Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			**A**	1	**<u>Examiner's Comments</u>** For the block to float, its weight (700 x V x g) must equal the weight of water displaced (1000 x k x V x g) where k is the fraction of the block under water. Equating these two expressions gives k as 0.7. The question, however, asks for the percentage of the block **above** the waterline, which is clearly 0.3, making A the correct answer.
			Total	**1**	
2			**C**	1	**<u>Examiner's Comments</u>** Candidates performed well on this question to correctly give that the magnitude of the upthrust of an object in a fluid is the weight of the fluid displaced by the object.
			Total	**1**	
3			**C**	1	**<u>Examiner's Comments</u>** Overall, candidates performed well on this question with many correctly calculating the change in elastic potential energy as 610 J. The most common distractor was answer A, with candidates relating compression to a decrease in the change of elastic potential energy rather than an increase in the store of elastic potential energy. **Misconception** This question highlighted a possible common misconception that when a spring or object is compressed, there is a decrease in the change of elastic potential energy. This is probably as a

					result that a compression results in a decrease in the length of an object which candidates then relate to a decrease in the change in elastic potential energy. Even though an object is compressed the change in potential energy will always be positive as work is done by a force in the same direction as the displacement.
			Total	**1**	
4		i	Calipers Repeat measurements in <u>different</u> / <u>several</u> positions and determine the mean (thickness)	B1 B1	**Allow** micrometer **NOT** rule(r) **Allow** places / points for positions **Allow** a specified number of positions for different **Allow** average for mean **<u>Examiner's Comments</u>** Since the thickness was determined to be 2.83 cm, this was measuring the thickness to the nearest 0.1 mm. Thus, a ruler would not be an appropriate measuring instrument. The majority of the candidates suggested that calipers should be used. The second mark was given for the determination of a mean value. It would be good experimental practice to take measurements of the thickness at different positions across the face of the prism. Often lower scoring candidates omitted this latter point.
		ii	$\frac{1}{2}\times0.600\times0.750\times2.83(\times10^{-2})$ OR 6.3675 ($\times 10^{-3}$) 630 (kg m^{-3})	C1 A1	**Allow** one mark for 6.3 or 6.25 (power of ten) **Allow** one mark for 310 or 313 (incorrect volume) **<u>Examiner's Comments</u>** A significant minority of candidates found calculating the volume of the prism challenging. Some candidates did not allow for changing 'cm' to 'm' for the thickness.
			Total	**4**	

5			$\rho = \frac{m}{V}$ and $V = \frac{4}{3}\pi r^3$ (≈ 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 × 10^{18} (kg/m^3) for star **and** 1.7 × 10^{18} (kg/m^3) for nucleon • r^3/m = 5.0 × 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**	
6	a		pV=nRT mass (or m) = nM Substitution into $\rho = \frac{m}{V}$ for m and V and cancelling n to give $\rho = \frac{pM}{RT}$	M1 M1 M1 A0	Not n=1 Not n=1 **<u>Examiner's Comments</u>** Successful candidates correctly identified the starting point for this question as the ideal gas equation, *pV = nRT.*

					Many candidates took the approach that *n* = 1 which was not sufficient. A more sufficient proof used the idea that the total mass of the gas was *n* × *M,* allowing cancelling of the *n* in the ideal gas equation.
	b	i	$\rho = \frac{100{,}000 \times 0.029}{8.31 \times 293}$ =1.19 kg m^{-3}	M1 A0	Accept R for 8.31, T = 293.1(5) Reject 20 for T. **<u>Examiner's Comments</u>** The vast majority of candidates correctly substituted values into the given formula, also remembering to convert the temperature from celsius into kelvin. Good practice for "show that" questions is to calculate the quantity required to at least one more significant figure in the question. In this example, that would mean evaluating the density to 1.19 kg m^{-3}.
		ii	Mass of air = 1.19 × 12,000 = 14 300 kg Weight of air = mg = 140 000 N	C1 A1	Accept all answers that round to 140 000 N, eg 140210, 141264 **<u>Examiner's Comments</u>** In part (b) (ii), finding the weight was a matter of finding the mass and then finding the weight, all by using data in the question.
		iii	<u>Upthrust</u> = weight of fluid or air displaced Airship in equilibrium/resultant force is 0 (so upthrust = weight of the airship)	B1 B1	Do not accept unqualified "Archimedes' principle" Not water for fluid **<u>Examiner's Comments</u>** Part (b) (iii) required understanding of Archimedes' principle, rather than merely referring to it. Most candidates successfully related the principle to this context, writing about the upthrust being equal to the weight of fluid or air displaced by the gasbag. This is *always* true, regardless of the other forces that may be in play. References to displacement of water at this point were rejected. Fewer candidates completed the explanation by mentioning that the upthrust must be equal to the weight of the gas bag

		iv			because we know that the gas bag is in equilibrium.
		iv	**Two** from • (Greater pressure) would increase the density/mass/weight of the helium • (increased pressure but) no change in volume therefore no more upthrust. • If the volume goes up then the upthrust will increase / ORA • Pressure only needs to be large enough to inflate the gasbag • (increased pressure difference or volume) may cause structural failure • (higher pressure means) more collisions of helium atoms with walls so more leakage of helium	B1 x 2	**Examiner's Comments** Most candidates scored a mark in part (b) (iv) because they referred to some sort of structural failure if the pressure increased. Others delved a bit deeper, correctly stating that an increase in mass without an increase in volume (and hence upthrust) would cause the gas bag to sink. **Misconception** Some candidates confused the ideas of mass and weight. Remember that weight = mass × gravitational field strength. **Misconception** Some candidates suggested that an increase in pressure alone would cause a change in temperature in this question, using the ideal gas equation as supporting evidence. Here, the pressure change has been caused by an increase in the number of moles of gas. As previously mentioned, candidates should take care to think about what is constant in such relationships and what is not.
	c		F = ([delta mass ÷ delta time] x speed =) 7.8 x 45 = 350N	C1 A1	reject 'F=ma = 7.8 x 45' score zero annotate XP **Examiner's Comments** Question 20 parts (c) and (d) group well here. Part (c) is similar in nature to previous questions about rate of change of momentum. We rejected the use of the idea *F=ma* as it is wrong physics, even though the numerical value is the same.
	d		Density or mass per unit time is less so the (rate of) momentum change from the engines is reduced.	B1 B1	**Examiner's Comments** The idea of rate of momentum transfer carries on in part (d). Most candidates correctly assumed that the density of

			There is less drag/resistive force on the airship.		air at high altitudes is much lower than at low altitudes. Many candidates implied that this meant a reduction in drag, which is correct. Far fewer correctly described the reduction of rate of change of momentum, causing less thrust. **Assessment for learning** Candidates should take care to use technical language. In this question, responses that included ideas of 'less air to push' or 'less mass moved per second' are insufficient at A2 Level.
			Total	**14**	
7			C	1	<u>**Examiner's Comments**</u> This question was answered well with most candidates giving the correct answer C by applying the equations $P = F/A$ and $\pi d^2/4$.
			Total	**1**	
8		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 $s^{-1}\left(=\frac{\Delta\theta}{t}\right)=\frac{3\times10^{-6}}{1000\times5\times4200}$ max temp rise $s^{-1} = 1 \times 10^{-13}$ (°C s^{-1})	C1 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** This too was a complex, multi-stage calculation.

				A1	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**	
9		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} **Examiner's Comments** 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**	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**) $F = W - U - R_B$

			• calculation of normal contact force at **B** <u>therefore</u> reaction force (must be) greater on **A**		Centripetal force (= ma = 760 × 5.4 × 10^{-7}) = 4.1 × 10^{-4} (N) Possible **ECF** from **(b)(i)** R_A (= $W - U = (680 \times 8.87) - 980$) = 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	**9**	
10	a	i	(diameter =) $6.4 \times 3.1 \times 10^{16}$ **or** 2.0×10^{17} (m) (volume =) $4/3\ \pi \times (9.9 \times 10^{16})^3$ (volume =) 4.1×10^{51} (m^3)	C1 C1 A0	**Allow** (radius =) $3.2 \times 3.1 \times 10^{16}$ **or** 9.9×10^{16} (m) **<u>Examiner's Comments</u>** Candidates successfully converted the radius from parsecs into metres and from there the volume of the nebula.
		ii	$(E = \frac{3}{2}kT)\ \frac{3}{2} \times 1.38 \times 10^{-23} \times 250$ **or** 5.2×10^{-21} (J) (N =) $1.0 \times 10^{12} \times 4.1 \times 10^{51}$ **or** 4.1×10^{63} ($E_k = 4.1 \times 10^{63} \times 5.2 \times 10^{-21}$) $E_k = 2.1 \times 10^{43}$ (J)	C1 C1 A1	**<u>Examiner's Comments</u>** This brief yet multi-stage question proved relatively challenging. The correct approach here was to find the average kinetic energy of a single particle (using Ek = 3/2 kT) and then multiplying this by the number of particles in the nebula. The number of particles in the nebula was found by multiplying the number density by the volume of the nebula.
	b	i	Mass is proportional to volume **or** diameter^3 **or** radius^3 or $(\frac{6.4}{3})^3$ or $(\frac{3.2}{1.5})^3$ ratio = 9.7	C1 A1	**Allow** attempt at calculating volume of second nebula and comparing volumes directly **Allow** 9.76 (if volume divided by volume of Sun's nebula) **<u>Examiner's Comments</u>** Candidates used several different approaches here. By assuming a similar density, the mass is directly proportional to the volume. Some candidates calculated the volume of

					the Sun's nebula. Others correctly assumed that the volume and hence mass of each nebula was directly proportional to the diameter^3 (or radius^3).
		ii	Fuel (hydrogen) runs out Super red giant star (Mass of core > Chandrasekhar limit /1.4 therefore) supernova neutron star or black hole (formed)	B1 B1 × 3	**Note: incorrect order is CON** **Allow** alternative route: Red giant formed (mass of star< 10 solar masses, therefore) planetary nebula (and) white dwarf formed **<u>Examiner's Comments</u>** Some candidates used the ratio from the previous part of the question to assume that the star from nebula X would eventually become a white dwarf, as suggested in one of the endorsed textbooks. Others used the information in the question, i.e. that the mass of nebula X was far greater than that of the Sun. This meant they were justified in assuming that this particular star would become a supernova. Both approaches were acceptable, provided the candidate chose one route and described it correctly.
			Total	**11**	
11	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

					Examiner's Comments Candidate's answers to this part were either jumbled or grounded in incorrect physics. This question is correctly answered by thinking about a cuboid of air that is 36 m long and has a cross-sectional area equal to that of the shaded side of the tent. That cuboid corresponds to the air that hits the tent in the three second period. The force applied will be equal to the rate of momentum change. This means multiplying the mass of air that hits the tent by the velocity change (i.e. 12 m/s) and then dividing by the time taken for that momentum change.
	b		***Level 3 (5–6 marks)** Clear descriptions **and** explanations, supported by quantitative analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description and some explanation or quantitative analysis **or** Clear explanation **or** Clear description **or** Clear quantitative analysis *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description	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

			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.*		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°) **<u>Examiner's Comments</u>** 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.

					 To withstand windspeed of 40 m s⁻¹ more ropes could be added. This reduces the force acting on each rope increasing the wind speed force ∝ A v² so as the maximum velocity doubles force acting on the tent quadruples. 4 times the number of ropes must be added. Alternatively reduce the area of the tent that comes in contact with the wind. Reduce the width or height of the side so the tent has less area in contact with the air. At 40 m s⁻¹ wind the area must quarter. Alternatively reduce the length of the rope as [illegible] so F ∝ 1/L. This will increase the force the rope can have across it before breaking. The lengths of the rope must quarter. Additional answer space if required You could also increase the thickness of the rope as F ∝ A. A ∝ r² so the area would need to increase by a factor of 4 or the radius must double. 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**	
12		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 **Examiner's Comments** 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** $\omega^2 = 37.7$ (rad^2 s^{-1})	C1	**NOT** $\omega = 37.7$ **Alternative route**:

			$\omega = 6.1$ $T = \frac{2\pi}{6.1}$ T = 1.02 (s) Oscillation is isochronous starting from (0,5) **2** Correct value(s) on the horizontal axis At least 2 oscillations shown **and** amplitude is decreasing The (driving) frequency is close to the natural frequency (of the system) / resonance will occur **3** (Level of) water will oscillate with large amplitude	C1 C1 A0 B1 B1 B1 B1 B1	• 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**	
13	a		$\rho = \frac{169 - 96}{87}$ or $\frac{73}{87}$ $\rho = \frac{0.169 - 0.096}{87 \times 10^{-6}}$ or $\frac{0.073}{87 \times 10^{-6}}$ ρ (= 839) = 840 (kg m^{-3})	C1 M1 A0	**Ignore** power of tens **Note** power of tens must be seen for both mass and volume **<u>Examiner's Comments</u>** Most candidates were able to determine the mass of the oil correctly and divide the mass by the volume. A significant number of candidates did not demonstrate that 73 g was 0.073 kg and that 87 cm3 was 87 × 10^{-6} m^3. More able candidates clearly showed how the cm3 was converted to m^3.
	b		volume = $\frac{4\pi(8.1\times10^{-3})^3}{3}$ or 2.226 × 10^{-6} (m^3) OR 840 × 9.81 × candidate's volume 840 × 9.81 × 2.226 × 10^{-6} or 0.0183	C1	**Ignore** power of tens **<u>Examiner's Comments</u>** Candidates who understood that the

			0.018 (N)	M1 A0	upthrust was equal to the weight of the oil displaced scored well on this question. To score the marks it was necessary to show how the volume of the ball was calculated. Some candidates had difficulties with the powers of ten. Some candidates then went on to use one equation of density × volume × *g* while other candidates calculated the volume, then the density and then the weight. Both these methods were acceptable.
	c	i	Terminal velocity is when the <u>velocity</u> is constant (Terminal) <u>velocity</u> is determined from the gradient when graph is a straight line / constant gradient OR evidence of calculation of gradient of straight section	B1 B1 B1	**Allow** acceleration is zero for velocity is constant Check read-offs are appropriate. **<u>Examiner's Comments</u>** Candidates needed to describe and explain how the terminal velocity was determined from the graph. A good way of answering the question was to state what was meant by terminal velocity, explain how velocity could be determined from the displacement time graph and then state where the velocity was constant. Candidates who were successful demonstrated the gradient calculation of the straight section by substituting numbers into the gradient formula and calculating 1.8 m s^{-1}.
		ii	Tangent drawn at t = 0.2 s extends at least two large squares (0.2 s) in the *x*-direction 1.2 (ms^{-1})	M1 A1	**Allow** 1.10 (ms^{-1}) to 1.30 (ms^{-1}) **<u>Examiner's Comments</u>** High scoring candidates drew a tangent to the line at 0.2 s. **Misconception** The instantaneous velocity from a displacement time graph is equal to the displacement divided by time.

					Assessment for learning Candidates should practice drawing tangents to curves. The tangent should cover as much of the graph paper as possible. **Assessment for learning** Candidates should practice determining the gradient from a graph. Two data points should be selected from the line (not from a data table). The two data points should be easy to read from the graph and as far apart as possible (at least half the length of the straight line). The data points should clearly be substituted in the equation to determine the gradient *m*. $m = \frac{y_2 - y_1}{x_2 - x_1}$ The advantage of this method is that it also allows correctly for both positive and negative gradient graphs. Although the *y*-intercept did not have to be determined in this question, this method also help candidates to easily determine the *y*-intercept by substituting a data point from the graph used in the determination of the gradient, i.e. *y-intercept* = $y_2 - mx_2$ or $y_1 - mx_1$
	d		$\eta = \frac{0.017 \times 9.81 - 0.018}{6\pi \times 8.1 \times 10^{-3} \times 1.8}\left(= \frac{0.14877}{6\pi \times 8.1 \times 10^{-3} \times 1.8}\right)$ 0.54 kg m^{-1} s^{-1} OR N s m^{-2} OR Pa s	C1 A1 B1	**Allow** 0.55 **Note** for power of ten errors 607 or 0.607 or 5.4×10^{-4} scores one mark **<u>Examiner's Comments</u>** This was a challenging question and as a consequence some candidates

					only attempted to determine the unit. Common errors included either not allowing for the powers of ten correctly or not determining *F* as detailed in the question. Candidates also needed to determine the unit of η. A common incorrect unit seen was N s^{-1} m^{-2}. **Assessment for learning** Candidates should practice determining units in base units and checking the homogeneity of equations.
			Total	**12**	