Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		$\lambda = \frac{v}{f}$ $(= \frac{340}{262})$ $\lambda = 2L$ $(L =) \frac{1.30}{2} = 0.65$ (m)	B1 B1 B1	Formula may be implied by substitution **Allow** *c* for *v* Relationship may be inferred from a correct diagram of fundamental drawn in a tube open at both ends,or from a statement such as 'half a wavelength fits inside the tube' Some working leading to correct answer must be shown; don't accept a bald answer **Allow** L = 0.649 (0.64885) as evidence of working Do not allow working backwards from the answer **<u>Examiner's Comments</u>** This is a 'show that' question and so every step of the calculation needs to be made clear. It is not enough to point out that 340 / (2 × 262) = 0.65: the examiner needs to know why the data is being combined in this particular way. The step that was most often omitted was saying that, for the fundamental (lowest) frequency, half a wavelength fits inside the flute. This could be demonstrated using a diagram, showing an open tube containing half a wavelength with antinodes at both ends. However, a written statement (length is half of a wavelength) or a mathematical statement ($L = \lambda/2$) are just as good.
	b	i	Any **two** from • particles occupy negligible volume (compared to volume of container/gas) • collisions are (perfectly) elastic • time of collisions is negligible (compared to the time between collisions)	B1 × 2	Mark as for Short Answer Questions (requiring only a list by way of a response) and contradictory responses see page 3. **Allow** zero / no / none for negligible throughout **Ignore** particles occupy negligible space

			• negligible <u>forces</u> exist between particles (except during collisions)		**Ignore** particles are very small **Allow** <u>kinetic</u> energy is conserved (during collisions) **Allow** the particles move at constant velocity (in between collisions) **Ignore** type of force if specified **<u>Examiner's Comments</u>** Most candidates confidently wrote two correct assumptions. Errors most often came about through careless wording, such as 'the time between collisions is negligible' (rather than the time of collisions) or 'the particles take up negligible space' (rather than volume).
		ii	$M = 4.00 \times 10^{-3}$ (kg mol^{-1}) $T = 263$ (K) $v^2 = \frac{1.67 \times 8.31 \times 263}{4.00 \times 10^{-3}}$ $v = 955$ (m s^{-1}) $f = (\frac{v}{\lambda} =) \frac{955}{1.30} = 730$ (Hz) **Alternative method using ratios** $\frac{f_1}{f_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ or $\frac{v_1}{v_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ $T = 263$ (K) $\left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2} = \left(\frac{1.67 \times 263 \times 29}{1.4 \times 293 \times 4}\right)^{1/2}$ $= 2.786$ f (= 2.786 × 262) = 730 (Hz)	C1 C1 C1 A1 C1 C1 C1 A1	This C1 mark is for converting M into kg mol^{-1} **Allow ECF** for an incorrect POT in M T = -10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of T. This C1 mark is for correct substitution into the given formula; v^2 does not need to be calculated for the mark but seeing v = 955 implies the mark **Allow** M given to 1sf **Allow** 8.3 or R for 8.31 If a value for γ or M is taken from the wrong row of the table, this is a TE (M must be in kg/mol). If both wrong values are used, count this as a single TE. **ECF** candidate's value of λ or (λ = 2L) from 1a **Allow** f = 740 (Hz) For reference, POT error in M gives v = 30.2 (ms^{-1}) and f = 23 (Hz) T = −10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of T

					This C1 mark is for substitution and the ratio 2.786 does not need to be calculated for the mark The values for *M* may be given in kg/mol or left in g/mol as long as there is consistency **Allow** *M* = 4 to 1sf **Allow** *f* = 740 (Hz) If using $\frac{v_1}{v_2}$ then v = 2.786 × 340 = 947 giving *f* (= *v* /*λ* = 947 / 1.3) = 730 (Hz) but **ECF** candidate's own value of *λ* or *L* (*λ* = 2L) from 1a **<u>Examiner's Comments</u>** **Common problems in 1 (b) (ii)** • failing to convert the molar mass *M* into units of kg mol^{-1} • substituting the length of the flute (0.65m) instead of 1.30m for the wavelength.
•			**Total**	**9**	
2	a		14.4 <u>and</u> 50.0	B1	Both values given to 1dp Mark entries in first table (on page 4) **only** if second table (on page 6) is left blank **<u>Examiner's Comments</u>** It is good practice to give all values in a column of a table to the same number of decimal places.
	b	i	y-axis labelled "*T* / *s*" y-axis scale completed correctly all six x-co-ordinates correctly plotted all six data points plotted accurately	B1 B1 M1 A1	**Allow** suitable equivalent e.g. *T* (s), Time in secs Scales markings of 100, 200, 300, 400 and 500 every 2 cm Check at 1, 4, 9, 16, 25 and 36; ±½ small square tolerance. Check visually by fit to bfl; ±½ small square tolerance. **ECF** candidate's values for *N* =1 and 2 **<u>Examiner's Comments</u>** It was easy to put a scale onto this

					graph, and very few candidates used a non-linear scale or one with a poor choice of intervals. Some candidates, however, forgot to add units to their time axis. Most plotted the points easily, although the first point often proved tricky.
		ii	suitable best fit line	B1	There must be an even scatter of points above and below the line **<u>Examiner's Comments</u>** Almost all candidates were able to draw a best fit line with an even scatter of points above and below the line
		iii	evidence of use of at least half of the width of the drawn line Gradient =14 (s)	B1 B1	Evidenced by triangle drawn on graph or by Δx in working for gradient Correct line should have $\Delta x \geq 17.5$ **Allow** any answer between 13 and 15(s) **ECF** candidate's own best fit line **<u>Examiner's Comments</u>** Again, this was well done, with most candidates choosing a large triangle to calculate their gradient and drawing it onto the graph. Note that it is important to use points on the line of best fit to calculate a gradient (which are not necessarily points from the table).
		iv	$R = \frac{gradient}{C \ln 2}$ Value of *R* is in the range 19 – 22 (kΩ) uncertainty is 5% of *R* with value given to same number of dp as *R*	B1 B1	For reference, *R* in $k\Omega = \frac{\text{gradient value in d(iii)}}{0.69}$ **ECF** candidate's gradient value in **d(iii)** **Allow** answer given in Ohms if unit clearly stated **Allow** answer given to 1sf i.e. 20 (kΩ) **Expect** 1 (kΩ) **Allow** to more than 1 s.f. but uncertainty <u>must</u> be given to same number of d.p. as candidate's value for *R* If answer given in Ohms, **allow** uncertainty also given in Ohms to same number of d.p. as *R*

					Examiner's Comments **Common problems in 2(d)(iv)** • giving the value of *R* in Ω rather than kΩ. • giving the value and its absolute uncertainty to a different number of decimal places.
	c	i	systematic	B1	**Examiner's Comments** This was a systematic error, since it would affect all the results for *N* = 6 (and for larger values of *N*, if taken) in the same way
		ii	(smaller T value for N = 6 so) smaller gradient and therefore smaller R value	B1	**Ignore** references to smaller or bigger *C* **Examiner's Comments** The students calculated their value for *R* by using the formula *R* (in kΩ) = ln (2) / gradient. If their sixth capacitance was too small then their gradient would also have been too small (because their point for *N* = 6 (N^2 = 36) would have been slightly lower). This means that their calculated value for *R* would have been too small.
			Total	**12**	
3	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 **Examiner's Comments** 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 **Examiner's Comments** 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 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	B1 B1	NB cube root of 2 is 1.2599… e.g. 1.26 × 44 = 55 (m s^{-1}) **Examiner's Comments** Even if they couldn't complete the calculation in the previous item, candidates needed to be able to state 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**	
4			**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**	
5			**C**	1	**Examiner's Comments** Neither option A nor option D can be correct since they contain units that

					are not base units. Option B cannot be correct as kg m s^{-2} is equivalent to the newton, not the joule.
			Total	**1**	
6			**A**	1	**Examiner's Comments** This should have been a straightforward starting question for all the candidates in identifying the correct S.I. base unit but only some gave the correct response of A. The most common distractor was B.
			Total	**1**	
7		i	The product has a higher binding energy (per nucleon)	B1	**Allow** the fusion of low Z number nuclei will result in a nucleus higher up the curve making it more stable **Ignore** statements regarding electrostatic repulsion **Examiner's Comments** This question was quite poorly answered with few candidates appreciating the idea that an increase in binding energy per nucleon would result in energy given out. Many candidates simply restated the question, by saying low mass would join to give higher mass or stated that iron was the most stable isotope.
		ii	Energy before = (1.1 × 2) + (2.8 × 3) (= 10.6 MeV) Energy after = 7.1 x 4 (= 28.4 MeV) Energy released = 28.4 -10.6 = 17.8 MeV = 17.8 × 10^{6} × 1.6 × 10^{-19} = 2.8 × 10^{-12} (J)	C1 C1 A1	**Allow** ± 0.1 MeV tolerance on binding energy values from graph Answer to at least 2sf (2.848) MAX value of energy within tolerances = 2.99 × 10^{-12} MIN value of energy within tolerances = 2.70 × 10^{-12} **Examiner's Comments** As always with a 'show that' question, it is vital to include as many steps as possible, the key to this question involved reading from the graph and then including the number of nucleons

					in the calculation. A fair number of candidates correctly read the point but did not multiply this with the nucleon number. There were relatively few misreads from the graph and the tolerance allowed some variation. Many simple (and incorrect) methods would give a value fairly close to 3 x 10^{-12} and so candidates would feel that they had correctly answered the question. Very few candidates struggled with the conversion from MeV to joules, although this may have been supported by having the power of ten given to them. It is also important to make sure that any value is given to a greater number of significant figures than that asked for, if appropriate. Around a third of candidates were able to obtain all 3 marks on what a potentially challenging calculation is.
		iii	Energy released per second = $4.3 \times 10^9 \times (3 \times 10^8)^2 = 3.87 \times 10^{26}$ (J) No of reactions = $3.87 \times 10^{26} / 2.85 \times 10^{-12} = 1.4 \times 10^{38}$ (s^{-1})	C1 A1	Alternative method: Mass per reaction = $2.85 \times 10^{-12} / (3 \times 10^8)^2 = 3.2 \times 10^{-29}$ (kg) No of reactions = $4.3 \times 10^9 / 3.2 \times 10^{-29} = 1.4 \times 10^{38}$ (s^{-1}) **Allow** use of 3×10^{-12} to give 1.29×10^{38} **Allow** use of (c)(ii) tolerance range for energy released value from to final answer in range 1.29 − 1.43 ($\times 10^{38}$) Correct to at least 2sf **Examiner's Comments** There are several routes to obtain the correct answer and credit is always given to any correct method. Neatly two thirds of candidates scored both marks on this question, even if they had not completed the previous part by using the 'show that' value. Candidates should always be aware that a 'show that' value is likely to be used in subsequent calculations.
			Total	**6**	
8			C	1	**Examiner's Comments** A little over half of candidates were

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>able to identify the correct response. Many candidates showed working to obtain their answer. D was a common incorrect response.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>9</td><td></td><td>i</td><td>510 (THz)</td><td>B1</td><td>Allow correct answer in answer space

<u>Examiner's Comments</u>

Most candidates were able to calculate the frequency, however, many candidates did not allow for the table heading in THz.

Assessment for learning

Candidates should be able to record data in a table using the units given in the column headings.</td></tr>
<tr><td></td><td></td><td>ii</td><td><table><tr><td>Glass</td></tr><tr><td>1.97×10^8</td></tr><tr><td>387</td></tr><tr><td>510</td></tr></table>
One correct scores one mark
All correct and in the table scores two marks</td><td>B1
B1</td><td>Allow ECF for wavelength for correct speed of wave / same frequency as (a)(i)
Allow 386, for 387
Allow 2sf answers, e.g.
<table><tr><td>2.0×10^8</td></tr><tr><td>390</td></tr><tr><td>510</td></tr></table>
ECF from (a)(i)
Ignore units in table

<u>Examiner's Comments</u>

Most candidates were able to calculate the speed of light in glass correctly. Lower scoring candidates often incorrectly believed that the frequency (as opposed to the wavelength) decreased in glass.

Misconception</td></tr>
</table>

					Many candidates did not fully understand effects of refraction on the quantities speed, frequency, and wavelength.
			Total	**3**	
10	a		4 (ms) OR 0.004 (s) 250 (Hz)	C1 A1	**Allow** one mark for 0.25 (Hz) to any power of ten **<u>Examiner's Comments</u>** The majority of the candidates gained credit. Some lower scoring candidates did not interpret the trace correctly.
	b		One node drawn at closed end and one antinode drawn at open end N and A correctly labelled	B1 B1	**<u>Examiner's Comments</u>** Many candidates understood what was meant by an antinode and a node but did not understand that for the fundamental mode of vibration a node was formed at the closed end and one antinode was formed at the open end.
	c		(3×250=) 750 (Hz)	B1	**Allow ECF** from (a) **Not** ECF from (b) **<u>Examiner's Comments</u>** This question was challenging. A value of 500 Hz was the common incorrect answer. Other incorrect answers included candidates who thought that the frequencies decreased. **Misconception** Many candidates did not fully understand the formation of stationary waves in closed tubes and the effect on the harmonics. Candidates should have the opportunity of drawing stationary waves in both open and closed tubes and determining the wavelength and frequency for each pattern.

			Total	**5**	
11		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	$\frac{685}{715}$, $\frac{4.11\times10^4}{4.29\times10^4}$ **Examiner's Comments** 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 **Examiner's Comments** 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**	
12			**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 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.*	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 metre 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

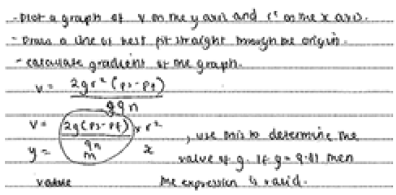
					• Determines percentage uncertainty in gradient • Percentage uncertainty in *g* either 2 × percentage uncertainty in gradient or from *g* values **Examiner's Comments** This question was designed to test candidates' understanding of practical techniques both designing an experiment and analysing results. 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**	
13			$\rho = \frac{m}{V}$ and $V = \frac{4}{3}\pi r^3$ ($\approx 4\ r^3$) density of neutron star ≈ **5×10^{17}** kg m^{-3} density of nucleus ≈ **4×10^{17}** kg m^{-3}	C1 A1 A1	Formulae may be inferred from either calculation **Allow** m/r^3 = constant **Ignore** number of s.f. in answer Volume of neutron star 4×10^{12} m^3 **Ignore** number of s.f. in answer Volume of nucleon ≈ 4×10^{-45} m^3 $m_{nucleon}$ ≈ u = 1.66×10^{-27} kg to 3 sf (**allow** 1.67×10^{-27} kg) If the calculation of separate densities is not shown explicitly then the two **A1** marks may be scored for either: • ratio of densities ≈ 0.8 **or** 1.2 • $m/r^3 = 2.0 \times 10^{18}$ (kg/m^3) for star **and** 1.7×10^{18} (kg/m^3) for nucleon • $r^3/m = 5.0 \times 10^{-19}$ (kg/m^3) for star **and** 6.0×10^{-19}(kg/m^3) for nucleon **<u>Examiner's Comments</u>** Most candidates were able to apply the correct formulae for density and

					for volume of a sphere. The calculation for the density of a neutron star was performed easily. However, rather than calculating the density of a single nucleon (whose radius had been given), many candidates tried to calculate the density of a different nucleus (such as deuteron or helium) whose radius had not been given. Some candidates lost marks through not stating the units in which their calculated densities were measured.
			Total	**3**	
14		i	Any two points from this list of three: • $v \propto r^2$ • (so) droplets with a small(er) <u>radius</u> have a small(er) v • (so) water droplets in mist must have a smaller <u>radius</u> (than water droplets of rain) Alternatively, **allow** any two points from the list below: • $v \propto (\rho_s - \rho_f)$ • $\rho_f \approx \rho_s$ for water droplets in <u>mist</u> giving $v \approx 0$ • $\rho_s > \rho_f$ (**or** $\rho_s \neq \rho_f$) for water droplets in <u>air</u> giving $v > 0$ (**or** $v \neq 0$) • ρ_f is greater in mist than air (with ρ_s constant) so v is smaller for water droplets in mist than for water droplets in air ORA	B1 x 2	**Allow** v increases with r (squared) OAW ORA ORA **Allow** density of water is similar to density of mist so $v \approx 0$ **Allow** water/rain is more dense than air so $v > 0$ **Allow** density of mist is greater than density of air so v is smaller for water droplets in mist than for water droplets in air ORA **<u>Examiner's Comments</u>** The density of water is the same in mist droplets and in rain droplets, and in both cases the droplets are falling through air. This means that the only variables in the formula are v and r^2, with v being proportional to r^2. Since mist droplets have a much lower terminal velocity v, this must be because they have a smaller radius than rain droplets. A reasonable suggestion using the formula, however, is that v is proportional to $(\rho_s - \rho_f)$ and so this was given credit. Although the density of the water droplet, ρ_s, remains the same, some candidates argued that the air through which raindrops fall

					has a lower density to the water vapour through which mist droplets fall. This argument was much more popular than v proportional to r^2. Unfortunately, many candidates were too vague and struggled to distinguish between water, rain, mist and air. Some thought that density of air/mist > density of water giving a negative terminal velocity, which is impossible.
		ii	**Level 3 (5–6 marks)** Clear description (must check for *terminal* velocity) **<u>and</u>** Clear analysis (**either** correct answer for lowest v (allowing POT error) **or** method which at least partially verifies the expression) *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 (several points made, leading to a measurement of velocity) **<u>and</u>** limited analysis (as below) **<u>or</u>** Limited description **<u>and</u>** clear analysis (see above) *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 (eg at least one valid point made) **<u>or</u>** Limited analysis eg • incorrect expression used with correct values • incorrect values used in correct expression • 'plot a graph' but with incorrect axes / no mention of how to	B1 x 6	Use the annotations e.g. L2 for 4 marks, L2^ for 3 marks etc. Place the appropriate number of ticks below the annotation. **Indicative scientific points may include:** **Description of experiment to measure terminal velocity *v*** • Use a <u>long</u>, <u>clear</u> tube containing the liquid • Check the tube is vertical using a spirit level or plumb line • Measure a distance d using metre rule or tape measure • Measure a time t using a stopclock **or** light gates **or** give details of a video method • Describe a method to reduce parallax error • Describe a method to check that the spheres have reached v • Repeat using a different liquid and/or a different metal sphere • Possibly use several spheres with different values of r, measuring diameter d of spheres using callipers or micrometer **Analysis** • Calculate $v = d / t$ • Calculate $r = d / 2$ • Verify expression by plotting a suitable graph e.g. v against r^2 • and see if the results lie on a straight line through the origin • Verify expression by substituting into expression

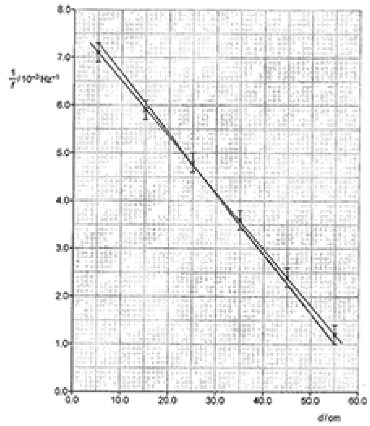
			use the graph to verify the expression *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** *No response or no response worthy of credit*		• e.g. calculating *g* from gradient and comparing result to 9.81 or comparing measured *v* to value of *v* predicted from expression • Steel spheres – lower ρ_s than lead so lower *v* • Sunflower oil – much higher η than water so lower *v* • Estimate lowest $v = 0.075$ m s^{-1} using steel and sunflower oil **<u>Examiner's Comments</u>** This experiment is one of the PAGs and it is essential that candidates explain how to verify that the sphere is falling *at a constant velocity* before *v* is measured. It is not enough to state that a long cylinder must be used or that *v* is measured near the bottom. It is important to describe which measuring instruments would be used and how the measurements taken would be combined to calculate *v*, rather than simply stating '*v* is measured using a light gate'. Some candidates did not read the question carefully and spent precious time explaining how to measure the density of the liquids and the spheres, which had been given in the table. They described carefully how to drop the sphere from exactly the same height each time using exactly the same amount of fluid, not realising that this would have no bearing on the terminal velocity. Candidates were asked to calculate the lowest terminal velocity possible using a sphere of diameter = 1 mm. Most candidates remembered to attempt this and correctly chose a steel sphere in sunflower oil. However, many used $\eta = 50$ rather than 50×10^{-3} and the majority used $r = 1$ mm rather than 0.5 mm. The purpose of the experiment was to verify the expression given in 4b(i) as accurately as possible. The best way

					to do this was to use a steel sphere in sunflower oil because then the sphere would be travelling more slowly, making it possible to measure *v* more accurately. The radius of the sphere could be varied and a graph of *v* against r^2 plotted. If the expression given is correct, then the graph would be a straight line *through the origin*. The gradient should be equal to $2g(\rho_s - \rho_f)/9\eta$ and, by using the values given in the table, $g \approx 9.81$ m s^{-2} could be verified. It is also possible to use the 4 different combinations of liquid and solid sphere of constant radius and plot a graph of *v* against $(\rho_s - \rho_f)/\eta$. Candidates should make sure that they state very clearly how their experiment can be used to verify the expression. A typical response was along the lines of 'I would measure *v* several times and take an average, then plot the results on a graph'. How are you going to get more than one result (you need at least four for a reasonable graph)? What are you going to plot and on which axis? Have you taken all the variables into account? How will you use your graph to show that the expression is correct? Exemplar 2  - Plot a graph of v on the y axis and r^2 on the x axis. - Draw a line of best fit straight through the origin. - calculate gradient of the graph. $v = \frac{2gr^2(\rho_s-\rho_f)}{9\eta}$ $v = \frac{2g(\rho_s-\rho_f)}{9\eta} \times r^2$, use this to determine the $y = m\ x$ value of g. If g = 9.81 then value the expression is valid. This response demonstrates good practice.
			Total	**8**	
15	a	i	*(W = ½ C V²so)* $400 \times 10^6 = 0.5 \times C \times (24 \times 10^3)^2$ **C = 1.4 (F)**	C1 A1	**Allow** *W* = ½ *Q V* **and** *C* = *Q* / *V* (*Q* = 3.3×10^4(C) so) *C* = *Q* / *V* = $3.3 \times 10^4 / 24 \times 10^3$ **<u>Examiner's Comments</u>**

					Most candidates seemed to find this quite straightforward and easily calculated the capacitance using $W = ½CV^2$. A common error was using $W = QV$(then $C = Q/V$) instead of $W = ½QV$. Some candidates clearly confused the use of C for capacitance with C for Coulombs as they had calculated charge rather than capacitance.
		ii	(putting capacitors in parallel) increases the total capacitance **ORA**	B1	**Allow** $C_T = C_1 + C_2 + ...$ **or** capacitors add together (in parallel) **Ignore c**apacitors in parallel can store more charge/ energy **<u>Examiner's Comments</u>** A few candidates lost the mark here by discussing voltage/energy across capacitors in series versus parallel without linking this idea to capacitance.
	b		power ≈ $400 \times 10^6 / 10^{-3} = 4.0 \times 10^{11}$(W) power required is equivalent to output of ≈ 400 power stations **or** time taken for power station to release stored energy $= 400 \times 10^6 / 10^9 = 0.40$s 0.4s is (much) longer than 1 ms	M1 A1 (M1) (A1)	**Allow** ECF (a)(i) for incorrect POT in 400GW **Allow** this is <u>much</u> more than could be provided by one power station **or** 4.0×10^{11}(W) » 1GW **Ignore** comments about household supply **Allow** ECF (a)(i) for incorrect POT in 400GW **Allow** it would take more time / too long **<u>Examiner's Comments</u>** Candidates were expected to link the power output of a conventional power station (1GW) given at the start of the question to the power requirement of the fusion reactor (400 MJ in less than 1 ms). Alternative approaches which received credit were finding the energy supplied by a conventional power station in 1 ms, or calculating the time required for a conventional power station to release 400 MJ. A

					common incorrect approach involved attempting to calculate the time constant of a capacitor. Many candidates disregarded the instruction to use a calculation in their response and thus were unable to earn any marks despite a good understanding of the problem.
			Total	**5**	
16		i	use (vernier / digital / dial) calliper(s) **or** micrometer (taking readings) at different positions / orientations (along the wire)	B1 B1	**Ignore** take multiple readings **<u>Examiner's Comments</u>** There are five measurements listed, so we were expecting candidates to comment on sampling the diameter at various locations/orientations as well as naming the measuring instrument used.
		ii	exclude the 0.495 (mm) anomaly add the remaining 4 values and divide by 4 / calculate mean of the remaining values calculate half the range of the remaining values	M1 A1 A1	May be inferred from calculations **Allow** the correct calculation which leads to 0.455 **Ignore** references to median or mode or average **Allow** the correct calculation which leads to 0.005 **Ignore** difference between mean and highest (or lowest) value **Ignore** references to resolution of the measuring instrument **<u>Examiner's Comments</u>** If you add all 5 results together and divide by 5, the answer does not come to 0.455 mm. So clearly the student in the question has discarded the anomalous result in the table before performing their calculation. The general rule for giving a single result from a set of data is to calculate the *mean* average (not the mode or the median). The uncertainty is found from half the range. Giving the uncertainty as ± half of the smallest scale division is the general rule to use when we have only one

					single reading, which is not the case here. **How to quote a single result from a set of data** • Use the *mean* average • Uncertainty = half the range
•			**Total**	**5**	
17			**Level 3 (5–6 marks)** Clear description of method to determine *f* **and** graph analysed to determine *v* and the percentage uncertainty in *v* *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 determine *f* **and** some analysis of data to determine *v* or the percentage uncertainty in *v* **or** Limited description of method to determine *f* **and** graph analysed to determine *v* and an attempt to determine the percentage uncertainty in *v* **or** Clear description of method to determine *f* **and** limited analysis of graph *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 determine *f* **or** Limited analysis to determine *v* *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	B1 × 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description of method** • Adjust frequency until maximum amplitude observed / heard • Start from a low frequency • Since fundamental frequency is the lowest resonance • Measure period of wave on oscilloscope • Period = timebase x horizontal distance • $f = 1/T$ • read frequency from signal generator. **Analysis of data** • Gradient = $-\frac{4}{v}$ • Determines gradient of line (-0.012 Hz^{-1} m^{-1}) • Determines *v* (330 to 344 m s^{-1}) • Correct power of ten and unit • Draws worst acceptable line • Determines gradient of worst acceptable line • Calculates absolute uncertainty in gradient • Determines percentage uncertainty in gradient • Percentage uncertainty in gradient = percentage uncertainty in *v*

			0 mark *No response or no response worthy of credit.*		**<u>Examiner’s Comments</u>** The second level of response question gave candidates the opportunity of drawing conclusions from an experiment as well as explaining how the fundamental frequency *f* may be determined experimentally. For good answers to these type of questions, candidates need to structure their answers logically so that all parts of the question are answered. An explanation to determine *f* should include the adjustment of the frequency and how to determine the fundamental frequency with the idea of the loudest sound. More successful candidates discussed the peak on the oscilloscope and starting from a low frequency. It was also expected that candidates could describe how to determine the frequency from an oscilloscope. Ideally reference would be made to the time-base. To determine the value of *v* with the percentage uncertainty, candidates needed to show their working clearly, taking into account the powers of ten and units from the graph. Exemplar 3 

					 Explain how the apparatus is used to determine *f* and use the graph to determine *v*. Include the percentage uncertainty in your value of *v*. [6] This candidate's response is structured and detailed. Firstly, this candidate has added the steepest worst acceptable line to the graph which passes through all the error bars. The candidate then identifies how the gradient is related to the frequency of the wave before calculating the gradient. The calculation of the gradient is demonstrated and the candidate has also clearly taken into account the powers of ten on each axis of the graph before determining *v* with a correct unit. This process is repeated for the worst acceptable line with each of the steps shown before percentage uncertainty is calculated. Throughout this section, it is easy to follow the candidate's method. It is clear that the candidate has used a large triangle to calculate the gradient. The candidate then explains how *f* is determined by adjusting the signal generator until a loud sound is heard and then explaining how the frequency is determined by the oscilloscope.
			Total	**6**	
18	a	i	$1.9 \times 1.60 \times 10^{-19}$ or 3.04×10^{-19} (3.0×10^{-19} J)	M1 A0	**<u>Examiner's Comments</u>** This question was well answered with the majority of candidates clearly writing $1.9 \times 1.60 \times 10^{-19} = 3.04 \times 10^{-19}$

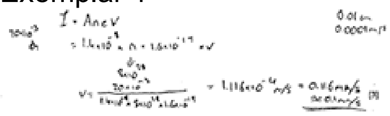
					(J). This is exactly how a show type question should be answered.
		ii	$f = 990\ (\text{THz}) + \frac{3.0\times10^{-19}}{6.63\times10^{-34}}\ (= 1450\ (\text{THz}))$ $\lambda = \frac{3.0\times10^{8}}{1450\times10^{12}}$ $\lambda = 2.1\times10^{-7}$ (m) OR Energy of photon = $6.56\times10^{-19} + 3.0\times10^{-19}$ (J) $\lambda = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{9.56\times10^{-19}}$ $\lambda = 2.1\times10^{-7}$ (m)	C1 C1 A1 C1 C1 A1	**Allow** alternative methods **Note** 2.1×10^{n} scores two marks **Note** 6.6×10^{-7} scores zero (omits work function) **Note** 3.0×10^{-7} scores zero (omits energy of electrons) **Note** 2.1×10^{n} scores two marks **<u>Examiner's Comments</u>** Candidates found this question challenging. The common error was to omit the work function of the metal. Other candidates determined the energy but omitted the energy of the electrons. A significant minority of candidates attempted to answer this question by determining the momentum of the electrons. **Assessment for learning** Understand the differences between the photelectric effect and electron diffraction.
	b	i	no change / stays the same	B1	**<u>Examiner's Comments</u>** The majority of the candidates correctly stated that there would be no change. Some candidates then added good reasons to explain their answer.
		ii	doubles	B1	**<u>Examiner's Comments</u>** Most candidates correctly realised that the rate of emission would increase but many did not give a quantitative

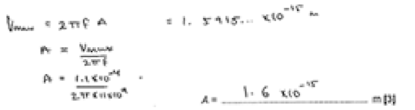
					answer (double) to match the stem of the question. **Assessment for learning** Where quantitative data is used in questions, answers should also be quantitative wherever possible. Practice explaining the effect on one quantity due to another quantity is doubled/halved/quartered, etc.
			Total	**6**	
19		i	Evidence that gradient = $\frac{AE}{L}$ $A = \frac{1600 \times 4.4}{120 \times 10^9}$ 5.9×10^{-8} (m^2)	C1 C1 A1	e.g. $F = \frac{AE}{L}x$ **ALLOW** *F* and *x* correctly read from linear section and substituted into *A* =*FL*/*Ex* **Note** 5.9×10^n scores two marks **<u>Examiner's Comments</u>** Many candidates did not understand the significance of the gradient. More able candidates derived an equation into a *y* = *mx* format and then successful calculated an answer. A number of candidates did not use an appropriate power of ten for the Young modulus or convert the gradient to be consistent with the length of the wire. Candidates who read a value of force and extension directly from the graph could still gain full credit – often the read-offs were from the non-linear section of the graph. **Assessment for learning** Candidates should make sure that they are using consistent units when calculating quantities and should know the common prefixes for units.

		ii	Area under graph = energy Evidence of <u>area</u> under graph determined, e.g. Counting squares (1cm^3 = 1.25 ×10^{-4} J and number of squares counted squares) OR Adding/subtracting shapes in the non-linear part 4.0 ×10^{-3} (J) to 4.4 ×10^{-3} (J)	C1 M1 A1	**IGNORE** sf **<u>Examiner's Comments</u>** For this question it was essential that candidates showed their working. Many candidates incorrectly used the extension for a force of 3.5 N and substituted it into an equation. More able candidates stated that the area under the line would be equal to the work done and then clearly showed the method used to work out the area under the line.
			Total	**6**	
20		i	newton in base units is kg m s^{-2} Substitution and cancelling of kg and m arriving at s^2 –> s^2	C1 A1	
		ii	One force is increased by kx and one is reduced by kx /AW Some working to include kx − (-kx)	B1 B1	reject 2 springs in series or 2 springs in parallel idea XP accept one extension is reduced by x and one is increased by x / AW **<u>Examiner's Comments</u>** Question 21 (a) (ii) is considerably more challenging. The two springs are not in series nor are they in parallel. When there is a displacement *x* one spring is extended by an *extra* amount *x* i.e. an extension of (e + x) and the other is extended by a reduced amount *x i.e.* an extension of (e − x) where e is the equilibrium extension. This meant that the resultant force was $k(e + x) − k(e − x)$, which is clearly 2kx. Neither spring goes into compression, although we condoned candidates who suggested that a reduction in extension meant the same as a compression.
		iii	period is independent of <u>amplitude</u> / AW No effect	M1 A1	Allow isochronous **<u>Examiner's Comments</u>**

					A reasonably large proportion of candidates did not link the idea of initial displacement to the amplitude of this motion. Those that did often scored both marks as they also recalled that SHM is isochronous. **Assessment for learning** Merely repeating the words in the question, in this case 'the initial displacement' instead of 'amplitude', is unlikely to give access to full marks. Think about which piece or pieces of technical language on the specification are the likely target of each question.
			Total	**6**	
21	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 $½ mv^2 = Fs$ 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 **<u>Examiner's Comments</u>** 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**	
22			A	1	**<u>Examiner's Comments</u>** The majority of candidates were able to correctly recall the ampere as the correct base unit. **C** was a common distractor, most likely as it contains the obvious metre.
			Total	**1**	

23		i	$I_{max} = nAv_{max}e$ $v_{max} = \frac{20 \times 10^{-3}}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.4 \times 10^{-8}}$ v_{max} = 1.1 × 10^{-4} (ms^{-1})	B1 M1 A1	**Allow** v for v_{max} throughout **Allow** I for I_{max} **Allow** q or Q for e / a for A / V for v but **not** N for n Substitution must be shown in full Answer must be given initially to 2 or more sf (but may later be rounded to 1sf) **<u>Examiner's Comments</u>** Since the answer is given here and candidates are being asked to show where it comes from, it is important to show every stage in the working. The following steps were necessary to gain full marks: write down the correct formula substitute the given values <u>and</u> the values of any physical constants (such as e) work out the answer to more significant figures than given in the question Exemplar 1  The exemplar above shows the type of response that gained full marks.
23		ii	$\omega = 2\pi f$ $A (= v_{max}/\omega) = \frac{1.1 \times 10^{-4}}{2\pi \times 11 \times 10^{9}}$ **or** $A (= v_{max}/\omega) = \frac{1.1 \times 10^{-4}}{6.9 \times 10^{10}}$ A = 1.6 × 10^{-15} (m)	C1 C1 A1	May be inferred from working $\omega = 2\pi \times 11 \times 10^{9} = 6.9 \times 10^{10}$ (rad s^{-1}) **Allow** use of V_{max} = 1 × 10^{-4} (m s^{-1}) **Allow** V_{max} from **(a)(i)** given to more than 2sf but **not ECF** from any value which does not round to 1 × 10^{-4} (ms^{-1}) **Allow** use of v_{max} = 1 × 10^{-4} (ms^{-1})[1] giving A = 1.4 × 10^{-15} (m) to 2sf or 1.45 × 10^{-15} (m) to 3sf Special case: **Allow** A = 1 × 10^{-15}(m) to 1 sf if v_{max} =

					1×10^{-4} (ms^{-1}) is used **<u>Examiner's Comments</u>** The formula sheet gives $v = \pm\omega(A^2 - x^2)^{½}$ as a starting point. The maximum velocity of the electrons has been given in (i) as 0.1 mm s^{-1}. The electrons are moving in simple harmonic motion, and so their maximum velocity occurs as they pass equilibrium i.e. when $x = 0$. This simplifies the formula to $v_{MAX} = \omega A$. Equal marks were given for using either the given value for v_{MAX} of 0.1 mm s^{-1} or the candidate's own value from (a)(i). **Exemplar 2**  The exemplar above shows the type of response that gained full marks.
		iii	($a_{max} = \omega^2 A$ and $v_{max} = \omega A$) $a_{max} = 2\pi f\, V_{max}$ Since V_{max} is constant, $a_{max} \propto f$	M1 A1	**Allow** $a_{max} = \omega\, v_{max}$ **Allow** a for a_{max} and V for V_{max} **<u>Examiner's Comments</u>** This was a difficult question; hard to visualise and involving some challenging algebra. Most candidates did not notice that the question specified the <u>maximum</u> acceleration of a free electron. Therefore the most common response was that $a = (2\pi f)^2 x$, showing that $a \propto f^2$. This gained no marks. Other candidates went further and said that the maximum acceleration occurs when $x = A$. This means that $a_{MAX} = (2\pi f)^2 A$ and so $a_{MAX} \propto f^2$, since A is constant. However, the amplitude A of the oscillation is itself dependent on the frequency. If the maximum current remains constant then the maximum

					velocity v_{MAX} of the electron must also remain constant. In (a)(ii), we used the fact that $v_{MAX} = 2\pi fA$, so fA must remain constant. $a_{MAX} = (2\pi f)^2 A = (2\pi)^2 fA - f$ = constant × f. So we conclude that $a_{MAX} \propto f$. An easy way to see this algebraically is: $a_{MAX} = (2\pi f)^2 A$ and $v_{MAX} = 2\pi fA$ Therefore $a_{MAX} = (2\pi f)\, v_{MAX}$ v_{MAX} remains constant and so $a_{MAX} \propto f$
			Total	**8**	
24		i	f (= $1/T$) = 1 / (40 × 10^{-3}) f = 25 (Hz)	B1 B1	**Allow** $f = 1/T$ **and** $T = 40 \times 10^{-3}$ (s) **Examiner's Comments** It is important to show how the information from the graph has been used to calculate the frequency. The correct answer did not score full marks unless some working had been shown.
		ii	**EITHER** Calculation of Q_o / e time constant (read from graph) = 14 (ms) **OR** Use of $Q = Q_o e^{-t/CR}$ time constant = 14 (ms)	C1 A1 (C1) (A1)	**Allow** any initial value of charge e.g. 8.0 / e = 2.9 (μC) **or** 37% × 8.0 = 3.0 (μC) **Allow** 14±1 (ms) e.g. $2.0 = 8.0e^{-0.02/CR}$ gives CR = 0.02 / ln4 Using the decay equation may incur two POT errors **Examiner's Comments** The question specifies using the discharging section of the graph. Some candidates tried to use the charging section, but this proved more difficult. Using the definition of the time constant, we need to find how long it takes for the charge to fall from any initial value to 37% (1/e) of that value. Many candidates chose 8μC for their initial value, but this is not vital.

					37% of 8μC is 2.9μC. The charge is 8μC at 20ms and 2.9μC at 34ms, so the time taken is 34 − 20 = 14ms. A common alternative approach was to insert values from the graph into the equation $Q = Q_0 e^{-t/CR}$ This gave the same result, but sometimes resulted in a POT error because of the need to give the answer in milliseconds.
		iii	tangent drawn to graph <u>at steepest part of curve</u> maximum current in range 5.0 × 10^{-4} to 7.0 × 10^{-4} (A)	M1 A1	Judge by eye, no daylight between curve and tangent **Allow** a negative answer **Allow** answer to 1sf **<u>Examiner's Comments</u>** Many candidates lost marks here because they did not realise that, to calculate the *maximum* current in the resistor, they had to draw the steepest possible tangent to the graph.
		iv	vertical axis labelled as current with the correct unit **and** at least one positive and one negative scale marking **and** scale should allow for their maximum current to be plotted exponential decay of current in each section sign of current alternates at 20, 40, 60 and 80 ms	B1 M1 A1	For example *I* / mA, *I* (mA), *I* /10^{-4} A, current in mA etc All scale markings shown must be correct **Allow** any curve with a decreasing gradient in each section **Ignore** value of minimum current but **not** zero **Ignore** sign of current for this marking point All curves should start at the correct maximum current value. However, If **B1** mark has not been scored, **allow** any value of maximum current as long as it remains consistent across all four sections **<u>Examiner's Comments</u>** Since $I = \Delta Q/\Delta t$, the graph of *I* against *t* can be found from the gradient of the graph of *Q* against *t.* The gradient is positive from 0 − 20 ms and negative from 20 − 40ms; this

					represents the current flowing one way around the circuit while the capacitor charges and then the opposite way while it discharges. Since the gradient is never zero, the value of the current is never zero either. **Tasks that caused problems in 6(b)(iv)** • drawing an exponential decay, particularly in the negative section of the graph (most drew a sinusoidal curve). • converting the maximum current into mA or μA. • labelling the vertical axis and drawing on a sensible scale. **Assessment for learning** Centres should consider providing more practice in drawing graphs without the aid of graph-plotting software.
			Total	9	
25		i	$\lambda_{max} \propto 1/T$ (T has decreased over time so in the past) the <u>peak</u> was at a shorter wavelength / further to the left on the graph	B1 B1	**Not** $\lambda_{max} = 1/T$ May be inferred from candidate's diagram **Ignore** overall shape of spectrum **<u>Examiner's Comments</u>** The mention of Wien's displacement law gave a clue that it would be useful in answering the question. A mark was given for stating the law. Note that the law is $\lambda_{MAX} \propto 1/T$ rather than $\lambda \propto 1/T$ or $\lambda_{MAX} = 1/T$. Candidates who did not draw on the diagram to illustrate their response sometimes missed the second B1 mark because they said that the wavelength (rather than the <u>peak</u> wavelength) would have been smaller. If an examiner says, 'You may draw

					on the diagram', it is generally a beneficial approach.
		ii	$E\left(=\frac{hc}{\lambda}\right)=\frac{6.63\times10^{-34}\times3\times10^{8}}{1.1\times10^{-3}}$ $E = 1.8 \times 10^{-22}$(J)	C1 A1	Full substitution needed if judging explicitly **Examiner's Comments** This was a straightforward question and most candidates correctly chose and applied the formula $E=\frac{hc}{\lambda}$ **Common problems in 4(b)(ii)** • not converting mm to m • trying to convert the answer to or from MeV
		iii	**EITHER** $\frac{3 x 10^{-6}}{1.8 x 10^{-22}}$ **or** 1.66×10^{16} (photons m^{-2} s^{-1}) **OR** $3 \times 10^{-6} \times (150 \times 10^{-4})$ **or** 4.5×10^{-8} (W) number of photons per second $\left(=\frac{3\times10^{-6}\times150\times10^{-4}}{1.8\times10^{-22}}\right)$ $= 2.5 \times 10^{14}$ (s^{-1})	C1 A1	**Allow** 2×10^{14} (s^{-1}) or 3×10^{14} (s^{-1}) Expect to see $1.66 \times 10^{16} \times 150 \times 10^{-4}$ **or** $\frac{4.5\times10^{-8}}{1.8\times10^{-22}}$ **Examiner's Comments** This is a complex, multi-stage calculation. A good approach was to use: number of photons per second × energy of each photon = amount of energy per second = power = intensity × area The total intensity of the microwave background radiation was given at the start of the question as 3×10^{-6} Wm^{-2}. Converting cm^2 into m^2 proved difficult for many.
		iv	$E = Pt = IAt$ and $V = Ah$ where A is CSA of cylindrical tank and h is height of tank $\Delta\theta=\frac{E}{mc}=\frac{IAt}{\rho A h c}=\frac{It}{\rho hc}$ and so $\frac{\Delta\theta}{t}=\frac{I}{\rho hc}$ $E = mc\theta$ **and** $m = \pi\rho V$ max temp rise $s^{-1}\left(=\frac{\Delta\theta}{t}\right)=\frac{3\times10^{-6}}{1000\times5\times4200}$	C1	**Allow** nonstandard letters as long as meaning is clear **Allow** 1000 (kg m^{-3}) for ρ **Allow** $\pi r^2 h$ or $5\pi r^2$ for V **Allow** answer to more than 1s.f. (1.43×10^{-13} (°C s^{-1})) **Examiner's Comments**

			max temp rise $s^{-1} = 1 \times 10^{-13}$ (°C s^{-1})	C1 A1	This too was a complex, multi-stage calculation. Most candidates correctly found their way into the question by writing down the formula $E = mc\Delta\theta$ and realising that they needed to use the formula $\rho = m/V$ in order to calculate the mass. The volume V of the cylindrical tank could be found using V = depth × cross-sectional area. However, although the depth was specified in the question, the cross-sectional area was not. Successful candidates realised that, if the cross-sectional area was not given, then it must cancel out later in the calculation. Some used algebra and called the cross-sectional area A. Others simply made up a value for A (A = 1 m^2 is the easiest).
			Total	**9**	
26	a		$g = GM/r^2$ $g = \frac{6.67 \times 10^{-11} \times 4.87 \times 10^{24}}{(6\,050 \times 10^3)^2}$ g = 8.87 (N kg^{-1})	C1 C1 A1	**Allow** m for M **Allow** d or D or x or X or R for r Full substitution needed **Allow** r = 6 050 for this C1 mark **Allow** a negative answer Answer must be to exactly 3sf for the A1 mark. Do not use the **SF** penalty for the paper here **<u>Examiner's Comments</u>** This was a gentle start to the paper, with the formula $g = GM/r2$ being provided in the data, formulae and relationships booklet. **Common problems in 1(a)** • omitting to convert r from km to m and so incurring a power of ten (POT) error • using a value of G from a calculator or from memory rather than copying the 3 significant figure (3sf) value given in the formula sheet

					• writing the answer to more (or less) than the 3sf specified in the question
•	b	i	$a = \omega^2 r$ **and** $\omega = 2\pi / T$ **or** $a = v^2/r$ **and** $v = 2\pi r / T$ **Either** $\omega = \frac{2\pi}{5830 \times 3600}$ **or** $v = \frac{2\pi \times 6050 \times 10^3}{5830 \times 3600}$ **or** $a = \frac{4\pi^2}{(5830 \times 3600)^2} \times 6050 \times 10^3$ $a = 5.42 \times 10^{-7}$ (ms^{-2})	C1 C1 A1	**Allow** use of $T^2 = 4\pi^2 r^3/(GM)$ **and** $v = 2\pi r/T$ $\omega = 2.99 \times 10^{-7}$ (rad s^{-1}) $v = 1.81$ (ms^{-1}) $a = \omega^2 r = (2.99 \times 10^{-7})^2 \times 6050 \times 10^3$ $a = v^2/r = 1.81^2 / (6050 \times 10^3)$ **Do not allow** incorrect or omitted conversion of T **Allow** answer given to 2sf **Allow** any answer which rounds to 5.4×10^{-7} Do **not** penalise incorrect km conversion (giving $a = 5.42 \times 10^{-10}$) if already penalised in **(a)** **<u>Examiner's Comments</u>** A slightly harder question, requiring the use of two formulas (either $a = \omega^2 r$ and $\omega = 2\pi / T$, or $a = v^2/r$ and $v = 2\pi r / T$). Some marks were available for calculating either ω or v correctly. **Common problems in 1(b)(i)** • omitting to convert T from hours to seconds, or converting T incorrectly • omitting to convert r from km to m and so incurring a POT error
•		ii	(Mass of fluid displaced = $\rho \times V$ =) 65 × 1.7 (Weight of fluid displaced = $\rho \times V \times g$ =) 65 × 1.7 × 8.87 U (= weight of fluid displaced) = 980 (N)	C1 C1 A1	Possible **ECF** from **(a)** but **do not allow** $g = 9.81$ N kg^{-1} **<u>Examiner's Comments</u>** Unfortunately, many candidates did not know how to calculate upthrust, often confusing it with the normal contact force. This may be because upthrust forms a small part of the syllabus and is therefore easily

					overlooked. Upthrust = weight of fluid (atmosphere) displaced by the probe. The volume of the atmosphere displaced by the probe is identical to the volume of the probe itself. **Common problems in 1(b)(ii)** • using the value g = 9.81 rather than the value of g on Venus calculated in (a) • using the mass of the *probe* instead of calculating the mass of the *atmosphere* using the formula mass = density of atmosphere × volume of probe
•		iii	Any 2 from: • Forces are balanced at **A** /there is no centripetal force at **A** / forces are unbalanced at **B** / there is a resultant **or** centripetal force at **B** • correct balanced forces equation at **A** • correct expression of Newton's second law at **B** • calculation of centripetal force at **B** • calculation of normal contact force at **A** • calculation of normal contact force at **B** <u>therefore</u> reaction force (must be) greater on **A**	B1 × 2 B1	**Allow** the pole for **A** and the equator for **B** throughout **Allow** weight provides the centripetal force but **do not allow** normal contact force/upthrust provides the centripetal force **Allow** acceleration in place of force **Ignore** any statement that suggests that centripetal force is a separate or additional force e.g. $R_A = W - U$ e.g. ($mr\omega^2$**or** ma**or**) $F = W - U - R_B$ Centripetal force (= ma = 760 × 5.4 × 10^{-7}) = 4.1 × 10^{-4} (N) Possible **ECF** from **(b)(i)** R_A (= $W - U$ = (680 × 8.87) − 980) = 5760 (N) Possible **ECF** from **(a)** and **(b)(ii)** R_B (= $W - U - ma$ = 5760 − 4.1 × 10^{-4}) Possible **ECF** from **(a), (b)(i)** and **(b)(ii)** Conclusion must follow some valid and relevant reasoning in which upthrust is mentioned **Allow** reverse argument **Allow** CF is negligible therefore

					reaction force is same at **A** and **B** **<u>Examiner's Comments</u>** Candidates often struggle to demonstrate a clear understanding of circular motion, and this year was no exception. Most candidates understood that probe **B** on the equator was acted on by centripetal force whereas probe **A** at the pole was not. However, some thought that the centripetal force acted outwards, away from the surface. Many thought that the centripetal force was a separate force acting on probe **B** in addition to its weight. These candidates wrongly concluded that this would increase the force towards the centre, resulting in an increased normal contact force. Whereas the opposite is actually the case; part of the probe's weight must be used to provide the centripetal force, and so the normal contact force would be smaller. A very common mistake was to ignore the effect of upthrust acting on the probe. Although the upthrust would be the same both at the equator and at the pole, it was worth a mention. Upthrust = 980N (from b(ii)) whereas the centripetal force was only 760 × 5.42 × 10^{-7}N (from b(i)). **Assessment for learning** The author of the examination paper structures questions to support candidates in writing their responses. 1(b)(i) is a calculation of the centripetal acceleration and 1(b)(ii) is a calculation of the upthrust. These provide a logical progression to 1(b)(iii) which involves both centripetal acceleration and upthrust (and not, say, the shape of Venus or its magnetic field).
			Total	**12**	

27	a		Allows only those gamma rays / waves / photons travelling along axis (of the collimator) to get through (and reach scintillator)	B1	**Allow** less fuzzy / clear image **Allow** all the gamma rays / waves / photons are parallel / in the same direction (to each other) **Allow** <u>absorbs</u> those gamma rays / waves / photons not parallel (to the axis of collimator) **Allow** so the photons are travelling perpendicular to the scintillator **Do not allow** the gamma rays are travelling vertically, unless it is clear the collimator is also vertical **<u>Examiner's Comments</u>** This question was well answered by around half of the candidates who appreciated that the long, narrow collimator would allow only gamma rays which were parallel to each other to be received by the scintillator. This can be expressed in a number of ways and marks were given to candidates who were able to state this using alternative descriptions. A common confusion appeared between using the terms perpendicular and parallel, with some candidates incorrectly stating that the collimator allowed photons perpendicular to the tubes to pass. Essentially, the collimator allows for a clearer image to form and so this is an acceptable response.
	b		Turn gamma (photons) into (many photons of) light	B1	**Ignore** reference to rays / waves **Ignore** reference to flash **<u>Examiner's Comments</u>** Around half of the candidates were able to correctly explain that the gamma photons produced visible light in the scintillator. Several candidates thought that the scintillator produced electrons or a voltage when the gamma photons were incident on it instead. Many candidates gave the extra correct information that many visible photons are produced from one gamma photon, although this was not a required detail on this occasion.

	c		number of electrons = $\frac{0.32 \times 10^{-6} \times 1.2 \times 10^{-9}}{e}$ number of electrons = 2400	C1 A1	**Ignore** any POT error for C1 mark **<u>Examiner's Comments</u>** This calculation was done well by a large majority of candidates. There were few errors in the unit prefixes, with the most common one being 1.2 ns as 1.2×10^{-12} s. A small number of candidates calculated the charge correctly, but then took it no further to determine the number of electrons.
	d		Any sensible <u>diagnostic</u> suggestion, e.g. <u>detection</u> of cancer / scans of (named) organ / scans of tissue / bone scans / observing functionality of (named) organ	B1	**Not** medical <u>treatment</u> e.g. radiotherapy **Not** body scan **Ignore** PET scanner **Do not allow** CAT scan **<u>Examiner's Comments</u>** The key word here was "diagnostic" and responses were expected to state any reasonable diagnostic use of a gamma camera and a wide variety of responses were given and accepted. Common responses included checking for brain tumours and observing kidney failure. Although a gamma camera may be used in a PET scanner, this alone was not acceptable as it does not explain the diagnostic use. Candidate should be encouraged to write in a clear sentence structure as simple responses such as "cancer" cannot be given marks.
			Total	**5**	
28			eV or J → [kg m^2 s^{-2}] in base units by any method base units = kg m^2 s^{-1}	C1 A1	**Allow** kg $(ms^{-1})^2$ **Allow** base units in any order **<u>Examiner's Comments</u>** This question was done correctly by around half of the candidates. The most common method was to use an equation for energy or work to give the base units of the joule. From this, multiplying it by s would lead to the correct response. Most candidates used $KE = \frac{1}{2} mv^2$ to determine the base units of the joule directly,

					although others used work done = force × distance and force = mass × acceleration. Encouragingly, there were relatively few arithmetic errors even with the negative indices. Some candidates got into difficulties attempting to use the given equation and struggled with the volt, attempting to use *V* = *IR* in a variety of ways. A very common error was to give the units simply as Js, often using *h* = *Eλ/c* to show [J × m / ms^{-1}] gives J s. There was a clear misconception (see below) about what constitutes a base unit. **Misconception** Candidates are reminded that base units are kg, m, s, A, K and mol. Other units are derived units.
			Total	**2**	
29		i	π (rad)	B1	**Allow** 3.14 or 3.1 (rad) **Do not allow** answer in degrees **<u>Examiner's Comments</u>** The first question can generally be expected to be accessible to most candidates and many were able to gain a mark on this. Common errors included π/2 and giving responses in terms of wavelengths. Although there is no requirement to show working for this question, many candidates converted from complete cycles (using wavelengths or 360°) to help them convert to radians.
		ii	− 5.0 (cm)	B1	**Allow** 1 SF. **Must** see negative sign. **<u>Examiner's Comments</u>** This proved to be a challenging question; it appears many candidates were unable to appreciate the progressive nature of the wave on a displacement-distance graph.

					By far the most common response was 0, where it is likely the candidates ignored the inclusion of time and simply gave the displacement at 1.5cm.
			Total	**2**	
30		i	$\Delta p = 0.10 \times 1000 \times 9.81$ $\Delta p = 980$ (Pa)	C1 A1	**Allow** 1 mark for 490 Pa; 5.0 cm used **<u>Examiner's Comments</u>** Most candidates thought that the height difference here was 0.05 m, because that is the difference between the final liquid level and the undisturbed level. The correct approach is to look at the difference between the liquid levels once the liquid has stopped moving.
		ii	**1** $\omega^2 = \frac{2\rho g A}{m}$ **or ω^2** = 37.7 (rad^2 s^{-1}) $\omega = 6.1$ $T = \frac{2\pi}{6.1}$ $T = 1.02$ (s) **2** Oscillation is isochronous starting from (0,5) Correct value(s) on the horizontal axis At least 2 oscillations shown **and** amplitude is decreasing **3** The (driving) frequency is close to the natural frequency (of the system) / resonance will occur (Level of) water will oscillate with large amplitude	C1 C1 C1 A0 B1 B1 B1 B1 B1	**NOT** $\omega = 37.7$ **Alternative route**: • Substitution of expression for omega • Re-arrangement to make T subject • Evidence of evaluation to T = 1.02 (s) Period same by eye. **Note** scale must be linear and increasing Amplitude of 2nd oscillation smaller by eye. **Allow** a description of consequence such as water leaving the tube or being unable to measure the height of liquid **<u>Examiner's Comments</u>** Very few candidates made the link that the gas pressure oscillating would cause a periodic force and so this would become a resonant system.

					The best way to describe a resonating system in this context is that the amplitude of vibrations becomes significantly larger.
			Total	**10**	
31			Working that leads to $t = \frac{15 \times 10^6}{280 \times 10^3} = 54$ (s)	B1	**Allow** KE = t × P approach **<u>Examiner's Comments</u>** This was completed well. The mark was lost by those, generally, that did not round their answer correctly.
			Total	**1**	
32		i	p.d across wire = 14.4 − 12.0 = (2.4 V) resistance of wire $\frac{2.4}{3.0}$ (= 0.80Ω) $0.80 = \frac{\rho \times 25.0}{0.54 \times 10^{-6}}$ ρ = 1.7 xd7; 10^{-8} (Ω m)	C1 C1 C1 A1	**ECF** R = 2.8Ω (V = 8.4 V) to give *ρ* = 6.0 × 10^{-8} (Ω m) for 3 marks **<u>Examiner's Comments</u>** Candidates did not perform well on this question as they did not understand what the question was asking candidates to calculate. The skill and understanding with this question were to first determine that the p.d. was shared across the two lamps and the metal wire which most candidates did not do and apply it to calculate a value of resistance of the metal wire. Candidates were able to select and carry out a correct calculation using *R* = *ρ L*/*A* which demonstrated that they understood a value for resistance was required for the calculation but many used an incorrect value of *R*. Many candidates would calculate the resistance of the metal wire as *R* = 6.0 V / 3.0 A = 2 Ω (the resistance of one of the lamps) and would also not correctly convert the cross-sectional area into m^2. **Misconception** Candidates did not fully read the question that the resistivity of the metal wire **only** was to be calculated

					and that to calculate the resistivity correctly they had to determine the p.d. across the metal wire (p.d. across the wire = 14.4 V – (2 × 6.0 V)). Conversion error as candidates did not convert mm^2 to m^2 for the cross-sectional area.
		ii	($I = Anev$) $3.0 = 0.54 \times 10^{-6} \times 1.60 \times 10^{-19} \times 8.5 \times 10^{28} \times v$ $v = 4.1 \times 10^{-4}$ ($m\ s^{-1}$)	C1 A1	Do not penalise the same **POT** error in 0.54 mm^2 from **(c)(i)** again **Examiner's Comments** Most candidates were given at least 1 mark with half the candidates correctly calculating the drift velocity using the formula $I = Anev$. Less successful responses did not select the correct formula and some candidates had an incorrect or absent conversion of the cross-sectional area to m^2.
			Total	**6**	
33	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 **Examiner's Comments** 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		$s = ½\ gt^2$ $120 = ½ \times 9.81 \times t^2$ $t = 4.9$ (s)	C1 C1 A1	**Allow** 4.95, **not** 5.0 **Examiner's Comments** 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**	
34		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	**4**	
35			Add (a range of) loads/force/weights to the spring **and** determine the compression (for each load) Plot a graph for force against compression **and** gradient is the force constant	B1 B1	**Allow** extension for compression throughout **Allow** W = mg **Not** length for compression **Allow** force constant = $\frac{\text{force}}{\text{compression}}$ and k = F/x (k must be subject) **<u>Examiner's Comments</u>** Most candidates accessed this question and were given 1 mark for either describing a method to measure the compression (extension) of a spring or using these measurements to determine the spring constant either from the gradient of a force–extension graph or manipulation of $F = kx$. Candidates often were not given the first marking point as even though they described a correct practical procedure in adding masses they did not qualify this by multiplying the mass by *g* to obtain the weight compressing the spring as it is this quantity along with the compression that is used to verify the force constant. Also, candidates did not always describe their method that could suitably be carried out in the lab as they described adding the 'clown' or a 'person' to the spring and then measuring the compression (extension).
			Total	**2**	
36			C	1	**<u>Examiner's Comments</u>** This question was generally answered well but candidates had to use the charge of an electron to calculate the total charge of the electrons flowing in

					the wire. If candidates missed this step in their working, they weren't able to access the correct value for the current.
			Total	**1**	
37		i	$I = \frac{1100 + 1700}{230}$ or $\frac{1100}{230}$ or 4.78 or $\frac{1700}{230}$ or 7.39 12(.2) (A)	C1 A1	**Examiner's Comments** This question was generally well answered with candidates often demonstrating that current was power divided by potential difference. Some candidates simply worked out the current in each ring but did not state the total current. Some candidates attempted to work out the maximum power using 13 A – this did not answer the question since the question required candidates to show that the maximum current in the cooker was less than 13 A **Assessment for learning** When answering "show" questions, it is essential to demonstrate that the answer matches the question. In this question high scoring candidates often stated that 12.2 A is less than 13 A.
		ii	Cost (= 2.8 × 0.5 × 18) = 25 (p)	A1	**Allow** 25.2 (p) **Examiner's Comments** This question was generally answered well. Where errors were made it was usually in the conversion of minutes to hours or not converting the power in watt to kilowatt.
			Total	**3**	
38	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 **Examiner's Comments** 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 = $\frac{4\pi(8.1\times10^{-3})^3}{3}$ 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	M1 A1	**Allow** 1.10 (ms^{-1}) to 1.30 (ms^{-1}) **<u>Examiner's Comments</u>**

			1.2 (ms^{-1})		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 **Examiner's Comments** 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**	