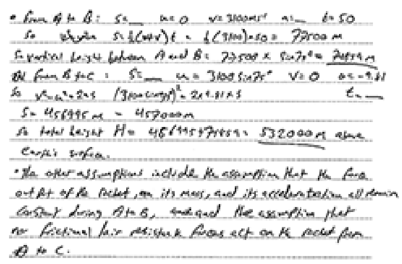
Mark scheme

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,

<table>
<tr><td></td><td></td><td></td><td>No response or no response worthy of credit.</td><td></td><td>
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
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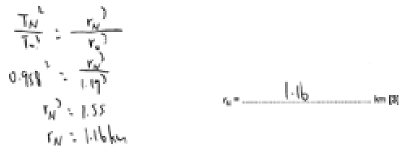
					OCR has a Guide to Level of Response Questions. This includes guidance on communication and the use of bullet points (page 5).
			Total	**6**	
2			**D**	1	**Examiner's Comments** Option C can be eliminated here because N m is equivalent to the joule, which is not equivalent to kW, the unit of power. Option A cannot be correct as it has a negative absolute temperature. Option B cannot be correct - the units are equivalent however 1 kg m s^{-1} and 1 N s are equivalent.
			Total	**1**	
3			**Level 3 (5-6 marks)** Clear description of experiment and observations and detailed comparison of de Broglie wavelengths *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 experiment **and** observations **and** some comparison of de Broglie wavelengths **or** Limited description of experiment and observations **and** detailed comparison of de Broglie wavelengths **or** Clear description of experiment and observations **and** limited comparison of de Broglie wavelengths *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 experiment and	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description of experiment and observations** • Electrons accelerated by a (high) p.d. • In a vacuum • Electrons fired at a (graphite) target • Rings observed • Diagram showing rings (or apparatus set-up) • Due to diffraction between spacing of atoms • So wavelength ≈ spacing of atoms • Increase in accelerating p.d. decreases spacing of rings • Multiple layers of (graphite) atoms means diffraction occurs in all directions • Since diffraction occurs in all directions, rings are observed

			observations **or** Attempt at calculating the de Broglie wavelength of the car *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.*		• Avoid touching the terminals / use insulated connections **Comparison of the Broglie wavelengths** • λ electrons in the experiment ≈ 10^{-10} m • $\lambda = \frac{h}{p}$ • Estimate of mass of car: 500 kg to 3000 kg • Speed of car: 30.5 or 30.6 (279/9) m s^{-1} • λ car ≈ 7 × 10^{-39} m to 4 × 10^{-38} m • λ electrons >> λ car. **<u>Examiner's Comments</u>** Many candidates appeared not to understand an experiment to demonstrate the wave nature of electrons often drawing a diagram of a double slit and using a screen, in effect the Young slit experiment for light. High scoring candidates often either stated an estimate of the de Broglie wavelength of electrons or used their knowledge and calculated a value for an estimated value of the accelerating potential difference. Ther were some very good answers working out the de Broglie wavelength of a car. The best answers clearly showed the working.
			Total	**6**	
4		i	$\frac{11\times60+25}{11\times60+55}$ OR $\frac{4.29\times10^4-30\times60}{4.29\times10^4}$ OR $\frac{11\times60\times60+25\times60}{4.29\times10^4}$ (=0.9580…)	M1 A0	$\frac{685}{715}$, $\frac{4.11\times10^4}{4.29\times10^4}$ **<u>Examiner's Comments</u>** The majority of the candidates correctly showed the ratio. There were many different methods. **Assessment for learning**

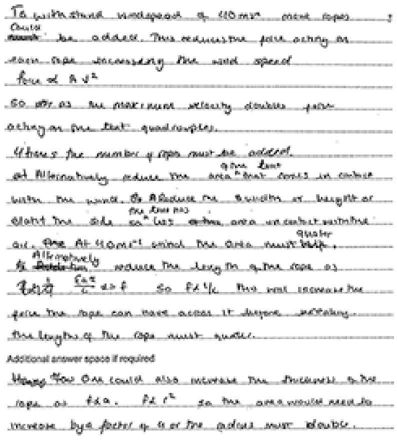
					Candidates should practise answering ratio type questions. Candidates should be able to determine the constant of proportionality. **Exemplar 1**  The candidate has clearly demonstrated the use of the given proportional relationship. The working is logical and is correct mathematically at each stage. The candidate has helpfully included intermediate stages, e.g. r_n^3 = 1.55 before giving the correct answer.
		ii	$r_N^3 = 0.958^2 \times 1.19^3$ OR $\left(\frac{11\times60\times60+25\times60}{4.29\times10^4}\right)^2 \times 1.19^3$ OR 1.55(x10^9) r_N = 1.156 to any power of ten r_N = 1.16 (km) given to 3 significant figures	C1 C1 A1	**Allow** any rearrangement $r_N = 1.19\sqrt[3]{0.958^2}$ **Allow ECF** from **(c)(i)** minimum 3sf **Note** must be km **<u>Examiner's Comments</u>** The majority of the candidates found this question challenging. Many candidates did not use the answer from Question 1 (c) (i) but did correctly use ratios perhaps by calculating the constant of proportionality to work out the correct answer. A few candidates did not correctly round their answer to 3 significant figures or gave an answer with a power of ten error.
			Total	**4**	
5			**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*	B1 x 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:**

			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 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.*		**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. • 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. 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**	
6			C	1	
			Total	**1**	
7	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}) (force = Δp / Δt = 5900/3.0) F = 2000 (N)	C1 A1	Expect to see mass of 490, 492, 492.5, 492.48 **Note** answer is 1970 to 3 SF using 492.48 **Note** answer is 1960 to 3 SF using 490 **<u>Examiner's Comments</u>** 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 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.*	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 • 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.  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**	
8			$\omega \rightarrow s^{-1}$ **or** $\omega^2 \rightarrow s^{-2}$ LHS = ms^{-2} **and** RHS = ms^{-2} clearly shown by unit algebra	M1 A1	**Allow** $\omega \rightarrow$ (radians) s^{-1} **Allow** $\omega^2 = (2\pi f)^2$ **or** $(2\pi/T)^2$ with some evidence of units afterwards e.g. RHS = m $(s^{-1})^2$ **<u>Examiner's Comments</u>** A large majority of candidates showed clearly that the units for acceleration were ms^{-2} and that the unit for angular frequency, in base units, was s^{-1}. Showing the resulting unit algebra clearly was often the only barrier to scoring both marks.
			Total	**2**	