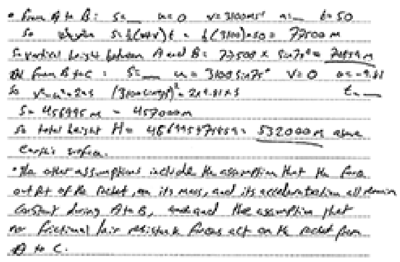
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			**Level 3 (5–6 marks)** Expect a correct calculation of *H* with correct assumptions **and** a clear evaluation supported with a calculation *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect **Either** a correct calculation of *H* but no evaluation **or** Some calculation **and** some evaluation **or** Incorrect calculations but a clear evaluation *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect **Either** Limited calculation (e.g. 3100 sin 75° seen, *AB* **or** *BC* calculated but not *H*, use of suvat but with wrong *v*) **or** Limited assumptions stated (note that 'g is always 9.81' is in stem) **or** Limited evaluation (e.g. *g* would be smaller at **C** than **A**) *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark**	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Calculation** vertical component of velocity at **B** = 3100 sin 75° (= 2994 ms^{-1}) <u>AB</u> • Assume (force and mass constant so) constant acceleration • Use of suvat, *u* = 0, *v* = 2994, *t* = 50 • *s* = 74.9 km <u>BC</u> • Assume no air resistance • Use of suvat, *u* = 2994, *v* = 0, *a* = -9.81 • *s* = 457 km Total *H* = 457 + 74.9 ≈ 530 km **Evaluation** • $g \propto \frac{1}{r^2}$ • $\frac{g_C}{g_A} = \frac{r_A^2}{r_C^2} = \frac{6400^2}{(6400+530)^2} = 0.85$ • 15% drop in g from **A** to **C** (or 17% increase from C to A) but use ECF for *H* • therefore constant *g* is a poor assumption • g_c ≈ 8.3 or 8.4 if g_A= 9.81 but use ECF for *H* • If g is smaller, then H would increase <u>**Examiner's Comments**</u> Level 3 candidates set out a correct calculation of *H*, together with the assumptions required at each stage,

			No response or no response worthy of credit.		plus an evaluation of the assumption that *g* remains constant at 9.81 ms^{-2} throughout. Level 2 candidates missed out one or more of these three parts, usually the evaluation at the end, which they found quite difficult. Level 1 candidates were often unable to calculate *H*, or the value of g at height *H*, correctly **Common problems in 3 (b)** • omission of sin 75° (or using cos 75°) when calculating velocity • not converting from m to km correctly • not squaring the r term in the calculation for *g* **Exemplar 1**  Exemplar 1 demonstrates good practice in answering a LoR question. The candidate has made sure they have answered each part of the question by using bullet points. Their calculations are clearly set out and so easy to follow, and their handwriting is legible. Instead of just calculating a value for *g* at height *H*, they have also given an explicit evaluation: 'The assumption that *g* remains constant is not reasonable'. Other candidates went on to say that this means that the rocket would reach an even greater height. **OCR support**

					OCR has a Guide to Level of Response Questions. This includes guidance on communication and the use of bullet points (page 5).
			Total	**6**	
2	a	i	Curve starts at (0,0) with gradient decreasing to a maximum value 30 on vertical axis matching highest point of candidate's line	B1 B1	Accept horizontal asymptote NB ignore candidate's response after their line reaches 30 (m/s) **Examiner's Comments** Most candidates used the grid effectively to put a suitable scale on the speed axis. They also communicated that the maximum speed was 30 m s^{-1}. Many candidates also got the shape of the curve correct, which starts with maximum gradient and then flattens out.
		ii	Resistive force increases (with speed) Zero net or zero resultant force	B1 B1	Allow drag / (air) resistance / friction for 'resistive force' Allow resistive force = component of weight down the slope NOT simply idea of resistive force = weight **Examiner's Comments** While many candidates appreciated that the car reached a maximum speed because the resultant force was zero, some contradicted this by saying that the weight = drag (as it would be in vertical motion) or something else incorrect. Far fewer candidates stated that the drag increases with speed effectively. Quoting the given expression $F = kv^2$ was deemed insufficient. **Examination Tip** Repeating information given in the question is rarely creditworthy by itself.

		iii	Component of weight down slope = 9300 sin 5° Re-arrange to (k=)$F \div v^2$ (k=)810 ÷ 900 = 0.9…	M1 M1 A1	Allow 810 or 811 seen Allow substitutions for variables Mark is for substitution <u>and</u> candidate's value seen **<u>Examiner's Comments</u>** As this question is a 'show that', all steps were required. Many candidates omitted the rearrangement stage, restricting their maximum score for this item to 1 mark. This approach was consistent throughout the paper for this type of question. **Examination Tip** Make sure that all steps of working are presented in 'show that' questions, especially the step that shows the relevant quantity as the subject of the equation. Always show your evaluation to at least 1 more significant figure than that shown in the question.
	b		evidence of substitution of $F=kv^2$ into $P = Fv$ $v =(P \div k)^{1/3}$ v = 44 (m s^{-1})	C1 C1 A1	e.g. $P = kv^3$, $P = (kv^2)\ v$, etc Allow use of k = 1 which gives 42 Allow answer within range 36 to 53 **<u>Examiner's Comments</u>** The key idea here is that the force from the engine (given by F = P / v) will equal the resistive forces (F = kv^2) when the car is at maximum speed. Candidates could choose which value of k they used here, either k = 1 from the question data or the value of k from the previous item. This gives an acceptable range of speeds as stated in the mark scheme.
	c		Power is proportional to the speed cubed / Max speed is proportional to the cube root of max power / power proportional to speed x kv^2	B1 B1	NB cube root of 2 is 1.2599… e.g. 1.26 × 44 = 55 (m s^{-1}) **<u>Examiner's Comments</u>** Even if they couldn't complete the calculation in the previous item, candidates needed to be able to state

			Valid reference to the cube root of 2 increase in velocity for double power / Valid reference to factor of 8 increase in power for double the velocity		the idea qualitatively for the first mark. No further calculations were required, except the correct answer that the maximum speed would increase by a factor of cube root (2).
			Total	**12**	
3			**C**	1	**<u>Examiner's Comments</u>** This question boils down to what acceleration is required for a displacement of 0.05 m between t = 0.10 s and 0.14 s. i.e. 0.05 = ½ a (0.14)2 − ½ a (0.10)2 from which the acceleration can be calculated.
			Total	**1**	
4			**A**	1	**<u>Examiner's Comments</u>** With all variables the same apart from the initial speed, there should only be one change to the graph, i.e. the initial speed. The gradient of the second phase should be the same, as the mass and braking force are the same. This gives option A.
			Total	**1**	
5	a		$mgh = \frac{1}{2}mv^2$ Or $v^2 = u^2 + 2as$ Or $v = \sqrt{2gh}$ Or $9.81 \times 2.0 = \frac{1}{2}v^2$ $v = \sqrt{2 \times 9.81 \times 2.0}$ 6.3 (m s^{-1})	C1 C1 C1	**<u>Examiner's Comments</u>** Candidates performed very well on this question by selecting and applying the correct equation of motion to calculate the speed of the ball when it hit the ground. **Selection and application of formulae** Candidates performed well on the selection and application of equations of motion from Module 3: Forces and motion.
	b		$\frac{0.62+0.68+0.60}{3}$ (=0.63) $2 = \frac{1}{2} \times g \times 0.63^2$ 10.1 (m s^{-2})	C1 C1 A1	**Allow** omittance of 0.68 if clearly identified as anomalous to give t=0.61s and v= 10.75 (m s^{-1}). If not clearly identified and correctly calculated 1 mark. **Allow** 9.97 and 10 (ms^{-2})

					Examiner's Comments Candidates performed well on this question as many candidates correctly calculated the mean time to fall/s and then selected and applied the equation of motion $s = ut + \frac{1}{2}at^2$ to calculate a value of *g* for the falling ball. Some candidates calculated a mean from the time values 0.62 s and 0.60 s, by omitting the result 0.68 s and this was given marks if they clearly identified the omittance of this value by identifying the result as anomalous.
	c		**Either** Use of auto electronic timer to measure time e.g. trap door connected to timer, video camera with time stamp/frame rate, "g" ball, light gates with data logger/timer To reduce/eliminate (random) errors due to (human) reaction time **Or** Increase height (Greater measurement of time) reduces %uncertainties in measurement of time	M1 A1 M1 A1	Improvements must relate to measurement of time **Ignore** ref. to human error **Ignore** ref. to repeating measurements for a range of heights and calculation of a mean value **Examiner's Comments** There were not many successful responses to this question, with most given 0 marks. Many candidates made attempts to suggest suitable improvements, but these were often vague and unspecific, e.g. use light gates but without any reference on how this piece of equipment would be used to time (such as by connecting to a data logger or (electronic) timer). To be given 2 marks, candidates had to achieve the first method mark for a correct improvement. Therefore, most candidates were not able to access the second mark as they had not achieved the first method mark for a correct improvement. Many candidates attempted to give reasons for their improvement but again these explanations were superficial as they were expressed without relating to the error due to reaction time. Some candidates did give a suggested improvement in terms of increasing the height of the fall of the ball, which meant they were given the first

					method mark but corresponding explanations linked to reducing the percentage uncertainty was not always fully developed to award the second mark. **Assessment for learning** Please refer to the Practical Skills Handbook for information on practical techniques including definitions of key scientific terminology and methodology
	d		Line with increasing negative gradient starting on y-axis at 2 m ending on x-axis at height=0 Line with decreasing positive gradient from *h*=0 on x-axis ending at a height < 2m at time t_{max}	B1 B1	**Not** lines drawn for constant velocity **Examiner's Comments** There were not many successful responses to this question, as many were given 0 marks for an incorrect sketch graph of the motion of the ball when it bounced after hitting the floor. Many candidates sketched a graph for a ball falling with constant velocity or for their graph drawn to a maximum height of 2.0m at time, t_{max} which represented an elastic collision when the ball hit the floor. **Misconception** A common misconception was to draw a graph representing the motion of the ball falling with constant velocity and hence zero acceleration. This may be because candidates did not interpret the graph as a displacement - time graph and assumed that the graph was a velocity - time graph. Also, candidates had another misconception that the collision of the ball with the floor was elastic and therefore the kinetic energy of the ball was conserved rather than an inelastic collision, which would result in the transfer of kinetic energy to other energy stores during the collision.

			Total	**10**	
6	a		$\frac{2\pi \times 1.19(\times 10^3)}{4.29 \times 10^4}$ 0.17 (m s^{-1})	C1 A1	**Allow** one mark for 1.7 to any power of ten 0.174 **Examiner's Comments** The majority of candidates gained credit on this question. The two common errors were either not changing 1.19 km to 1190 m or incorrectly working out the circumference of a circle. Some candidates just use distance divided by time while others used the area of a circle.
	b		Similarity: same magnitude or same speed or (still) 0.17 (m s^{-1}) Difference: (different) direction or (approximately) opposite direction	B1 B1	**Allow ECF** from (a) for 0.17 **Not** same velocity **Allow** negative **Examiner's Comments** Most candidates understood that velocity was a vector quantity and there were many correct answers explaining the similarity in that the magnitude of the velocity was the same and the difference was the direction. Lower scoring candidates often stated that the velocity was the same. This suggests that there was not the full understanding of the physical quantities speed and velocity.
			Total	**4**	
7	a	i	**X** marked on orbit at closest point to Mars	B1	Horizontal line through centre of X must pass through or touch the label 'Mars' **Allow** a single dot/circle marked on the orbit **Examiner's Comments** Most candidates put their cross in the correct place. The most common wrong response was to place a cross placed at the furthest point from Mars.

<table>
<tr><td></td><td></td><td>ii</td><td>orbits in an <u>ellipse</u> / orbit is <u>elliptical</u>

with (COG of) Mars at one focus</td><td>B1
B1</td><td>Allow a general statement even if not applied to MAVEN eg (all) orbits are elliptical
Ignore references to Sun or other planets

Not the Sun at one focus

<u>Examiner's Comments</u>

The main difficulty here was remembering which was Kepler's 1st Law. Many candidates described how a line between Mars and MAVEN would sweep out equal areas in equal times.

Sometimes valuable time was spent describing planetary orbits before restating the salient points for MAVEN.</td></tr>
<tr><td></td><td>b</td><td>i</td><td>$T^2 \propto r^3$

Correct calculations involving at least two sets of data which lead to a (reasonably) constant value</td><td>C1
A1</td><td>Not $T^2 = r^3$
Allow T^2 / r^3 = (any) constant or T^2 = (any) constant × r^3
Allow $T_1{}^2 / T_2{}^2 = r_1{}^3 / r_2{}^3$
May be inferred from a subsequent calculation

For example, T^2/r^3 (or r^3/T^2) calculated correctly at least twice:
Allow a constant value calculated for one set of data and then applied to at least one other object
Calculations do not need corresponding names of objects
Ignore number of sf;
ignore any incorrect calculations
Ignore statements about whether or not Kepler's 3rd Law applies

Values below are for benefit of markers, POTs removed

<table>
<tr><td rowspan="2">Object</td><td colspan="2">T^2 / r^3</td><td colspan="2">r^3 / T^2</td></tr>
<tr><td>T(hr)</td><td>T(s)</td><td>T(hr)</td><td>T(s)</td></tr>
<tr><td>MAVEN</td><td>7.4</td><td>9.6</td><td>1.4</td><td>10.5</td></tr>
<tr><td>Phobos</td><td>7.1</td><td>9.3</td><td>1.4</td><td>10.8</td></tr>
<tr><td>Deimos</td><td>7.4</td><td>9.6</td><td>1.4</td><td>10.4</td></tr>
<tr><td>Areostationary</td><td>7.8</td><td>10.1</td><td>1.3</td><td>9.9</td></tr>
</table>
</td></tr>
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					Examiner's Comments The majority of candidates remembered Kepler's 3rd Law correctly. There were a number of different approaches which could gain credit here. The main one used was to find the ratio of T^2/r^3 for corresponding pairs of values, showing that this ratio was approximately constant. Another common approach was calculating the constant k in $T^2 = kr^3$ using the data for MAVEN and then applying it to the distance of Phobos, for example, to show that it gave the correct value for the time period. The best responses were those where candidates thought carefully about how they were going to set out their calculations, naming the orbits under consideration or tabulating their values, whereas other responses were characterised by a sprawl of figures leaving the examiner to hunt for appropriate values.
		ii	(MAVEN needs) to see the whole planet / atmosphere **or** not just part of the planet / atmosphere (MAVEN needs) to be in / near to the atmosphere	B1 B1	**Ignore** comments about potential collisions / mass / orbital period / speed / direction **Allow** (if placed in an areostationary orbit, then) MAVEN would always orbit above the same place / it could only see one location / it could not see multiple locations / it could not see (atmosphere at) the poles / it could only see part of the (atmosphere of) Mars **Allow** (if placed in an areostationary orbit, MAVEN's orbital radius would be large that) it would not pass through the atmosphere / it could not analyse the atmosphere **Not** MAVEN is too close to see the atmosphere properly Note:

					Atmosphere does not need to be seen to award first BI Atmosphere must be mentioned somewhere in the response to award second B1 **<u>Examiner's Comments</u>** The strongest responses were given in terms of the function of MAVEN, which was to study the upper atmosphere of Mars. An areostationary orbit would be too far from Mars for this purpose, plus it would only allow MAVEN to sample one small part of its atmosphere. A common approach was to make partial statements such as 'MAVEN would be too far away...' and such responses were often too vague to be creditworthy. A few candidates misread the question and were obviously attempting to answer the question. 'H ow do we know that MAVEN is not in an areostationary orbit?'.
			Total	**7**	
8			**Level 3 (5-6 marks)** Clear description of method to measure *h* and *t* **and** graph analysed to determine *g* and the percentage uncertainty in *g* *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Some description of method to measure *h* and *t* **and** analysis of graph attempted to determine *g* and percentage uncertainty in *g* **or** Clear description of method to measure *h* and *t* **and** limited analysis of graph to determine *g* **or** Limited description of method to measure *h* or *t* **and** graph analysed to	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description of method to** measure *h* and *t* • Use of <u>metre</u> rule(r) / tape measure (not ruler) • Place rule in retort stand • Use of set square / fiducial marker • Timer (or datalogger / computer with detail) connected to electromagnet / trapdoor • Switch off electromagnet to start timer and drop ball • When ball hits trapdoor timer is stopped.

			determine *g* and the percentage uncertainty in *g* *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1-2 marks)** Limited description of the method to measure *h* or *t* **or** Limited analysis to determine *g* *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** *No response or no response worthy of credit.*		• Allow for diameter of ball in height measurement • Resolution of instruments millimetre /millisecond **Ignore** light gates, video **Analysis of data** • Gradient = $\sqrt{\frac{2}{g}}$ or $g = \frac{2}{\text{gradient}^2}$ • Evidence of method of determining gradient • Gradient in the range 0.44 to 0.47 • Determines *g* (≈9.5 m s^{-2}) • Correct power of ten and unit • Draws worst acceptable line • Determines gradient of worst acceptable line • Calculates absolute uncertainty in gradient • Determines *g* from worst acceptable line • Determines percentage uncertainty in gradient • Percentage uncertainty in *g* either 2 × percentage uncertainty in gradient or from *g* values <u>**Examiner's Comments**</u> This question was designed to test candidates' understanding of practical techniques both designing an experiment and analysing results. High scoring candidates described measuring *h* using a metre rule or tape measure and allowed for the diameter of the ball. Many candidates were unable to explain the use of the electromagnet to release the ball. Some low scoring candidates suggested using a stopwatch. Since the time measurements were recorded to the nearest millisecond it was expected that candidates would describe how the electromagnet and light gate would connect to an electronic timer or datalogger.

9	a				For the analysis, candidates were expected to link the given equation to the equation of a straight line and thus identify how *g* was related to the gradient. The next logical step would then be to calculate the gradient. For this, it was expected that candidates would demonstrate substituting values from the line on the graph (not data points from the table) to determine the gradient and thus calculate a value of *g* with an appropriate unit. To determine percentage uncertainty, candidate needed to draw the worst acceptable line. This should be either the steepest or shallowest line that passes within all the error bars. Candidates then needed to calculate the worst acceptable gradient. Candidates gained credit for either calculating the percentage uncertainty in *g* from twice the percentage uncertainty in the gradient or from calculating worst value of *g* and then determining the percentage uncertainty. **Assessment for learning** Candidates should have the opportunity to practise determining values for constants using the gradient and *y*-intercept of straight-line graphs. Candidates should have the opportunity to practise drawing worst acceptable straight lines through error bars and understand the techniques to determine uncertainties in calculated constants using the worst acceptable gradient and/or *y*-intercept.
			Total	**6**	
9	a		22.3 cos 84 (= 2.33) 2.33	M1 A0	**ALLOW** 22.3 sin 6 **Examiner's Comments**

					Most candidates clearly showed how the initial velocity of the ball could be resolved into its horizontal component. Most candidates used cos 84° although there was a significant minority who correctly used sin 6°.
	b		$v_v^2 = 2.33^2 + 2 \times 9.81 \times 2.4$ $v_v = \sqrt{52.517}$ OR 7.247 7.25	M1 M1 A0	**ALLOW ECF** from (a) **<u>Examiner's Comments</u>** For this part of the question it was necessary for candidates to clearly show the substitution of the data into the equation. This includes the value of *g* (as 9.81 m s^{-2}) from the data sheet. It was also necessary for candidates to show that having determined v^2, this value needed to have the square root taken. Higher performing candidates wrote the final answer as 7.247 or 7.24685 ≈ 7.25 (m s^{-1}).
	c		u_h =22.3 sin 84 = 22.2 $v = \sqrt{22.2^2 + 7.25^2} = 23.35$ $\left(= \frac{1}{2} \times 0.210 \times 23.35^2\right) = 57.2$ (J) OR Change in potential energy = 0.210 ×9.81 ×2.40 = 4.94 Initial kinetic energy = $\frac{1}{2} \times 0.21 \times 22.3^2$ OR 52.2 (J) (4.94 + 52.2 =) 57.1 (J)	C1 C1 A1 C1 C1 A1	**ALLOW** v^2 = 545 **ALLOW** 57.2 (J) **<u>Examiner's Comments</u>** This question proved challenging to candidates. The common error was to calculate the kinetic energy using a value of 7.25 m s^{-1}. There were two main methods of answering this question: Either: determining the horizontal component of the velocity of the ball, (which remains constant) then working out the resultant velocity of the ball as it hits the ground and then calculate the kinetic energy. Or: Calculate the change in gravitational potential energy Calculate the initial kinetic energy of the ball

					And then add the two values together. **Misconception** Omitting the kinetic energy in the horizontal direction when calculating the kinetic energy of the ball. Candidates should be able to compare the motion of a projectile in two perpendicular directions and also confirm that similar results are obtained by considering energy transfers.
	d		(change of) Momentum = mass ×(change of) velocity As velocity increases, the momentum increases OR force = rate of change of momentum gravitational force acts on the ball and increases momentum OR Momentum is a vector quantity, change in direction means that the momentum changes.	M1 A1 M1 A1 M1 A1	**ALLOW** changes for increases **<u>Examiner's Comments</u>** There are many possible explanations as to why the momentum of the ball changes. To score full marks candidates needed to state a property of momentum, e.g. momentum = mass × velocity before then explaining why the momentum would change, e.g. as the ball falls, velocity increases so for constant mass the momentum increases.
			Total	**8**	
10	a	i	$\left(\frac{(-)18}{2.7} =\right)$ (-) 6.7 (m s^{-2})	A1	**Ignore** sign **<u>Examiner's Comments</u>** This question required candidates to calculate the gradient of the sloping line. More able candidates clearly demonstrated the co-ordinates used and substituted the values into $\frac{y_2-y_1}{x_2-x_1}$. Candidates should be encouraged to show working since the read-offs could have helped with gaining credit in Question 1 (a) (iii) and (iv) where the values from the graph were used again. Some candidates incorrectly gave the answer to one significant figure (as

					“7”). Other candidates incorrectly wrote 6.6; this should have been rounded to 6.7.
		ii	(1200 ×6.7 =) 8000 (N)	B1	**ALLOW ECF** from **(a)(i)** **IGNORE** “-” **<u>Examiner’s Comments</u>** This question was answered well with the majority of candidates multiplying 1200 by the answer to Question 1 (a) (i).
		iii	$d = 18\times0.7+\frac{1}{2}\times18\times2.7$ OR $d = (3.4+0.7)\times\frac{1}{2}\times18$ 37 (m)	C1 A1	**ALLOW ECF** from **(a)(i)** **ALLOW** $d = 18\times0.7+18\times2.7-\frac{1}{2}\times6.7\times2.7^2$ 36.9 **ALLOW** one mark for $\left(\frac{1}{2}\times18\times2.7=\right)24(.3)$ (m) **<u>Examiner’s Comments</u>** Candidates who showed working usually gained credit. A common error was to calculate the distance travelled while braking rather than the stopping distance. **Assessment for learning** Understand the meaning of the terms thinking distance, braking distance and stopping distance.
		iv	$8000\times24(.3)$ OR $8000\times\frac{1}{2}\times18\times2.7$ 190 000 (J)	C1 A1	**ALLOW ECF** from **(a)(i)** and **(ii)** and **(iii)** **ALLOW** $\frac{1}{2}\times1200\times18^2$ **ALLOW** 194 000 / 200 000 (J) **ALLOW** one mark for (8000 ×37 =) 296000 (J) **<u>Examiner’s Comments</u>** Many candidates multiplied force (from Question 1 (a) (ii)) by the braking distance. A common error was to use the stopping distance rather than the braking distance. Other candidates correctly calculated the kinetic energy. One error that was occasionally

					observed was the incorrect use of $P = Fv$.
	b		Horizontal line starting at 9 m s^{-1} Horizontal line from (0, 9) to (0.7, 9) <u>and</u> a straight line from (0.7, 9) to between (2.0, 0) and 2.1, 0)	C1 A1	**Note** calculation gives 2.05 s **<u>Examiner's Comments</u>** Most candidates correctly realised that the horizontal section of the line would now start at 9.0 m s^{-1}. Many candidates also realised that the thinking time remained constant and that the acceleration (deceleration) remained constant. Errors usually occurred when drawing the sloping line either so that it ended on the *x*-axis at 3.4 s or it was a much shorter time (implying a larger acceleration).
	c	i	Horizontal line / section would be longer (and no change to sloping line)	B1	**IGNORE** idea of a tired driver applying a different braking force **IGNORE** thinking time / distance **<u>Examiner's Comments</u>** Many candidates stated the change in thinking time rather than explaining how the horizontal line on the graph would change. More successful candidates explained that the horizontal line would be longer.
		ii	Sloping line / section would be steeper (and no change to horizontal line)	B1	**ALLOW** (magnitude of) gradient is greater **IGNORE** gradient is lower **IGNORE** braking time / distance **<u>Examiner's Comments</u>** Many candidates stated the change in the braking time rather explaining how the sloping line on the graph would change. More successful candidates explained that the sloping line would be steeper.
			Total	**10**	
11	a	i	=110x1000÷3600 =31 ms^{-1}	B1 B1	Allow 30.55,30.6 etc Allow answer with consistent unit i.e. 0.031 km/s

		ii	time = distance × speed = 40 ÷ 31 =1.3s	B1	Allow any number of significant figures
		iii	Correct calculation of thinking distance (21 m) or thinking time (0.69 s) thinking distance less than 40m (distance between markings) OR thinking time less than 1.3 s (time taken between markings) OR braking distance less than 80 m (distance for two gaps) OR stopping distance is less than 120 m **Correct** conclusion consistent with comparison	B1 M1 A1	allow "stopping distance greater than 80m" without reference to 120 m but this prevents award of A1 ignore references to increased likelihood of collisions
	b	i	F=ma and a=v(-u) × t (F= 1600 × 31 ÷5.6) =8900 N (8.86kN)	C1 A1	Allow F=change in momentum÷time Allow energy approach using the data in the table Allow table distance of 75m or calculation of distance using $v^2 = u^2 + 2as$ and then $\frac{1}{2} mv^2 = Fs$ Allow ECF from (a)(ii) e.g. use of 110 gives 31,400 Allow answers that round to fall in range from 8700 to 8900 Allow 9950 or 10100 for 2 marks (use of 5.6s as stopping time) Allow 10250 for 2 marks (use of 75m braking distance) **<u>Examiner's Comments</u>** In Question 16 (b) (i), most candidates used the data available in the question to calculate an acceleration and hence a resultant force.
		ii	Using forces A component of the weight is acting backwards or there is additional backwards force or greater resultant force down the slope A smaller distance is required to do the <u>same</u> work or transfer the <u>same</u> quantity of KE	B1 B1	Allow energy approach Some of the KE turns to GPE or less KE to be transferred to heat A smaller distance required because the brakes must do less work using the <u>same</u> force Allow equivalent approach e.g. justification using increased deceleration and hence shorter distance for second mark.

					NB Unqualified smaller distance is insufficient **Examiner's Comments** In part (b) (ii), rather fewer used acceptable technical language to communicate their ideas. Useful phrases for explanations on this idea were 'resultant force' and 'component of weight parallel to the slope' rather than 'extra force' or 'some of the vehicle's gravity helped'.
			Total	**10**	
12	a	i	Arrow **along** the line of the support rod labelled tension or T.	B1	Allow unlabelled single arrow along either rod Allow unlabelled arrows along both rods Allow arrow(s) up, down or both NOT any contradictory arrows **Examiner's Comments** In Question 17 (a) (i) of this question, the phrase 'tension in the rod' can mean several different things, all of which were given in the mark scheme.
		ii	11.1 sin 35 or 11.1 cos 55 seen addition of 3.9 (half the diameter of the support disc) to candidate's horizontal component of rod length Total= 10.3m	M1 M1 A0	NOT use of tan 35 or tan 55 allow 7.8/2 for 3.9 10.27 to 2 dp NB use of 11.1 cos 35 or 11.1 sin 55 arriving at 12.99 scores 1 (wrong trig) NB reject use of radians (scores 0) **Examiner's Comments** Many candidates approached part (ii) with some confidence, spotting that the horizontal portion of the rod was 11.1 sin(35) and that it should be added to the radius of the disc.
		iii	mg=T cos 35	C1 C1 A1	Allow use of sin 55 NOT use of tan 35 or tan 55

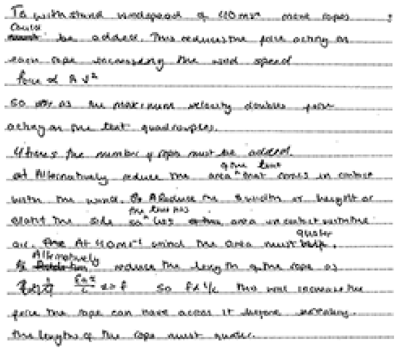
			T= mg ÷ cos 35 = 140 N		Answer is 143.7 N to 4 sf **Examiner's Comments** Parts (a) (iii) and (iv) were more challenging, requiring good knowledge of both circular motion and how to calculate components of forces. Again there were several legitimate routes to the right answer, all of which were mentioned in the mark scheme. Very logical approaches were in part (a) (iii), to equate the vertical component of the tension with the weight of the sandbag.
		iv	T sin 35 = mrω^2 $\omega=\sqrt{\frac{T\sin 35}{mr}}$ =0.8(17) radian s^{-1}	M1 A1 A0	Allow use of W tan 35 or W tan 55 Allow use of cos 55 and/or mv^2/r Allow use of Pythogoras to find centripetal force (82.4...) NOT use of T tan 35 or T tan 55 Allow ω^2 subject. Allow any combination of rearrangement and substitution ECF allowed for T and r. Use of 2 s.f. values for T and r gives 0.84 m **Examiner's Comments** In part (a) (iv), the quickest approach was to equate the horizontal component of the tension with the centripetal force. The data booklet provides a convenient expression for the centripetal force in terms of the angular velocity, without the need for finding the tangential velocity.
	b	i	Use of 17=1/2 gt^2 =1.9 (1.86) s	C1 A1	i.e. substitution of 17 and g or 9.81 or 9.8 e.g. s=(ut)+ ½ at^2 $t=\sqrt{\frac{2s}{a}}$ $=\sqrt{\frac{2 x 17}{9.81}}$ Allow any subject

		ii	Horizontal speed = rω or Horizontal distance = speed × time = 0.82 radians s^{-1} × 10.26 m × 1.86 s = 16 m (15.6 m)	C1 C1 A1	Use of data in the question stem (0.8 and 10) allowed, which gives 15.2 m. Ecf for use of candidate's value of r and ω, giving values rounding to between 14.9 and 16.0 m
		iii	Relevant variable identified Effect on speed of shoe or time of flight of shoe correctly identified Conclusion consistent with relevant physics e.g. • Shoe is lower mass yet no change in angular velocity or radius since independent of mass so no change in horizontal displacement. • Shoe is below seat so would be travelling with larger radius/speed so larger distance travelled horizontally • Shoe might have be kicked off backwards so have lower speed so lower distance • Shoe would come from below the seat/lower than the sandbag i.e. vertical distance to fall less, thus time of flight and horizontal distance less. • Effect of air resistance hadn't been included so shoe suffers drag, decelerating horizontally so distance would be smaller	M1 M1 A1	e.g mass/weight, drag/air resistance, radius, height, starting condition (e.g. kicking shoe off) Assume "it" in response refers to the shoe. ignore velocity for first M1 allow correct explanation of "no effect" on speed or time by change of mass **Examiner's Comments** Question 17 (b) explored ideas about parabolic flight due to gravitation. The only force acting on the sandbag and the shoe after they have been released is the weight force, which acts vertically downwards. Many candidates realised that the vertical velocity of the sandbag when it left the swing was zero, enabling them to calculate the time for the bag to fall 17m vertically downwards (using $s = ½ gt^2$) To calculate the horizontal distance travelled required both the horizontal velocity (from $v = r\omega$) and the time of flight from part (b) (iii). There was lots of scope for applying error carried forward rules as mentioned in the mark scheme. ? **Misconception** In lots of questions, candidates make assumptions when trying to use formulae to justify their ideas. In this case, it was that for the same radius, the shoe must leave the seat faster than the sandbag, purely because the shoe had less mass. Often, what is constant is as important

					to consider as what is changing. Here, if the radius for the sandbag and the shoe are the same, then the horizontal velocity at release must be the same, since the radius and angular speed for both are the same, using $v = r\omega$.
			Total	**16**	
13			A	1	
			Total	**1**	
14			3.6 × 0.58 / 2.09 (m) target distance = 1.85 m to 2.15 m **or** 2.09 − 2.0 = 0.09 m = 9 cm 1.85 < 2.09 < 2.15 / 2.00 < 2.09 < 2.15 **or** 9 cm < 15 cm	M1 C1 A1	This mark can be implied by the A1 mark. **Examiner's Comments** Most candidates correctly calculated that the ball landed at a distance of 2.088 m from the wall and then compared this to the range of the target ring from the wall as 2.0 m ± 0.15 m to show that the child won the ring. Where candidates did not score full marks they had not clearly compared where the ball had landed with the full range of the target ring.
			Total	**3**	
15			A	1	**Examiner's Comments** Just over half of the candidates correctly interpreted the graph to understand that the object was falling with constant acceleration due to gravity to give the answer A. The most common distractor was B.
			Total	**1**	
16	a	i	(area of shaded region =) 1.9 × 6.0 or 11.4 (m^2) (volume of air in 3.0 s =) 11.4 × 3.0 × 12 (mass of air = 11.4 × 3.0 × 12 × 1.2) mass of air = 492(.48) (kg)	C1 C1 A1	**Allow** volume found in one second leading to mass per second multiplied by 3 for 2nd and 3rd mark **Note**: volume of air is 410 (m^3)
		ii	Δp = 12 × 490 or 5900 (kg ms^{-1})	C1	Expect to see mass of 490, 492, 492.5, 492.48

			(force = $\Delta p / \Delta t$ = 5900/3.0) *F* = 2000 (N)	A1	**Note** answer is 1970 to 3 SF using 492.48 **Note** answer is 1960 to 3 SF using 490 **Examiner's Comments** Candidate's answers to this part were either jumbled or grounded in incorrect physics. This question is correctly answered by thinking about a cuboid of air that is 36 m long and has a cross-sectional area equal to that of the shaded side of the tent. That cuboid corresponds to the air that hits the tent in the three second period. The force applied will be equal to the rate of momentum change. This means multiplying the mass of air that hits the tent by the velocity change (i.e. 12 m/s) and then dividing by the time taken for that momentum change.
	b		***Level 3 (5–6 marks)** Clear descriptions **and** explanations, supported by quantitative analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description and some explanation or quantitative analysis **or** Clear explanation **or** Clear description **or** Clear quantitative analysis *There is a line of reasoning presented*	B1×6	**Indicative scientific points may include**: **Description** • Increasing the area/diameter of the guy ropes • A different material with a larger breaking or yield stress • A more streamlined shape that allows the wind to pass over or around the tent **Explanation** • Correct reference/use of F = $\Delta p / \Delta t$ • Greater cross-sectional area of rope would reduce the stress • The rope would not exceed a higher breaking/yield stress

			with some structure. The information presented is in the most part relevant and supported by some evidence. **Level 1 (1–2 marks)** Limited description **or** Limited explanation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		• Changing shape produces a smaller momentum change and a smaller force • If the air passes over/around the tent, it still has some forward momentum and hence the change and force is less • Reduction of angle of ropes from ground reduces component of tension perpendicular to ground so tension decreases. **Quantitative analysis** • Mass (per unit time) and velocity **both** double (at 40 m/s) • Momentum change is ×4 • Force would increase by a factor of 4 • Rope cross section must be × 4 (or diameter × 2) • Breaking or yield stress of material would need to be × 4 • Use of trigonometry to determine the angle of deflection that would reduce the momentum change by a factor of 4 (about 15° compared to the original 90°) **Examiner's Comments** This question tested ideas about forces, resolution of forces, behaviour of materials under stress and rate of change of momentum transfer. Level 1 answers were restricted to merely suggestions of what could be done to make the support of the tent stronger. Level 2 answers developed at least one of those suggestions by referring, qualitatively, to the underlying physics. Level 3 answers were rare, as the requirement was for some quantitative physics. Candidates that attempted a quantitative answer often believed that the force would be doubled, when in fact it is quadrupled. This is because both the mass of the air depends on the velocity of air, so doubling the

					speed will also double the mass, thus quadrupling the momentum transfer.  Additional answer space if required This candidate clearly states, on lines 3–5, that the force is directly proportional to the square of the speed by thinking about their answers to previous parts of the question. The statements following this, after the page break, are sensible and grounded in physics in topics typically covered in the first year of study. The candidate mentions about quadrupling the number of ropes and reducing the area presented to the wind by a factor of four. The candidate goes on, in the additional answer space, to refer to the thickness of the ropes and how the radius would need to double. Level 3 response.
			Total	**11**	
17		i	Extension (from graph) is 6.0 (cm) Use of E = ½ kx^2 elastic potential energy = 0.90 (J)	M1 M1 A1	**Allow** Use of E = ½ Fx and F = kx **Allow** 1 SF of 0.9 (J)
		ii	(KE = ½ mv^2) 0.90 = ½ × 0.030 × v^2 v =7.7 (ms^{-1})	M1 A1	**Allow** 1 J instead of 0.90 J **Note** using 1 J gives an answer of 8.2 ms^{-1} **Note** allow possible ECF with energy approx 1 J
		iii	1.5 = ½ gt^2	C1	**Allow** 8 ms^{-1} or 8.2 ms^{-1} instead of 7.7 ms^{-1}

			t = 0.55 (s) (R = 7.7 × 0.55) *R* = 4.2 (m)	C1 A1	**i.e**. 4.4, 4.5 (m) **Possible** ECF from **(b)(ii)**
		iv	(Actual distance is smaller than calculated R) Valid explanation The velocity /speed (in flight) smaller than expected **or** The initial velocity / speed will be smaller than expected	M1 A1	Examples of valid explanation include: For velocity / speed decreases • drag/air resistance For initial velocity /speed is smaller • not all the energy transfers to the ball • the cord also has KE • hysteresis (so cord heats up) **Ignore** references to efficiency and unqualified energy dissipation. **<u>Examiner's Comments</u>** Questions 16 (a), (b) (i) and (ii) were answered very well indeed. Most candidates recalled the experimental procedure for investigating force-extension relationships well. Question16 (b) (iii) required knowledge of independent motion. Successful candidates used the vertical motion of the object to find the time taken for it to hit the ground. After that, they used that time to find the horizontal range. Question 16 (b) (iv) was answered well by candidates that realised the distance in real life would be less and could explain why that was the case.
			Total	**10**	
18			(thinking distance =) 0.40 × 42 or 17 m Acceleration = 7 (ms^{-2}) or ½ m v^2 = F d (braking distance =) 125 m	B1 C1 A1 B1	**Allow** ECF in subsequent marks if thinking distance incorrect or omitted **Alternative approach using braking distance** (work done =) 120 × 10^3 × (167 – thinking distance)

			Total stopping distance is 142 m (which is less than 167m)		(work done =) 18 × 10^6 (J) Work done calculated **and** this is less than the initial KE **Allow** braking distance calculated and 125 m is less than the available braking distance of (167 – thinking distance) **<u>Examiner's Comments</u>** Candidates employed a range of strategies to demonstrate that the engine will stop before the obstruction. Very successful candidates often calculated the deceleration of the engine and then employed an equation of motion to work out first the braking distance and then added the thinking distance. Those candidates also added words to signpost their calculations clearly.
			Total	**4**	
19			**A**	1	
			Total	**1**	
20	a		(2.0 + 3.0) v = 10 v = 2.0 (m s^{-1})	C1 A1	**Allow** answer of 2 **1sf**, without any **SF** penalty **Ignore** sign **<u>Examiner's Comments</u>** About half of candidates were given 2 marks for correctly calculating the velocity of objects A and B combined after the collision. Most candidates used an expression for the momentum of the combined objects (5v) and equated this to the total momentum of the two objects before the collision (10 kg m s^{-1}). A significant number of candidates did not apply the conservation of momentum correctly and used a momentum value from the graph or didn't use the combined mass of the objects A and B.
	b		$s = ½ gt^2$ 120 = ½ × 9.81 × t^2 t = 4.9 (s)	C1 C1 A1	**Allow** 4.95, **not** 5.0 **<u>Examiner's Comments</u>**

					Candidates at the higher end performed better on this question as they were able to identify and apply the correct equation of motion and determine that the initial vertical component of the velocity was zero. Candidates at the lower end tended to either omit the question or make an incorrect attempt to use an equation of motion using a value for the initial velocity (usually the velocity calculated from part c). **Misconception** Candidates did not realise that horizontal and vertical motion are independent to each other and hence that the initial vertical component of velocity for the falling objects was zero.
			Total	**5**	
21	a		distance = area under the graph/suvat equations ½ (4.0 + 10.0) × 3.0 / 10.0 × 5.0 horizontal distance = 71 (m)	C1 C1 A1	**Allow** any attempt to calculate part of the area under the graph or suvat equations **Allow** any correct calculation of part of the area under the graph/suvat eqn e.g. 9, 12, 20, 21, 30, 32, 50 (m) **Examiner's Comments** Most candidates performed well on this question by achieving at least 1 or 2 marks for either correctly identifying that the distance travelled = area under the graph and/or attempting to calculate a distance from the area. Nearly two thirds of candidates scored 3 marks for correctly calculating the total distance travelled.
	b	i	$a = \frac{6.0}{3.0}$ 2.0	C1 A0	**Allow** any correct gradient calculation **Examiner's Comments** Candidates had to show that the acceleration was 2.0 m s^{-2} which 90% of candidates demonstrated successfully by using values from the

					graph and calculating a gradient value which equalled the acceleration. To be given this mark, candidates had to clearly show their working out using values taken from the graph.
		ii	680cos55 / 150 × 2.0 680cos55 – R = 150 × 2.0 R = 90 (N)	C1 C1 A1	If both components given (vertical and horizontal) it must be clear that the 390N is the horizontal component. **Examiner's Comments** Candidates performed less well on this question as it was mostly only the most successful responses that were given 3 marks for resolving the horizontal component of the tension in the rope to correctly calculate the horizontal resistance *R*. About 40% of candidates were given 1 mark for either correctly resolving the horizontal component of the tension to give 390 N or calculating the resultant force ($F = ma$) to give 300 N. It would have helped candidates understand the question to draw a free body force diagram to identify the forces acting on the buggy and direction and magnitude of the resultant force.
			Total	**7**	
22	a	i	E_p(= 0.16 × 9.81 × 2.5)= 3.9 (J)	A1	3.924 **Examiner's Comments** This question was generally answered well.
		ii	$v^2 = \frac{2\times3.9}{0.16}$ or 48.75 OR v^2 = 2 × 9.81 × 2.5 or 49.05 v = 7.0 (ms^{-1})	C1 A1	**Allow ECF** from (a)(i) **Allow** 1sf **Examiner's Comments** Most candidates correctly equated the change in gravitational potential energy to kinetic energy and gained the correct answer. Other candidates correctly used $v^2 = 2gh$. A number of candidates gave the answer as 7 (ms^{-1}) – since the data in

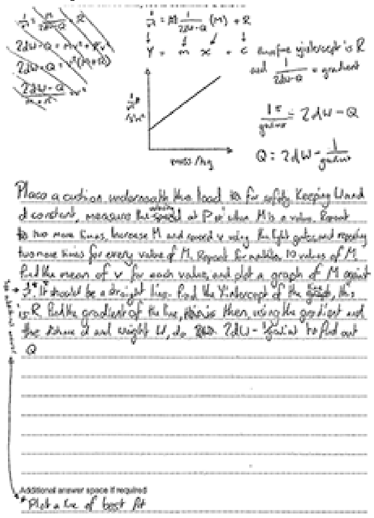
					the question was given to two significant figures the answers should also be given to two significant figures. Ideally the substitution of data into appropriate equations should be shown.
	b	i	$R(=12 \times 0.71) = 8.5(2)$ (m)	A1	**<u>Examiner's Comments</u>** It was expected that candidates would multiply the horizontal velocity by the time. This was generally answered well. **Assessment for learning** When considering projectile motion, candidates should treat the vertical and horizontal velocities independently.
		ii	$E_k = \frac{1}{2} \times 0.16 \times 12^2$ or 11.5 OR $= \frac{1}{2} \times 0.16 \times 13.9^2$ or $\frac{1}{2} \times 0.16 \times 193$ E_k (= 11.5 + (a)(i) = 11.5 + 3.9) = 15(.4) (J)	C1 A1	**Allow** use of vertical v = 6.97 (calculated using $v = u + at$;) **Allow** 15.5 (J) **Allow ECF** from (a)(i) **<u>Examiner's Comments</u>** Many candidates calculated the kinetic energy of the ball using the velocity of the ball in the horizontal direction but then did not add the change in potential energy of the ball as it fell. Other candidates determined the resultant velocity of the ball and then calculated the kinetic energy.
		iii	$\theta\left(= \tan^{-1}\left(\frac{(a)(ii)}{12}\right) = \tan^{-1}\left(\frac{7}{12}\right)\right) = 30°$	A1	**Allow** ECF from (a)(ii) 30.256 **<u>Examiner's Comments</u>** Candidates achieving on this question correctly determined the angle using the horizontal and vertical velocities. Where the response was incorrect,

					candidates had used either energies or distances.
			Total	**7**	
23	a		$\rho = \frac{169 - 96}{87}$ or $\frac{73}{87}$ $\rho = \frac{0.169 - 0.096}{87 \times 10^{-6}}$ or $\frac{0.073}{87 \times 10^{-6}}$ ρ (= 839) = 840 (kg m^{-3})	C1 M1 A0	**Ignore** power of tens **Note** power of tens must be seen for both mass and volume <u>**Examiner's Comments**</u> Most candidates were able to determine the mass of the oil correctly and divide the mass by the volume. A significant number of candidates did not demonstrate that 73 g was 0.073 kg and that 87 cm3 was 87 × 10^{-6} m^3. More able candidates clearly showed how the cm3 was converted to m^3.
	b		volume = $\frac{4\pi(8.1 \times 10^{-3})^3}{3}$ or 2.226 × 10^{-6} (m^3) OR 840 × 9.81 × candidate's volume 840 × 9.81 × 2.226 × 10^{-6} or 0.0183 0.018 (N)	C1 M1 A0	**Ignore** power of tens <u>**Examiner's Comments**</u> Candidates who understood that the upthrust was equal to the weight of the oil displaced scored well on this question. To score the marks it was necessary to show how the volume of the ball was calculated. Some candidates had difficulties with the powers of ten. Some candidates then went on to use one equation of density × volume × *g* while other candidates calculated the volume, then the density and then the weight. Both these methods were acceptable.
	c	i	Terminal velocity is when the <u>velocity</u> is constant (Terminal) <u>velocity</u> is determined from the gradient when graph is a straight line / constant gradient OR evidence of calculation of gradient of straight section	B1 B1 B1	**Allow** acceleration is zero for velocity is constant Check read-offs are appropriate. <u>**Examiner's Comments**</u> Candidates needed to describe and explain how the terminal velocity was determined from the graph. A good way of answering the question was to state what was meant by terminal velocity, explain how velocity could be

					determined from the displacement time graph and then state where the velocity was constant. Candidates who were successful demonstrated the gradient calculation of the straight section by substituting numbers into the gradient formula and calculating 1.8 m s^{-1}.
		ii	Tangent drawn at t = 0.2 s extends at least two large squares (0.2 s) in the x-direction 1.2 (ms^{-1})	M1 A1	**Allow** 1.10 (ms^{-1}) to 1.30 (ms^{-1}) **<u>Examiner's Comments</u>** High scoring candidates drew a tangent to the line at 0.2 s. **Misconception** The instantaneous velocity from a displacement time graph is equal to the displacement divided by time. **Assessment for learning** Candidates should practice drawing tangents to curves. The tangent should cover as much of the graph paper as possible. **Assessment for learning** Candidates should practice determining the gradient from a graph. Two data points should be selected from the line (not from a data table). The two data points should be easy to read from the graph and as far apart as possible (at least half the length of the straight line). The data points should clearly be substituted in the equation to determine the gradient m.

					$m = \frac{y_2 - y_1}{x_2 - x_1}$ The advantage of this method is that it also allows correctly for both positive and negative gradient graphs. Although the *y*-intercept did not have to be determined in this question, this method also help candidates to easily determine the *y*-intercept by substituting a data point from the graph used in the determination of the gradient, i.e. *y-intercept* = $y_2 - mx_2$ or $y_1 - mx_1$
	d		$\eta = \frac{0.017 \times 9.81 - 0.018}{6\pi \times 8.1 \times 10^{-3} \times 1.8} \left(= \frac{0.14877}{6\pi \times 8.1 \times 10^{-3} \times 1.8}\right)$ 0.54 kg m^{-1} s^{-1} OR N s m^{-2} OR Pa s	C1 A1 B1	**Allow** 0.55 **Note** for power of ten errors 607 or 0.607 or 5.4×10^{-4} scores one mark **<u>Examiner's Comments</u>** This was a challenging question and as a consequence some candidates only attempted to determine the unit. Common errors included either not allowing for the powers of ten correctly or not determining *F* as detailed in the question. Candidates also needed to determine the unit of *η*. A common incorrect unit seen was N s^{-1} m^{-2}. **Assessment for learning** Candidates should practice determining units in base units and checking the homogeneity of equations.
			Total	**12**	
24			**Level 3 (5–6 marks)** Clear diagram and procedure and measurements including explanation of the use of one light gate **and** analysis including determination of *Q* and *R*. *There is a well-developed line of*	B1 × 6	**Indicative scientific points may include**: **Diagram and procedure** • labelled diagram including light gate positioned at P

			reasoning which is clear and logically structured. The information presented is relevant and substantiated. **Level 2 (3–4 marks)** Some procedure, some measurements and some analysis. OR Limited procedure, limited measurements and detailed analysis OR Detailed procedure, detailed measurements and limited analysis *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** limited procedure and limited measurements and limited analysis *There is an attempt at a logical structure with a line of reasoning.The information is in the most part relevant.* **0 mark** No response or no response worthy of credit.		• card added to trolley to interrupt light beam • description of procedure • repeats experiment for each *M* • keep *d* constant • method to keep *d* constant, e.g. mark start position • method to stop trolley hitting pulley / load hitting floor e.g. cushion / sand bag • method to fix *M* to the trolley • use a release mechanism **Measurements** • use ruler to measure length of card / object interrupting light beam • use of balance to determine *M* • method to determine *W* • use of ruler to measure d. **Analysis** • v = length of card ÷ time • plot a graph of $1/v^2$ against *M* (or equivalent graph • gradient = $\frac{1}{2dW-Q}$ • *R* = y-intercept • $Q = 2dW - \frac{1}{\text{gradient}}$ <u>**Examiner's Comments**</u> The question was designed to assess candidates' practical skills. Candidates were advised to draw a 'suitable diagram', it was anticipated that they would draw a diagram with one light gate positioned at point P and a rectangular card added to the trolley to interrupt the light beam. To gain a Level 3 mark on this question candidates needed to explain both the procedure and measurements that needed to be taken. In particular candidates needed to explain how the velocity *v* was determined at P. Many candidates

					incorrectly used two light gates and determine the average speed to travel distance *d*. Appropriate measuring instruments should be specified to determine the other constants. The analysis of the data should include an appropriate graph to plot and an explanation of how *Q* and *R* could be determined from the gradient and intercept. *Q* and *R* should be the subject of the equation. **Exemplar 1**  Exemplar 1 - The candidate was awarded 4 marks as the scientific content of the response meets the Level 2 descriptors and the communication statement is also satisfied. The candidate structures the response by initially determining the graph that would need to be plotted to determine the constant *Q* and *R*. The candidate then explains how the gradient and *y*-intercept is used to determine *Q* and *R*. The candidate describes a brief procedure and includes the use of a cushion, repeating results and keeping *d* and *W* constant. To gain Level 3, the candidate needed to have included a diagram showing

					the position of the light gate and explained the measurements that would need to be taken to determine *v* from a light gate connected to a timer. **Assessment for learning** Candidates should understand how light gates attached to a timer can be used to determine velocity and acceleration. In particular, candidates should understand the distance measurements and shape of the interrupt card. Other data logging methods such as a motion sensor should also be understood. **Misconception** Many candidates incorrectly calculated the velocity *v* at P since they measured the time for the trolley to travel distance *d* and then calculated the average speed to travel distance *d*. **Assessment for learning** Candidates should be able to determine appropriate axes to plot graphs and then explain how constants can be determined from the gradient and *y*-intercept.
			Total	**6**	