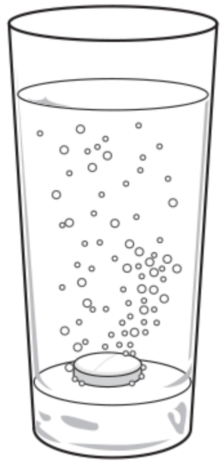


Use ideas about forces and motion to explain how the running helps Amir jump further.

The quality of written communication will be assessed in your answer.

--- **[6]**

7(a). The picture shows a glass of water with a vitamin tablet at the bottom.



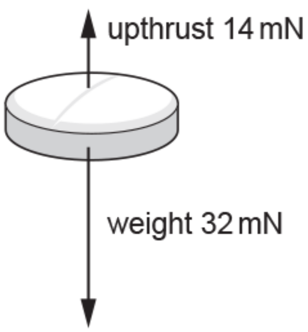
The tablet reacts with the water to produce bubbles of carbon dioxide.

The tablet stays at the bottom of the glass. The bubbles rise to the top of the glass.

The diagram below is a free-body diagram for the tablet resting on the bottom of the glass.

Two of the forces acting on the tablet have already been drawn.

Draw **one** further force for the tablet and label it with its name and magnitude.



[2]

(b).

(i) Explain what causes the force of upthrust that acts on the tablet.

[2]

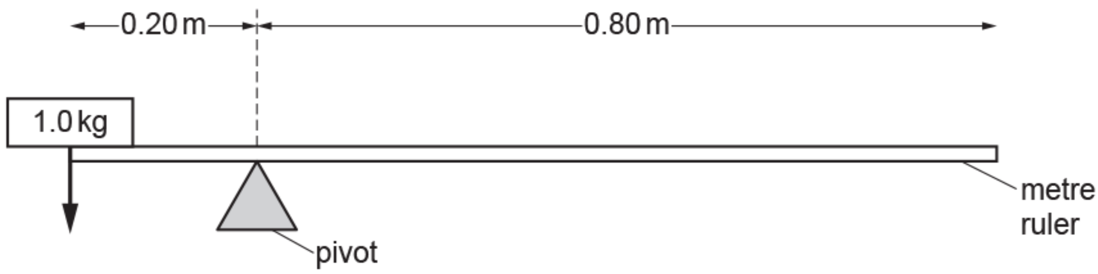
(ii) The upthrust on the tablet is bigger than the upthrust on any one bubble.

Give a reason for this.

[1]

8(a). Jack investigates using weights to balance a seesaw. He makes the seesaw out of a metre ruler with a pivot placed at the 20 cm mark, as shown in the diagram.

He places a 1.0 kg mass with its centre exactly at one end of the metre ruler.



Calculate the moment of the 1.0 kg mass about the pivot, in units of Nm.

Use the equation: moment of a force = force × distance (normal to the direction of the force)

gravitational field strength = 10 N / kg

Moment = ... Nm **[3]** (b). Jack predicts where he should put masses on the right-hand side of the seesaw to make it balance.

He then carefully places those masses at points which make the seesaw balance and measures the actual distances to the pivot.

The table shows his results.

Mass (g)	Predicted distance to pivot (m)	Measured distance to pivot (m)
400	0.50	0.46
600	0.33	0.31
800	0.25	0.23
1000	0.20	0.19

(i) The measured distances to the pivot are all slightly smaller than the predicted distances to the pivot.

Explain why.

____

____ [1]

(ii) Suggest **one** way to improve his experiment to remove this difference.

____

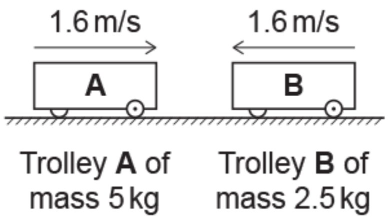
____ [1]

9(a). Trolley **A** of mass 5.0 kg moves at a constant speed of 1.6 m / s.

Calculate the momentum of trolley **A**.

Momentum = ... kg m / s **[2]**

(b). Trolley **B** of mass 2.5 kg heads straight towards the first trolley in the opposite direction at the same speed of 1.6 m / s.



The two trolleys collide and stick together.

(i) Show that the velocity of the joined-up trolleys after the collision is about 0.5 m / s.

[4]

(ii) The collision takes a total time of 0.20 s.

Calculate the average force acting on trolley **A** during the collision.

Average force = ... N **[4]**

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1		i	(normal) reaction	1	**Examiner's Comments** The correct term, reaction, was not known by the majority of candidates. Common wrong answers were upthrust, lift, gravity, air resistance and resultant.
		ii	(Interaction pair act) on different bodies (2);	2	**allow** for 1 mark: these forces/they are on same body (OWTTE)
		ii	OR these forces are not the same type of force (1); these forces are gravitational and reaction/(normal) contact force (1)		
		ii			**ignore** references to equal and opposite forces **Examiner's Comments** There were just a very small number of candidates who gave answers showing an understanding of what an interaction pair of forces is, usually by saying that they act on different bodies. A significant number of candidates argued wrongly that an interactive pair are not equal otherwise the lorry would not move.
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
2	a	i	friction: (friction from) shoe on surface weight: pull of shoe on Earth	2	do not award first mark if it seems that the candidate is referring to any force that is not along the surface Examiner's Comments This question on interaction pairs proved to be the most difficult question on the paper. Almost no correct responses were seen. Very few candidate could demonstrate that to describe any single force they must; (a) state the **two** objects involved in the force and (b) state the direction the force acts in. e.g. **object X** exerts a force on **object Y**. Almost all candidates referred to a single object (or indeed, no object at all) in their responses. The majority of candidates treated the question as multiple choice, choosing from the 3 forces listed.
		ii	a (positive) force down the slope / parallel to the slope	1	**allow** force is 'forward' Examiner's Comments Relatively few candidates demonstrated good understanding of resultant force in relation to change in motion, in this case resulting in acceleration down the slope in the first instance. A common response involved discussing all of the forces, but with no conclusion, or simply stating that 'it moved down because of gravity', which was insufficient to score a mark.

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>b</td><td></td><td>
<table>
<tr><th></th><th>Time</th><th>Mass of the trainer</th><th>Weight of the shoe</th><th>Height of slope</th><th>Length of slope</th></tr>
<tr><td>average speed along slope</td><td>✓</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>average vertical velocity</td><td>✓</td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>change in gravitational potential energy when the shoe slides down the slope</td><td></td><td>(✓)</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>average momentum of the shoe down the slope</td><td>✓</td><td>✓</td><td></td><td></td><td>✓</td></tr>
</table>
</td><td>4</td><td>ignore mass if included for gPE third row

<u>Examiner's Comments</u>

Most candidates accessed this question well, with the majority picking up marks for the average speed along the slope and/or the change in gravitational potential energy. Very few candidates picked up the mark for calculating average momentum, with no real pattern to incorrect responses. The weakest candidates only ticked one box in each row, perhaps misunderstanding the requirements of the task.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>7</td><td></td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>3</td><td></td><td></td><td>(Level 3)
Uses appropriate physics to explain how helmets reduce injuries **and** discusses the data using the idea of correlation and cause. Quality of written communication does not impede communication of the science at this level.
(5–6 marks)

(Level 2)
Uses appropriate physics to explain how helmets reduce injuries **and / or** discusses the data using the idea of correlation and cause. Quality of written communication partly impedes communication of the science at this level.
(3–4 marks)

(Level 1)
Uses basic physics ideas to explain how helmets reduce injuries **or** discusses the data using the idea of correlation and cause. Quality of written communication impedes communication of the science at this level.
(1–2 marks)

(Level 0)
Insufficient or irrelevant science. Answer not worthy of credit.
(0 marks)</td><td>6</td><td>This question is targeted at grades up to C

Possible points relevant to data:
• recognises that correlation between sets of data does not automatically mean it is causal
• correlation not consistent over time
• cannot draw a sensible conclusion from limited data
• do not know whether the people who died wore helmets / other comment about the accidents
• other factors need to be considered to reach a sensible conclusion
• discussion of where the data comes from.

Physics points

Points indicative of L2/3:
• time of collision increased
• same momentum change / same change of speed
• so smaller rate of change of momentum / smaller deceleration therefore reduced force
• (or alternative discussion in terms of work done).

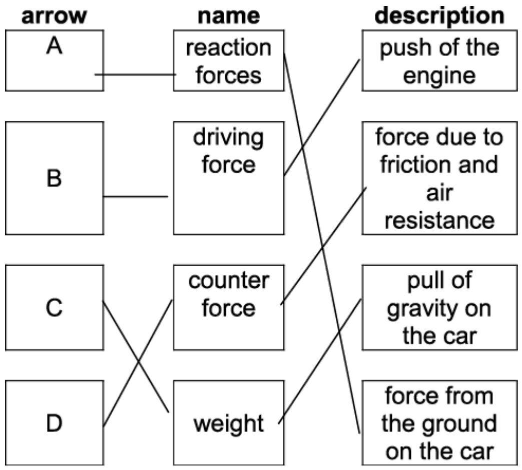
Points indicative of L1:
• idea of helmet reducing force / absorbing energy
• comparison to crumple zones
• idea that collision time is longer
• may suggest alternative reasons for the drop in deaths.

Use the L1, L2, L3 annotations in Scoris; do not use ticks.

Examiner's Comments

This was a six-mark extended-writing question examining ideas about correlation in data sets as well as applying knowledge of car safety features to a novel context.</td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
					The question was targeted at grades up to C. This question differentiated well in terms of ability. Weaker candidates tended to present answers using their general knowledge rather than the data provided. Very few candidates carried out a correct analysis of the graphs as a whole. The majority of candidates failed to compare the trend between two points e.g. 2004 to 2008, instead referring to a single point e.g. "in 2008 % who used helmets was high and rider deaths were high". This capped their performance in terms of the correct use of data. Many candidates were able to relate the operation of the motorcycle helmet in reducing injury to the physics involved in car safety, although very few explained that the momentum change would be the same with or without the helmet.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
4		i		2	1 mark for all four lines on the left hand side 1 mark for all four lines on the right hand side
		ii	6500 (N) forwards / to the right / toward B	2	**allow** any clear indication of direction e.g. arrow drawn Examiner's Comments This question considered aspects of the P4 topic, including resultant force and acceleration. It was well answered by the majority of candidates, although some weaker candidates confused reaction force for counter force.
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
5		i	1.0(2) (kgm/s)	1	**not** 1 unless 1.02 seen in working **Examiner's Comments** The vast majority of candidates calculated the momentum correctly.
		ii	10.(2) **but** if incorrect, for 1 mark, look for correct **substitution**: (change of momentum / time =) 1.0(2)/0.1	2	ecf from (i) gains both marks ecf from (i) **Examiner's Comments** The majority of candidates performed the correct calculation. The most common wrong answers involved a failure to realise that the answer to part (i) should be used.
		iii	shorter time (to stop) OWTTE (1) larger (resultant) force (1)	2	**allow** e.g. stops quicker / faster / slows down faster **do not allow** stops immediately / straight away **ignore** references to impact / harder **Examiner's Comments** Not all candidates understood that 'explain' means more than just saying what happens to the resultant force and were not prompted by the beginning of the question where the time to stop was restated. The most common misconception was that the can bounced and hence the resultant force was smaller as it took longer to stop. A variety of answers were seen with various combinations of increased/decreased resultant force and shorter/longer time to stop. There was no evidence that candidates used the relationship between change of momentum and resultant force given at the front of the paper. Some candidates did not gain any credit because they used terms such as 'harder' to describe the change in the resultant force instead of 'increased'.

Question			Answer/Indicative content	Marks	Guidance
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
6			(Level 3) Describes two or more aspects of making the long jump (running and / or jumping) and explains link between distance of the jump and time in the air, and uses it to justify running beforehand. Quality of written communication does not impede communication of the science at this level. (5–6 marks) (Level 2) Describes two or more aspects of making the long jump (running and / or jumping). Quality of written communication partly impedes communication of the science at this level. (3–4 marks) (Level 1) Describes one aspect involved in increasing speed during running. Quality of written communication impedes communication of the science at this level. (1–2 marks) (Level 0) Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	This question is targeted at grades up to A* Points may be made on diagrams. Indicative scientific points may include: Running: • running increases forwards momentum / velocity / speed / kinetic energy • increasing forwards velocity / momentum increases distance jumped • forces acting during run, eg friction between shoe and ground, action and reaction • ignore air resistance during run. Jump: • Amir's foot pushes down on ground when he jumps • reaction force from ground pushes up on Amir • jump gives Amir upward velocity / momentum • gravity provides downwards force during jump • downwards force of Amir brings him back to ground in a certain time • forwards distance moved during jump depends on forwards velocity / momentum • energy transformation from KE to GPE • air resistance during jump. Use the L1, L2, L3 annotations in Scoris; do not use ticks. Examiner's Comments This was a six-mark extended writing question. Many responses met the criteria for level 1 or 2 by discussing momentum or kinetic energy or forces during the run. However, very few candidates considered the actual jump and even fewer mentioned the time in the air, which was necessary in order to access level 3. Ideas about forces were very general and muddled and the

Question			Answer/Indicative content	Marks	Guidance
					connections between force, momentum and energy were often confused. Many answers lacked planning and repeated the same idea over and over again.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
7	a		upwards arrow on tablet labelled reaction ✓ force labelled 18 mN ✓	2 (AO 1.1 ×2)	**ALLOW** contact force / normal reaction force Independent mark, unit required <u>Examiner's Comments</u> Only the higher ability candidates were able to score one or both marks on this third of the three synoptic questions. Specification statements 4.3.2 (use free body diagrams where several forces lead to a resultant force) and 6.4.10 (factors which influence floating or sinking) are assessed. Many candidates recognised that the further force was in the upwards direction but were unable to recall the name of this force (reaction). A common error was to add a down arrow labelled gravity. Only the candidates who were able to deduce that 'resting on the bottom' implied zero resultant force were able to calculate that 18mN is needed to balance the forces.
	b	i	**Any two from:** pressure (of water) ✓ pressure increases with depth / there is a pressure difference between the top and bottom of the tablet ✓ so **net** force is upwards ✓	2 (AO 1.1 ×2)	**ALLOW** Archimedes principle e.g. water displaced by tablet **ALLOW** the weight of this water is equal to the upthrust **ALLOW more** force upwards <u>Examiner's Comments</u> This question assesses specification statement 6.4.9 (the increase in pressure with depth leads to an upward force). Only the most able candidates were able to recall this explanation. There were many confused attempts at an explanation but a common error was to ascribe the cause of upthrust to the bubbles produced by the dissolving tablet.

Question			Answer/Indicative content	Marks	Guidance
		ii	**Any one from:** tablet has larger volume ✓ tablet has greater thickness ✓ tablet has more pressure difference ✓ tablet has larger area ✓	1 (AO 1.1)	**DO NOT ALLOW** 'it is bigger' on its own **ALLOW** ORA **DO NOT ALLOW** it is heavier/more mass <u>Examiner's Comments</u> A very common misconception is that the table has more upthrust due to its greater mass or weight or density.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
8	a		FIRST CHECK THE ANSWER ON ANSWER LINE **If answer = 2.0 (Nm) award 3 marks**	3	
			Recall: W = mg ✓	(AO 1.2)	**ALLOW** Force down = 10N = 1kg × 10
			= 1.0 × 10 × 0.2 ✓	(AO 2.1)	Also gains m.p.1 **ALLOW** for 2 marks 1.0 × 10 × 20 = 200
			= 2.0 (Nm) / 200 Ncm ✓	(AO 2.1)	**ALLOW** '2' (Nm) Examiner's Comments Most candidates gained three marks for this calculation. Where this was not the case, candidates were unable to recognise that the force could be calculated using mass × gravitational field strength. It was clear from many responses that candidates simply recalled that 1 kg is 10N and did not show this step of the calculation in their working.
	b	i	moment due to metre ruler not included ✓	1 (AO 3.2a)	**ALLOW** any clear reference to the unbalanced nature of the metre rule e.g the ruler has mass/weight
		ii	centre / balance metre ruler on pivot / use ruler made of material with negligible mass /use weights much larger than weight of ruler / use extra weights to balance ruler before checking predictions ✓	1 (AO 3.3b)	Examiner's Comments Only a handful of candidates scored any marks for these two questions. Commonly, candidates held the misconception that the difference in predicted and actual measurements was due to the overhang of the 1.0 kg mass at the end of the ruler thereby increasing the moment on the left hand side. Candidates are not required to know that the mass of an object acts through its centre on this syllabus, but the increased left hand side moment line of reasoning does not explain why the measured right hand distance is less than predicted. Candidates who recognised that with the pivot in the position shown, there would be a moment due to the ruler itself were able to suggest moving the pivot to the middle to remove this moment.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
9	a		FIRST CHECK THE ANSWER ON ANSWER LINE **If answer = 8 (kg m/s) award 2 marks** Recall: momentum = mass × velocity / 5 kg × 1.6 m/s ✓ = 8 (kg m/s) ✓	2 (AO 1.2) (AO 2.1)	<u>Examiner's Comments</u> Almost all candidates were able to multiply 5 by 1.6 to get 8 here.
	b	i	momentum of **B** = 2.5 kg × 1.6 m/s = (–) 4 (kg m/s) ✓ Total momentum before collision = 8 (kg m/s) – 4 (kg m/s) = 4 (kg m/s) ✓ Total momentum after collision = 4 (kg m/s) **and** total mass × *v* = 7.5 (kg) × *v* = 4 (kg m/s) ✓ *v* = 4 (kg m/s) / 7.5 (kg) = 0.53 (m/s) ✓	4 (AO 1.1) (AO 2.1) (AO 2.1) (AO 2.1)	**ALLOW** for 3 marks 1.6 (m/s) with working shown (the candidate has added 8 and 4 to give the total momentum = 12) **ALLOW** bald answer 0.53 only (=2 mks) (candidate may have used only the momentum of trolley B) **ALLOW** if no other mark awarded, 1 mark for 7.5 (= total mass after the collision) **OR** m.p.3 & 4 can be Momentum of joined trolleys = 7.5 (kg) × 0.5 (m/s) = 3.75 (kg m/s) ✓ Which agrees with the momentum before (so speed ≈ 0.5 (m/s) ✓ <u>Examiner's Comments</u> Most candidates gained at least one mark for calculating the momentum of trolley **B** (2.5 × 1.6 =) 4. A common error was then to divide the momentum of **B** by the momentum of trolley **A** (1.6 × 5 =) 8. Conveniently, this produces the number 0.5 but many candidates clearly did not realise that this number is not a speed and so felt that they had answered the question. Candidates who set out their calculation to show the conservation of momentum were able to deduct the momentum of A from B and equate that to the combined mass multiplied by the unknown velocity.

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE **If answer = 27 (N) award 4 marks** select **and** rearrange to get $F = \Delta p/\Delta t$ ✓ for **A**, Δp = 5 kg × (0.53 (m/s) – 1.6 (m/s)) **OR** = (–)5.35 (kg m/s) ✓ F = 5.35 (kg m/s) / 0.20 (s) ✓ = 26.75 (N) = = 27 (N) ✓	4 (AO 1.1) (AO 2.1) (AO 2.1) (AO 2.1)	ECF throughout **ALLOW** F = momentum ÷ time / F = m × Δv÷t Using v_{final} = 0.5 (m/s) gives Δp = 5 .5 (kg m/s) Also gains m.p.2 and F = 27.5 (N) <u>Examiner's Comments</u> Candidates often gained one mark for selecting and rearranging the impact equation in the form Force = change in momentum ÷ time. Many then struggled to determine the change in momentum of trolley A but were able to gain a compensatory mark for dividing the number that they had calculated as Δρ by 0.2. Candidates who were able to use the mass of A (5kg) multiplied by its change in speed (1.6 – 0.53) generally gained all four marks after dividing their answer by 0.2.
			Total	10	