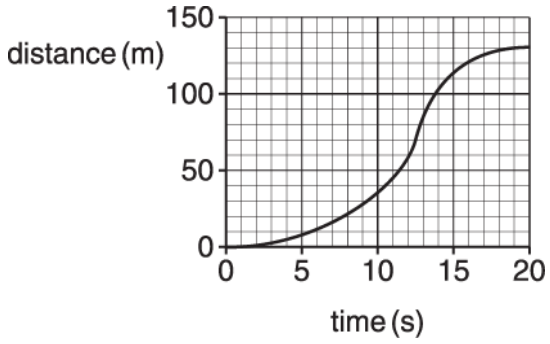
1. Lorries are fitted with tachometers that automatically record their speed and distance travelled.

The data from the tachometer can be used to produce graphs.

Here is the distance-time graph for a journey lasting 20 s.



Use the graph to determine:

(i) The time when the lorry has the greatest instantaneous speed.

time = _____ s **[1]**

(ii) The average speed for this journey.

average speed = _____ m/s **[2]**

(iii) Here are some descriptions of the motion of the lorry during this 20 s journey.
Put a tick (?) in the box next to the correct description.

Speed increases, then decreases until the lorry becomes stationary. ☐

Speed increases, then decreases until the lorry is moving at constant speed. ☐

Speed increases until the lorry moves at constant speed. ☐

Speed increases until the lorry becomes stationary. ☐

[1]

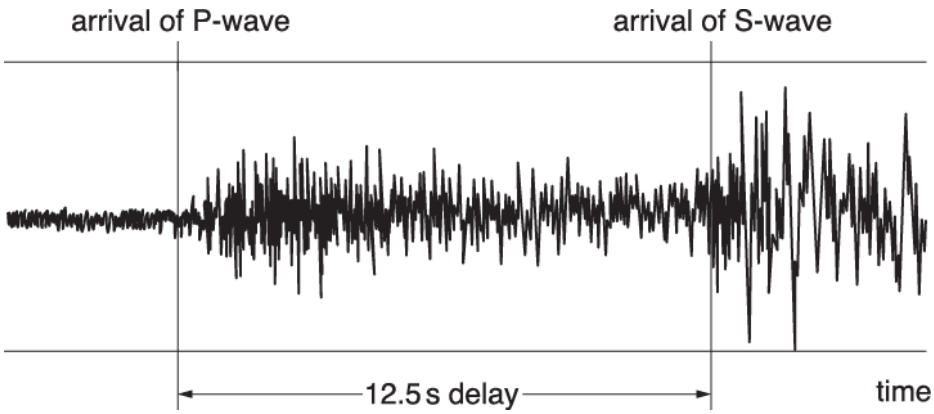
2. An earthquake happened 100 km away from town **A**.

The P-waves arrived at town **A** 12.5 s later.

(i) Calculate the speed of the P-waves.

speed = _____ km / s **[1]**

The diagram shows the earthquake detector trace in town **A**.

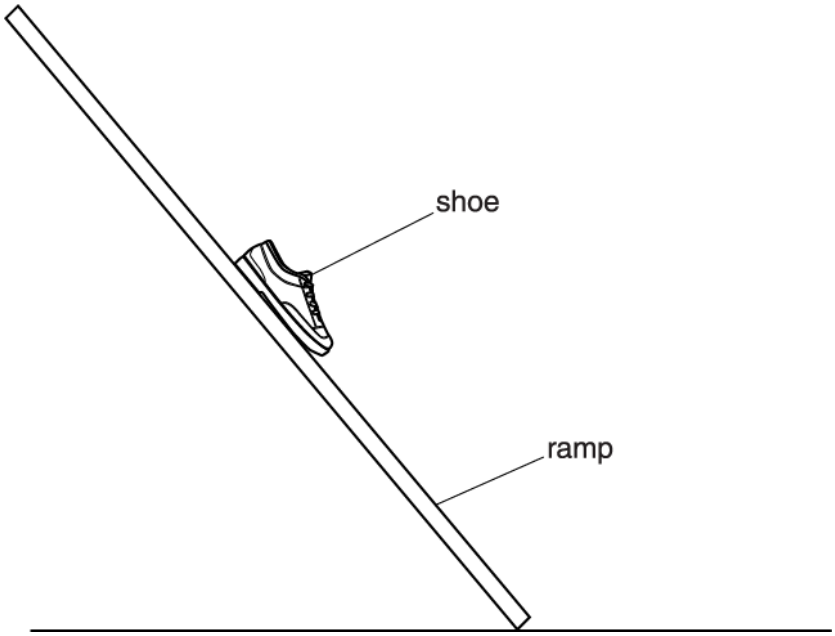


(ii) Calculate the speed of the S-waves.
Show your working.

speed = _____ km / s **[2]**

3(a). Ross is doing an experiment with shoes.

He places a shoe at the top of a ramp and measures the time it takes the shoe to slide down the ramp.



Ross has three different size shoes.

He does the experiment three times with each shoe.

Here are his results.

Shoe size	Time to slide down the ramp in seconds		
	Test 1	Test 2	Test 3
5	1.0	0.9	0.8
7	1.3	1.2	1.1
9	1.4	1.5	1.2

(i) What conclusions could Ross make from this data?

Justify your answer.

---

[2]

(ii) Another student tries to make the same measurements with another ramp and a shoe of size 4.

Here are the results.

Shoe size	Time to slide down the ramp in seconds		
	Test 1	Test 2	Test 3
4	1.2	1.4	1.3

Ross says: “You must have made a mistake. Your results do not fit my data.”

Is Ross correct?

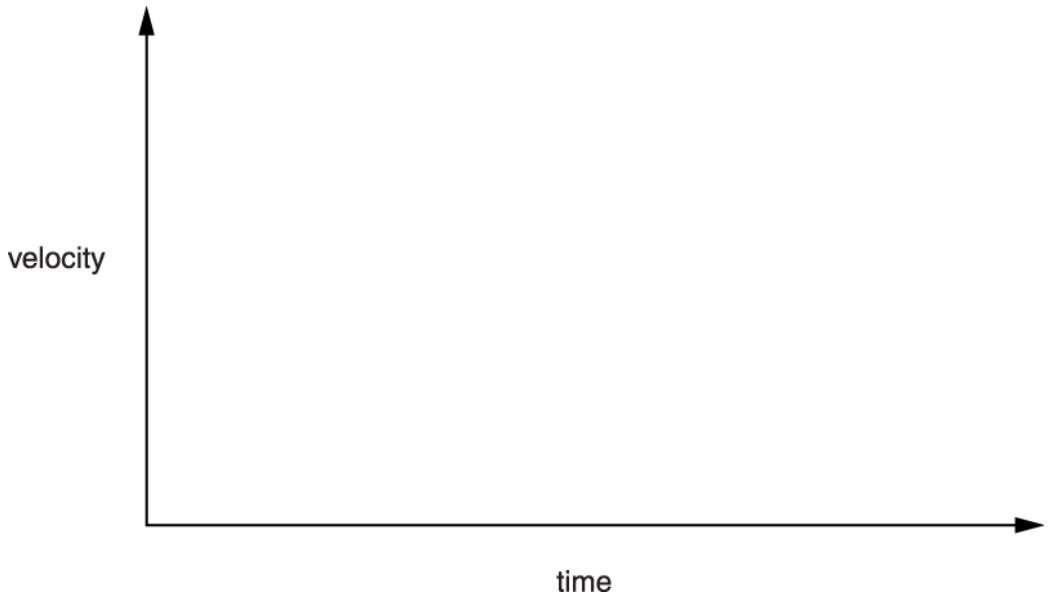
Justify your answer.

---

[3]

(b). As the shoe moves down the slope, it speeds up.

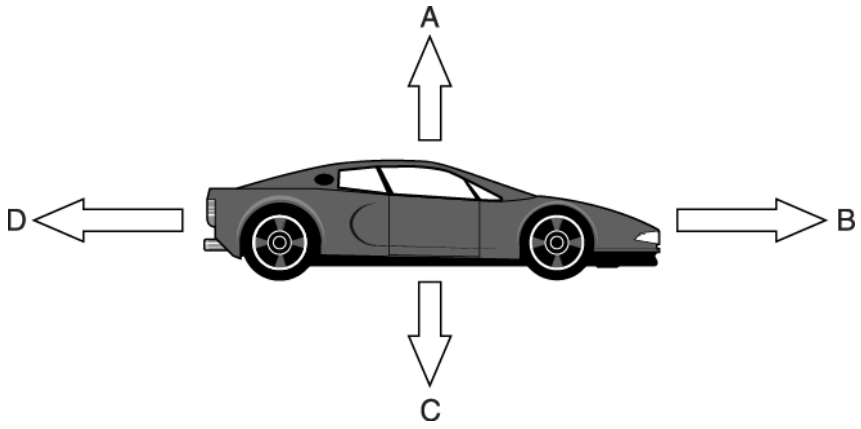
On the axes below, sketch the shape of the velocity-time graph that shows the velocity of the shoe along the slope.



[2]

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

Some of the forces on a car are shown below.



The car is travelling at a steady velocity and then it suddenly accelerates for 2.0 s at a rate of 7.5 m/s^2.

It reaches a velocity of 40 m/s.

What velocity did the car start at?

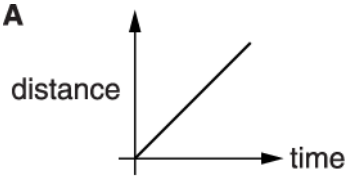
Show your working.

velocity = _____ m/s **[2]**

(b). A car accelerates from rest.

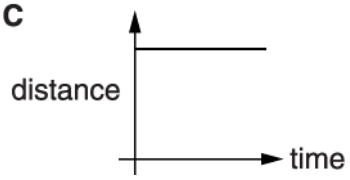
Which distance-time graph, **A**, **B** or **C**, and velocity-time graph, **W**, **X** or **Y**, show the motion of the car as it accelerates at a constant rate?

A

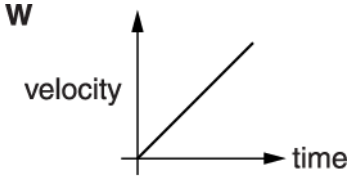


B

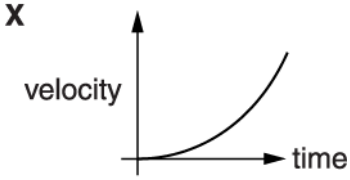
C



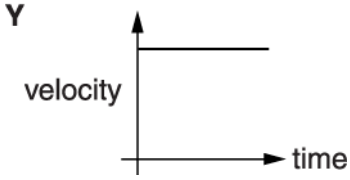
W



X



Y

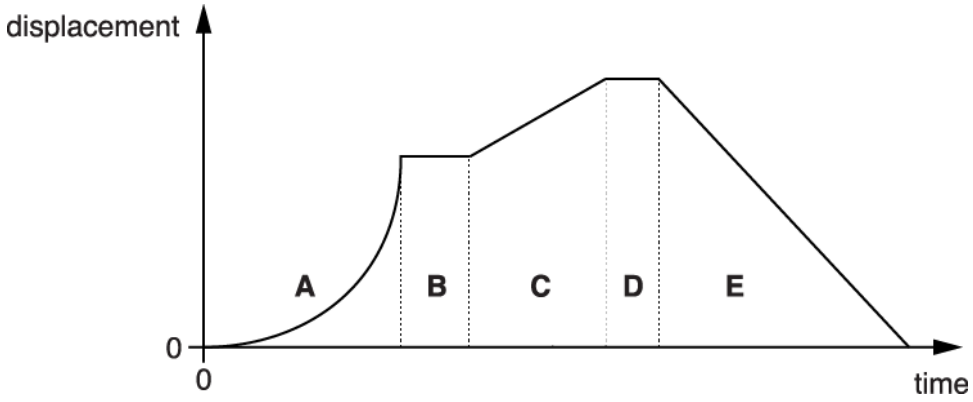


correct distance-time graph _____ correct velocity-time graph _____

[1]

5(a). Alex goes for a ride on his bike.

The graph shows how his displacement from the start of his ride changes with time.



The graph has been divided into five regions, **A**, **B**, **C**, **D** and **E**.

Which region or regions show each type of motion?

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

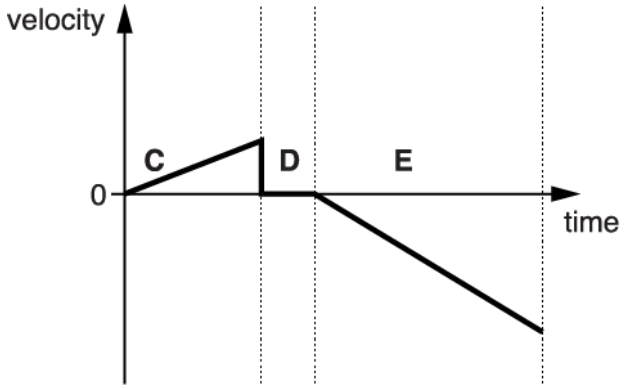
You may tick more than one box in a row.

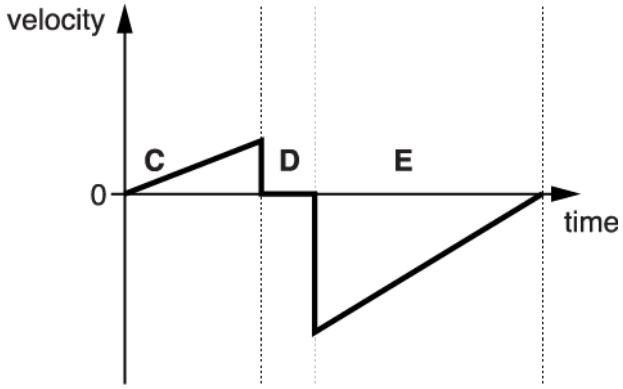
Type of motion	Region				
	A	B	C	D	E
Stationary					
Moving with constant speed					
Fastest instantaneous speed					

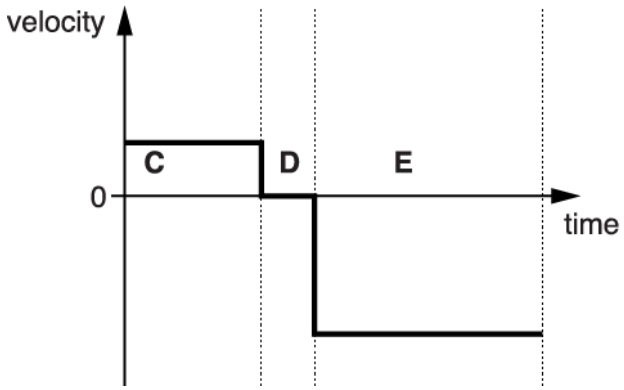
[2]

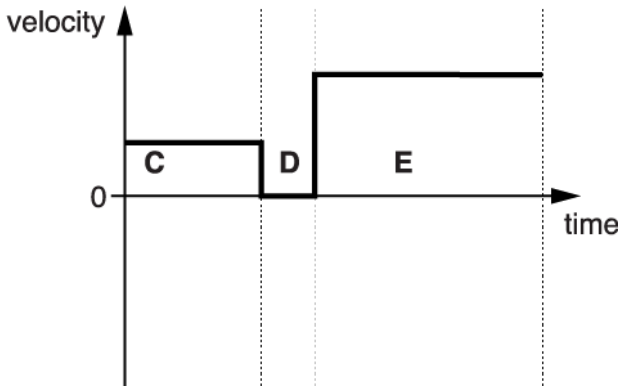
(b). Which of the following sketch graphs shows Alex's velocity in regions **C**, **D** and **E**?

Put a (ring) around the correct graph.



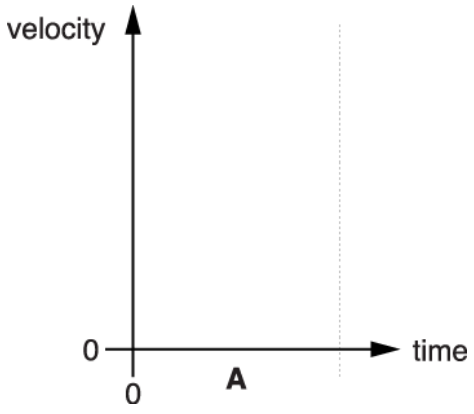






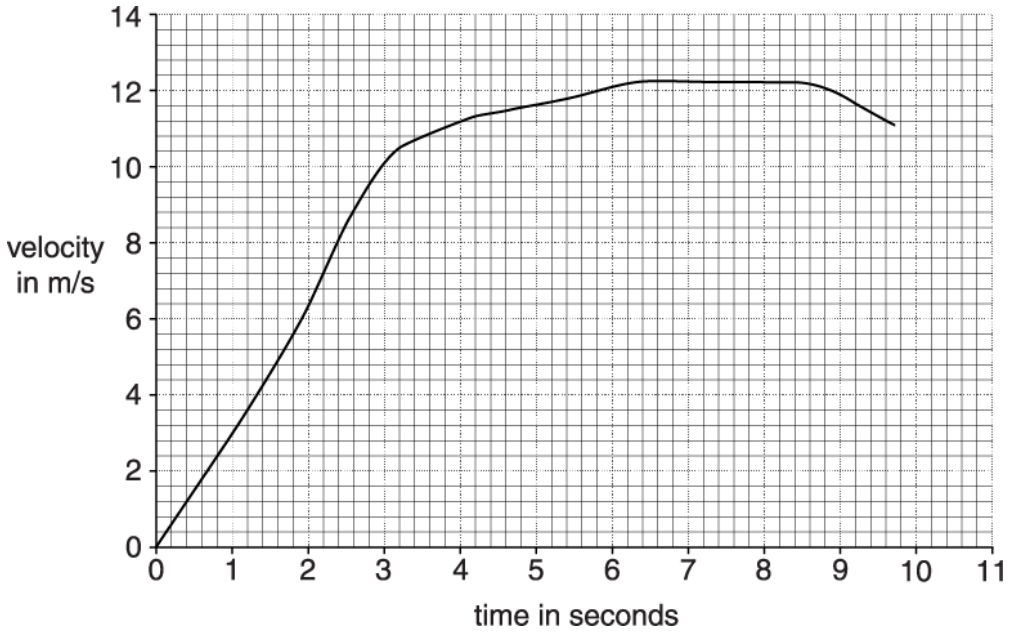
[1]

(c). On the sketch graph below show how Alex's **velocity** changes with time in region **A**.



[2]

6(a). In 2008 Usain Bolt set a new world record for the 100 m race.
This is a velocity-time graph for the race from start to finish.



What was the world record time set by Usain Bolt in 2008? _____ [1]

(b). The data can be used to show that the race was 100 m long.

Complete the equation below.
Choose a word from the list.

average **final** **initial** **instantaneous** **maximum**

The distance of the race = the time taken × the _____ velocity [1]

(c). Some commentators said that Usain Bolt could have got a faster time.
What evidence from the graph supports this?

_____

_____ [1]

(d). At what time during the race was Usain Bolt accelerating the fastest?

_____ seconds. [1]

(e). All the velocities on the graph are positive, what does this mean?

---

[1]

7. A car travels along a straight horizontal road.

The table shows how the displacement of the car varies for part of its journey.

Time (s)	0	10	20	30	40	50	60	70	80
Displacement (m)	0	200	400	600	800	975	1100	1175	1200

Describe and explain the motion of the car.

Use the data to support your answer.

You may draw a **sketch** graph with important points labelled clearly to help you answer the question.

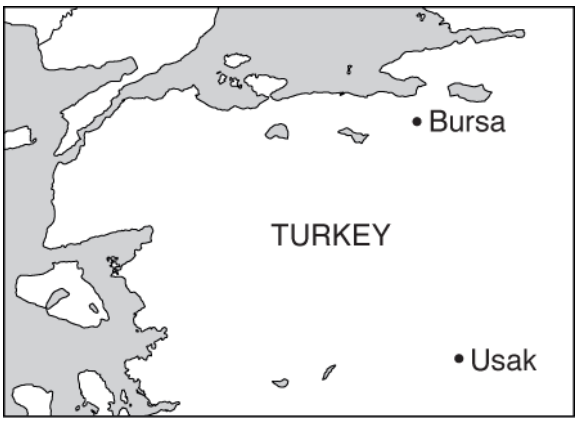
The quality of written communication will be assessed in your answer.

[6]

8. This question is about earthquake waves.

P-waves travel at 8.1 km/s and S-waves travel at 5.1 km/s. A small earthquake occurs in Usak in Turkey.

The waves are detected in Bursa, which is a distance of 169 km away.



Show that the P-waves will arrive at Bursa about 12 seconds before the S-waves.

time difference = ---------- s **[2]**

9. There is a film about an astronaut named Mark Watney. He is left alone on the planet Mars. He has to use science to stay alive until he can be rescued.

To be rescued, Watney needs to drive a vehicle to a site 3200 km away. The vehicle is powered by batteries of capacity 18 kWh.

Watney knows that the vehicle can travel at 25 km/hour using 5 kW of power from the batteries to do this. When the batteries are discharged Watney has to wait until the next day to continue. He has solar panels to recharge the batteries after a day's travel.

(i) Use these data to calculate the smallest number of days it would take to drive to his destination.

Number of days = ---------- days **[4]**

(ii) Give **one** reason why it would actually take longer than the time calculated in **(i).**

---

[1]

10(a) This question is about a measurement of the speed of sound in air that Isaac Newton made over 300 years ago.

.

At Newton's college in Cambridge there was a long outdoor corridor where clapping his hands would give a loud echo a fraction of a second later.

Newton measured the distance from where he stood to the reflecting wall as 64 m.

To measure the time, he made a very tiny pendulum - a weight swinging on a thin cotton thread - and adjusted the length until one to-and-fro swing of this pendulum matched the time between the clap and the echo.

This happened when the length L of the pendulum was 4.6 cm (0.046 m).

(i) Newton showed that the time of one swing, T, was given by the equation:

$T^2 = kL$

L = the length of the pendulum
k = 4.02 s^2/m.

Calculate the swing time T of his 0.046 m pendulum.

T = ---------- s **[3]**

(ii) Use Newton's data to calculate the speed of sound.
Distance to wall = 64 m

Speed of sound = ---------- m/s **[3]**

(b). Newton's calculated value for the speed of sound was low when compared with the speed found by modern measurements.

(i) Explain which of Newton's measurements (distance or time) was likely to be the least accurate.

---

[1]

(ii) Explain why Newton's value for the speed was too low.

---

[2]

11(a)

. The maximum speed of a racing car is 320 km / hour.

Calculate this speed in metres per second.

Maximum speed = ... m / s **[2]**

(b).

(i) A different racing car is moving with a speed of 80 m / s.

Before turning a corner, it slows down to a speed of 20 m / s.

While slowing down, it has a constant acceleration of -40 m / s^2.

Calculate the distance that it travels as it slows down.

Distance travelled = ... m **[3]**

(ii) The car moves at a constant speed around the corner.

Explain why its velocity is changing as it moves around the corner.

---

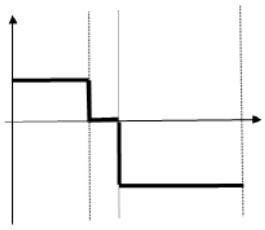
[2]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1		i	12.5 (s)	1	**allow** 12-13 **Examiner's Comments** Most candidates scored at least 3 marks for this question dealing with forces and motion. A common wrong answer was 20.
		ii	130/20 (1); 6.5 (m/s) (1)	2	6.5 without working gets 2 marks **Examiner's Comments** Those candidates who chose the correct distance of 130 usually calculated the average speed correctly. The most common wrong answer was 7.5 obtained by candidates who read the distance as 150 m.
		iii	Speed increases, then decreases and the lorry becomes stationary – tick in top box	1	**Examiner's Comments** Less than half the candidates chose the correct answer.
			Total	**4**	
2		i	Speed = 8 (km/s)	1	**Examiner's Comments** Most candidates could calculate the speed of the P-waves
		ii	Time is 12.5s + 12.5s = 25s (1); Speed = 100 km / 25s = 4 (km/s) (1)	2	4 km/s without working = 2 marks 8 km/s = 1 mark **Examiner's Comments** About half of the candidates could do the two-step calculation to find the speed of the S-waves.
			Total	**3**	
3	a	i	larger shoes take longer (1) any 1 for justification from the following list, larger shoes experience greater friction / resistive force, numerical comparison of average times (1)	2	**accept** answers that state no real trend because the data overlaps too much so no conclusion can be drawn (1) there needs to be more data (1)

Question			Answer/Indicative content	Marks	Guidance
		ii	**ignore** yes or no **A maximum of 2 marks from:** *(Ross thinks the mistakes are):* • idea that ramps are different • idea that shoes are different • results are affected by different reaction times **A maximum of 2 marks from:** *(Discussion of data):* • the new result doesn't fit his data e.g. the times should be lower than size 5/7 ORA • sample size is small • time differences are small, so correlation (between shoe size and slide-time) is weak • slide–time depends on a combination of factors • calculation of the average of the other student's results = 1.3 seconds (1) • idea that both sets of data show good repeatability (1)	3	the maximum mark is 3 **allow** e.g length / start-point / steepness / friction **allow** e.g weight / tread / friction Examiner's Comments Required the candidate to analyse some experimental data involving sliding different size shoes down a ramp. Candidates showed great familiarity with this type of exercise and most were able to arrive at an appropriate conclusion and justify it. The majority also suggested reasons why the additional data may not fit the trend, although many did not describe how the new result did not fit i.e. the mean time obtained was significantly higher than you might expect.
	b		graph starts at origin with any kind of positive gradient	2	curve must not show velocity decreasing **allow** curve increasing or decreasing in gradient or a straight line Examiner's Comments A wide range of graph sketching skills were seen, with some excellent practice. Significant numbers of candidates did not take sufficient care to ensure that their sketch graph passed through the origin. In such cases, full marks were not awarded. A vast array of shapes was accepted, provided that an upward trend was shown, with no doubling back. Overdrawn or multiple graph lines were penalised.
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
4	a		2 × 7.5 = 15 (change in speed) (40 ? 15) = 25 (m/s)	2	**allow** 2 × 7.5 unevaluated for 1st marking point **allow** 1 mark if answer = 15 (m/s) answer of 25 scores 2 marks. **allow** 1 mark ecf for final answer of 40-(their value for change in speed) **Examiner's Comments** More able candidates had no difficulty in calculating the change in speed and using this to arrive at a value for the initial speed. A significant number of candidates stopped after calculating the change in speed, presenting this as their final answer.
	b		distance: B velocity: W	1	**both** required for the mark **Examiner's Comments** Weaker candidates commonly identified graph A as representing constant acceleration.
			Total	3	

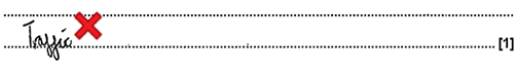
Question			Answer/Indicative content	Marks	Guidance
5	a		Type of motion / Region A B C D E stationary ? ? moving with constant speed ? ? fastest instantaneous speed ?	2	**mark by row** all rows correct = 2 marks 1 or 2 rows correct = 1 mark **Examiner's Comments** The majority of candidates completed all lines of the table correctly. The middle row was the one most commonly incorrect.
	b		 bottom left diagram	1	**Examiner's Comments** Most candidates did not choose the correct option. The most common choice was the top left graph.
	c		velocity starts at 0 (1) line with continuously positive slope to dotted line (1)	2	**allow** slope beginning anywhere between origin and letter A on *x*-axis **allow** straight or curved or combination of both **ignore** lines on or to right of dotted line **Examiner's Comments** The majority of candidates drew a correct sketch graph. Some candidates did not attain both marks due to careless drawing such as not starting the line at 0 velocity or not continuing the line to the dotted line.
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
6	a		9.7 (s)	1	**allow** from 9.6 to 9.8 (inclusive) **Examiner's Comments** Most candidates were able to read the time the race lasted within the tolerance set on the mark scheme. A few candidates thought the question was asking for the maximum velocity reached.
	b		average	1	**allow** if indicated in list **Examiner's Comments** The majority of candidates selected the correct response, 'average'. The wrong responses were spread amongst all the other options.
	c		velocity / speed decreases at the end / he slows down at the end	1	**allow** reference to correct time instead of at end **Examiner's Comments** Many candidates correctly linked this question with what was happening at the end of the race. However, those candidates who had confused this graph with a distance-time one thought that he slowed down around 3 s because the gradient became less.
	d		any value from 2.0 to 2.8	1	**allow** 2 **Examiner's Comments** The change in the gradient at 2 s was not noticed by many candidates which resulted in incorrect answers between 1 s and 2 s. A single time or a range within the limits 2 s to 2.8 s was accepted as correct. Other candidates confused maximum acceleration with maximum velocity.
	e		(always) running in the same direction / forward	1	**Examiner's Comments** This question was answered well. Incorrect responses included 'always accelerating' and 'shows positive correlation'.

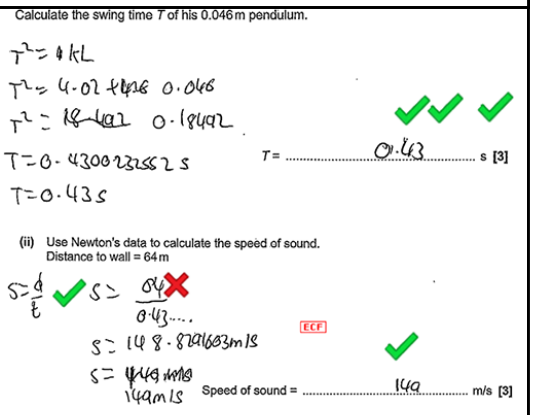
Question			Answer/Indicative content	Marks	Guidance
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
7			**[Level 3]** **Both** types of motion described **and both** supported by use of data **and** one type of motion is explained. Quality of written communication does not impede communication of the science at this level. (5–6 marks) **[Level 2]** **Both** types of motion described **and** one is explained **OR both** types of motion described **and** one type is supported by use of data. Quality of written communication partly impedes communication of the science at this level. (3–4 marks) **[Level 1]** One type of motion described **and** explained **OR** one type of motion described **and** supported with data. 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*** **Indicative scientific points may include:** **describe motion:** • initially constant velocity / speed / steadily increasing displacement • finally / then slowing down / negative acceleration / deceleration **use of data** • initial constant velocity e.g. 200/10 = 20 m / s / eg. 200m in 10s • finally average velocities: e.g. 40–50 =17.5; 50–60=12.5; 60–70=7.5; 70–80=2.5 • decrease in average velocity e.g. 975/50 = 19.5 m/s • (constant) deceleration = 5/10=0.5 m/s^2 • calculations show smaller increments in displacement • identifies that the motion changes at 800 m **or** at 40 s (allow between 800 and 975 / 40 to 50 s) *This point can count for either type of motion but not both* **explanation:** • constant velocity / speed: due to balanced forces • slowing down due to unbalanced / resultant force • deceleration due to braking / no driving force Look for points next to table and on sketch graph **Use the L1, L2, L3 annotations in RM Assessor; do not use ticks.**
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
8			One of t_P = 169 km/8.1 km/s = 20.9 s t_S = 169 km/5.1 km/s = 33.1 s (1) ; 33.1 – 20.9 ≈ 12 (s) (1)	2	m.p.1 is for calculating either time; m.p.2. is for the repeat calculation and subtraction to show it is about 12 s (to 4 s.f., times are 20.864 s & 33.137 s; allow rounding to 33 s & 21 s) not just '12': it needs to be clear that 12 s ≈ 33.1 s - 20.9 s, which can be inferred from e.g. 12.273 s answer
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
9		i	FIRST CHECK THE ANSWER ON THE ANSWER LINE. If answer = 36 (days) award 4 marks Driving time per day = 18 (kWh) / 5 (kW) = 3.6 (h) ✓ Distance / day of travel= 25 (km/h) × 3.6 (h)= 90 (km) ✓ Number of travelling days = 3200 (km)/90 (km) ✓ = 35.6 = 36 (days) ✓ OR Travelling time = 3200(km)/25(km/h) = 128 (hours) ✓ 128 hours at 5kW gives 128 × 5 = 640(kWh) needed from battery ✓ 18kWh per battery charge per day gives 640/18 = 35.6 (days) ✓	(AO 2.2) (AO 1.2) (AO 1.2) (AO 1.2) 4	ECF. mp1 Examiner's Comments Most made good effort in this question which involves a number of calculation stages, with some estimating extra time needed between runs to allow the batteries to regain full charge.
		ii	Any one from: solar cell not charging enough (due to dust/angle to Sun/day length change) ✓ mean speed reduced by rough terrain/going round hills/going up hills ✓ may break down and need repair✓	1 (AO 3.1b)	A sensible suggestion for why extra time is needed Examiner's Comments Some answer here lacked enough detail, e.g. 'not enough Sun' rather than 'Sun obscured by dust clouds' but many answers showed they had forgotten the context of the whole question. Exemplar 12  [1]
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
10	a	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE. If answer = 0.43 (s) award 3 marks $T^2 = kL$ = 4.02 (s^2 /m) × 0.046 (m) ✓ = 0.185 (s^2) ✓ T= √{0.185 (s^2)} = 0.43 (s) ✓	3 (AO 1.2) (AO 2.1) (AO 2.1)	
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE. If answer = 298 or 300 (m/s) award 3 marks s = 2 × 64 (m) = 128 (m) ✓ $v = s/t$ ✓ = 128 (m) / 0.43 (s) = 298 (m/s) (= 300 m/s) ✓	3 (AO 1.2) (AO 1.2) (AO 2.1)	ECF. own t from (a)(i) ALLOW s = 64 (m) here if incorrectly quoted for mp1 <u>Examiner's Comments</u> Most correctly calculated the pendulum period as 0.43 s in (a)(i), but a number then forgot to double the distance in (a)(ii), losing a mark. Exemplar 13 This candidate successfully calculates the swing time (i) gaining 3/3 but then forgets to double the distance (ii). However, the application of ECF allowed them to be credited with 2/3 because they had shown their workings.

Question			Answer/Indicative content	Marks	Guidance
					 Calculate the swing time T of his 0.046 m pendulum. $T^2 = 4\pi^2 L$ $T^2 = 4 \cdot 02 \times 0.046$ $T^2 = 0.18492$ $T = 0.430023255 2\,s$ $T = 0.43\,s$ $T =$ 0.43 s [3] (ii) Use Newton's data to calculate the speed of sound. Distance to wall = 64 m $s = \frac{d}{t}$ $s = \frac{64}{0.43}$ $s = 148.8791603\,m/s$ ECF $s =$ 149 m/s Speed of sound = 149 m/s [3]
	b	i	Measuring t is harder **because** time is very short/not easy to match pendulum to sound / pendulum is very short /easy to measure distance (accurately) ✓	1 (AO 3.1b)	<u>Examiner's Comments</u> Few candidates were specific enough to suggest why the time measurement was Newton's poorer observation. This was probably because they had not considered the effect of judging the synchronicity of the pendulum swing and the echo for such a small intervals would have on the observation error. While Newton would be able to measure the distance accurately even with the instruments available to him in the 1680s.
		ii	(*v* is too small) *t* is too large ✓ Using $v = s/t$ / his reaction time will extend timing ✓	(AO 3.2a) 2 (AO 3.2b)	**ALLOW** discussion of inaccurate actual length of oscillating pendulum for mp2 <u>Examiner's Comments</u> Only a few candidates were specific enough to suggest in (b)(i) why the time measurement was the poorer one. However, many realised that the over-large value for time would result in a too low a value for the speed of sound. A few candidates suggested that Newton's value was too low because he had not doubled the 64 m in his calculations.
			Total	9	

Question			Answer/Indicative content	Marks	Guidance
11	a		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 89 / 90 / 88.9 (m/s) award 2 marks 320 × 1000 / 3600 ✓ = 88.9 = 89 (m/s) ✓	2 (AO 2.2 ×2)	ALLOW for 1 mark answers that round to 8.89×10^{n} ALLOW answers that round to 88.9 <u>Examiner's Comments</u> The common errors in responses to this question were failing to convert hours to seconds and giving the final answer incorrectly rounded.

Question			Answer/Indicative content	Marks	Guidance
	b	i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 75 (m) award 3 marks	3	
			select and rearrange equation: $s = (v^2 - u^2)/2a$ ✓	(AO 1.2)	ALLOW one mark for correct substitution before rearrangement $20^2 - 80^2 = 2 \times -40 \times s$
			$= (20^2 - 80^2)/(2\times-40)$ ✓	(AO 2.1)	IGNORE incorrect signs, but DO NOT ALLOW $20^2 + 80^2$
			= 75 (m) ✓	(AO 2.1)	ALLOW –75 (m)
			OR		
			Recall and rearrange s = (average) speed × (change in v ÷ acceleration) ✓		ALLOW if both formulae are seen separately
			= 50 × 1.5 (s) ✓		
			75 (m) ✓		ALLOW evaluation of distance using 1.5 × either 80 or 20 Examiner's Comments Candidates needed to select the equation $v^2 - u^2 = 2as$. Most candidates who were able to substitute the numbers into this equation did the rearrangement at the end and gained full marks. Many of the lower ability candidates attempted to use speed = distance ÷ time which was insufficient to gain any marks. Some candidates determined, using the relationship acceleration = speed change ÷ time, that it would take 1.5 seconds. However, only the candidates who were able to multiply this time by a velocity gained credit for this alternative approach. By applying the average velocity (50 m/s) were able to get 3 marks. Two marks were gained for applying the initial or final velocities.
		ii	velocity has a direction/is a vector ✓	2 (AO 1.1 ×2)	Examiner's Comments
			direction is changing (as it turns corner) ✓		This was generally well answered as most candidates understand that velocity is speed with a direction and that the direction of the car changes.
			Total	7	