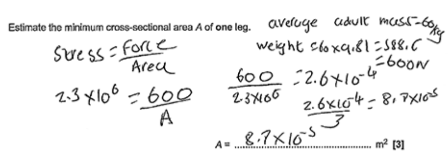
Mark scheme – Forces in Action Density

Question			Answer/Indicative content	Marks	Guidance
1			**C**	**1**	
			Total	**1**	
2			**B**	1	**Examiner's Comments** This question proved particularly straightforward and accessible to nearly all candidates.
			Total	**1**	
3			$(V =)\frac{0.1}{5300}$	M1	**Note** the mark is for substitution of values
			1.89 × 10^{-5} (m^3)	A0	**Examiner's Comments** This mark was scored by most candidates. A power of ten error was usually the cause of losing this mark.
			Total	**1**	
4			C	1	
			Total	**1**	
5			A	1	
			Total	**1**	
6			C	1	
			Total	**1**	
7			D	1	
			Total	**1**	
8			A	1	
			Total	**1**	
9			**D**	1	
			Total	**1**	
10			A	1	
			Total	**1**	
11			D	1	
			Total	**1**	

12			D	1	
			Total	**1**	
13			$p = \rho gh = 1.3 \times 9.81 \times h = 1.0 \times 10^5$	B1	
			h = 7.8 km	B1	
			Total	**2**	
14			volume = $\pi \times 0.035^2 \times 0.085 = 0.000327$	C1	
			$m = \rho V = 1000 \times 0.000327$	C1	
			mass = 0.33 (kg)	A0	
			Total	**2**	
15			Doubling the depth is too much / d is not (directly) proportional to h Qualifying statement using evidence from graph e.g. decreasing gradient, use of numbers to show not proportional, comment about non-zero intercept etc	**B1** **B1**	**Examiner's Comments** Candidates generally had the right idea on this item yet lacked clear enough language to express themselves adequately. Many had some success by referring specifically to data from the graph or the shape of the trendline to support their assertions. Less convincing attempts included those that suggested that there was square root relationship presumably with Newton's equations of motion in mind, without any justification for doing so from the graph. Centres are reminded that situations with changing accelerations are not expected to be solved algebraically at A2 level.
			Total	**2**	
16	a		Use a thermometer (with ± 1 °C) Stir water bath / avoid parallax (for glass thermometer)	**B1** **B1**	**Allow** 'temperature sensor / gauge' **Allow** 'avoid touching sides of water bath with thermometer' **Allow** 'take temperature in several places / times and average' **Allow** idea of 'leave thermometer for long time (to reach thermal equilibrium)' **Not** idea of 'use thermometer with finer resolution' **Examiner's Comments** A large majority included a correct measuring device, such as a thermometer. Significantly fewer described a technique for accurate measurements such as stirring the water or taking the temperature at several points and calculating a mean temperature.
	b	i	Smaller (spacing between) divisions / increments (AW)	**B1**	**Ignore** any reference to accuracy or precision **Allow** 'less uncertainty' **Allow** better or smaller or greater or higher resolution **Examiner's Comments** Approximately half of the candidature made a correct comment

					regarding resolution or that the smaller intervals on the psi scale made it a sensible choice of scale.
		ii	*p* = 37.0 × 4.448 / (1000 × 0.0254^2) 255 (kPa) uncertainty = 3 (kPa)	**B1** **B1**	**Allow** clearly identified correct answer in table or in working area. Must be 3sf Must be 1sf **Allow** 255.1 ± 3.4 scores mark 1 **Examiner's Comments** The vast majority of candidates correctly calculated the pressure in kPa and stated that the absolute uncertainty was 3 kPa. A very small number of responses were rounded inappropriately.
	c	i	Point plotted at (44, 255)	**B1**	ECF from **(b)(ii)** Plot to with ± half a small square **Ignore** checking error bars **Examiner's Comments** Most candidates correctly plotted the point with error bars. In this instance during marking Examiners were instructed to ignore the error bars as they were too difficult to view when scanned.
		ii	**Level 3 (5–6 marks)** Clear explanation, description **and** determination *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 explanation, description **and** determination Or Some explanation and clear determination *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 explanation or description or determination *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks**	**B1 × 6**	**Indicative scientific points may include:** **Explanation and Description** • Absolute zero is the minimum possible temperature / at absolute zero KE is zero • At absolute zero *p* is zero • At absolute zero, the internal energy is minimum (allow 0) • Absolute zero should be (about) −273 <u>°C</u> • Reference to $pV = nRT$ or $pV = NkT$ or $p \propto T$ • A graph of *p* against θ is a straight line / straight line drawn on graph • Intercept of straight line with *x*-axis or θ-axis is absolute zero calculated by using y= mx + c **Determination** • Gradient in the range 0.7 to 0.9 (kPa K^{-1}) • $y = mx + c$ used to determine the intercept *c* or absolute zero

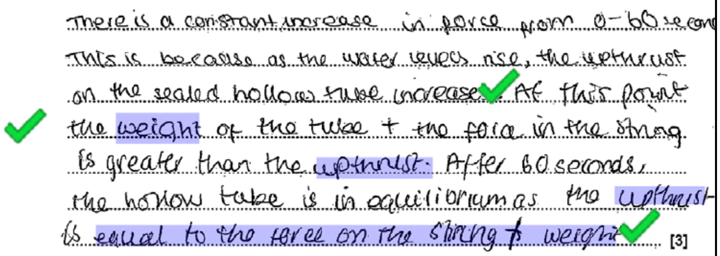
			No response or no response worthy of credit.		• Absolute zero in the range −320 °C to −240 °C Use only L1, L2 and L3 in RM Assessor. **Examiner's Comments** It was clear that the majority of candidates had either performed this experiment themselves or had otherwise seen it before. The concept of absolute zero was very successfully described and many knew that an extrapolation or calculation involving the equation of a straight line was required to find absolute zero as the x-intercept of the straight line. Common errors included mis-calculating the gradient, inability to rearrange the equation or inappropriate conversion to kelvin. Re-plotting the graph was not required and merely wasted time for little reward.
	d		Draw the worst fit line (through all the error bars) (AW). Determine the new value for absolute zero and find the difference between the value in **(c)(ii)** and this new intercept. (AW)	**B1** **B1**	**Examiner's Comments** Many candidates realised that drawing a line of worst fit was sensible. Far fewer were clear that using the line of worst fit to find a new x-intercept, leading to a spread in values for absolute zero was the correct procedure. Many incorrectly suggested finding the difference in gradients, or percentage differences in gradients.
	e		Cooling gas value of absolute zero is lower than **(c)(ii)** (Whilst cooling, the) temperature of gas lags behind the temperature of water (AW, ORA) Graph is shifted to the left Stir water / wait for temperatures to be the same / attempt at measuring temperature of gas directly (AW)	**B1** **B1** **B1** **B1**	**Allow:** gradient is too shallow **Allow:** p measured is higher than expected for incorrect measurement of T (so affects the graph) (AW, ORA) **Not** insulation of water bath **Not** heat losses **Examiner's Comments** The first mark for this item was intended to be for a straightforward comparison that the repeated experiment yielded a lower value than that from part **c(ii)**. Many candidates calculated a percentage difference yet did not refer to the direction of difference. Some candidates successfully suggested that the water would always be cooler than the gas and so the thermometer reading would be systematically lower than the true temperature of the gas. Rather fewer discussed that the pressure reading would therefore be higher than it should be for the thermometer reading. Very few candidates linked this idea to the effect on the graph,

					namely that the points would all be shifted to the left, causing a lower x-intercept or a less steep line of best fit. There were three acceptable experimental approaches to avoid this systematic error. Stirring the water and waiting until the gas and water equilibrated would have reduced the effects of the rapid cooling. A sensible approach employed by some candidates was to take the temperature of the gas directly using a thermometer or temperature inside the flask.
			Total	**18**	
17			(Mass of adult =) 50 kg to 150 kg or W = 500N to 1500 N $\text{Area} = \frac{\text{weight}}{2.3 \times 10^{n}}$ $\text{Area} = \frac{1}{3} \times \frac{\text{weight}}{2.3 \times 10^{6}} = \text{value for area (m}^2\text{)}$	B1 C1 A1	**Allow** use of 10 for *g* (since estimate) **Allow ECF** for incorrect weight **Ignore** POT **Allow** one significant figure **<u>Examiner's Comments</u>** A good proportion of the candidates scored full marks on this question. Some candidates found the total area rather than the area of one leg. A few candidates assumed that the stool had four legs. This question required candidates to estimate the mass or weight of an adult. In general, in this type of question a more generous mass is sensible. Candidates who did well on this question started by stating the mass (or weight) of an adult. Examiners allowed a mass between 50 kg and 150 kg. Candidates then often worked out the total area before working out the area of one of the legs. Some candidates did not correctly understand that 2.3 MPa was equal to 2.3 × 10^6 Pa. Some candidates incorrectly divided the stress by three. **Exemplar 4**  Estimate the minimum cross-sectional area *A* of one leg. average adult mass = 60kg weight = 60×9.81 = 588.6 = 600N Stress = Force / Area 2.3×10^6 = 600 / A 600 / 2.3×10^6 = 2.6×10^-4 2.6×10^-4 / 3 = 8.7×10^-5 A = 8.7×10^-5 m² [3] This candidate has clearly identified the average weight of an adult and then indicated how the weight of the adult is determined. The candidate has then clearly stated the equation for stress and shown their working for full marks. **AfL**

					Candidates should be encouraged to practise making estimates of physical quantities.
			Total	**3**	
18	a		pV = constant (or $p_1V_1 = p_2V_2$) $p_{final} = 2.4 \times 10^5 \times 1.2/1.5$ $= 1.9(2) \times 10^5$ (Pa)	C1 C1 A1	Alternative method: $p = nRT/V$ (p must be the subject) **Allow** use of $p = NkT/V$ (with $N = 7.2 \times 10^{22}$ and $k = 1.38 \times 10^{-23}$) Substitute $p = 0.12 \times 8.31 \times 290 / 1.5 \times 10^{-3}$ ECF from 1a for incorrect n and/or T $p = 1.9(3) \times 10^5$ (Pa) **Examiner's Comments** Questions 1(a) and 1(b) took the ideal gas equation and applied it to an unfamiliar situation, that of a toy rocket. Most candidates answered these questions well, remembering to convert the temperature from 17°C to 290K.
	b	i	$\Delta p = (2.4 – 1.0) - 10^5 = 1.4 \times 10^5$ (Pa) upwards force ($= \Delta pA$) $= (2.4 – 1.0) \times 10^5 \times 1.1 \times 10^{-4} = 15$ (N)	C1 C1 A0	Alternative method: Downwards force (from trapped air) $= pA = 2.4 \times 10^5 \times 1.1 \times 10^{-4} = 26.4$ (N) **and** upwards force (from atmosphere) $= pA = 1.0 \times 10^5 \times 1.1 \times 10^{-4} = 11.0$ (N) So total upwards force = 26.4 – 11.0 = 15.4 (N) **Ignore** any attempt to calculate weight **Special case: Allow** 1/2 for the use of $\Delta p = 2.4 \times 10^5$ (Pa) giving upwards force = 26.4 (N) **Examiner's Comments** Most candidates realised that a difference in air pressure between the inside and outside of the bottle would force the water downwards, producing an upwards force on the bottle which could be calculated using p = F/A.
		ii	$m = 0.3 + 0.05$ (= 0.35) (kg) (Resultant force = upwards force – $W = ma$) $15.4 – (0.35 \times 9.81) = 0.35a$ **or** $a = 12/0.35$ $a = 34$ (m s^{-2})	C1 C1 A1	$0.050 + (10^3 \times 0.3 \times 10^{-3})$ Alternative approach: $a = (15.4/m) - g$ ECF for incorrect value of m **No** ECF ci (since we are told that upwards force = 15(.4)(N)) Upwards force = 15 (N) gives a = 33 (m s^{-2}) **Examiner's Comments** This question, although a simple F = ma problem, challenged many candidates. **Exemplar 1**

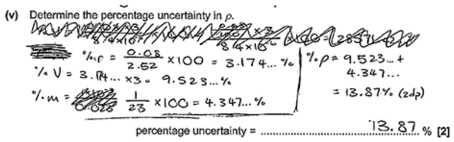
					(ii) Hence calculate the initial vertical acceleration of the rocket. $\rho = \frac{m}{V}$ $m = \rho V = 1\times10^3 \times 0.3\times10^{-3}$ $= 0.3$ $F = ma$ $a = F/m = \frac{15.4}{0.3+0.05} = 44\ ms^{-2}$ initial acceleration = 44 ms⁻² [3] Exemplar 1 shows the most common incorrect response. The correct value for mass (m = 0.35kg) has been used, but the value for the upwards force (15.4N) rather than the resultant force (15.4 – mg) has been used for F.
			Total	**8**	
19	a		pV/T = constant	B1	
			$(1.0 \times 10^5 V)/290 = (1.0 \times 10^3 \times 1.0 \times 10^6)/230$	B1	
			$V = 1.26 \times 10^4$ (m³)	B1	
	b	i	$n = pV/RT = 1.0 \times 10^5 \times 1.26 \times 10^4/(8.31 \times 290)$	B1	**ecf**
		i	$n = 5.2 \times 10^5$	B1	**allow** 5.4×10^5 using 1.3×10^4
		ii	$4.0 \times 10^{-3} \times 5.2 \times 10^5 = 2.1 \times 10^3$ (kg)	B1	**ecf (i)**
	c		(internal energy ∝ T) E = 1900 × 230/290 = 1500 (MJ)	B1	
	d		$U = \rho Vg = 1.3 \times 1.26 \times 10^4 \times 9.81 = 1.61 \times 10^5$	C1	**or** $1.3 \times 1.3 \times 10^4 \times 9.81 =$
			Ma = U − Mg	C1	1.66×10^5
			$27\ M = 1.6 \times 10^5 - Mg$ giving $M = 4.3 \times 10^3$ kg	A1	$M = 4.6 \times 10^3$ kg
			Total	**10**	
20			Use of $M = gr^2 / G$ (accept any subject)	C1	Calculation using g = 1.72 at radius of 15300 km Possible ecf from **(b)(i)**
			Density = $3g / 4\pi rG = 3 \times 9.81/4\pi \times 6.4 \times 10^6 \times 6.67 \times 10^{-11}$	C1	Density = $\frac{3 \times 1.72 \times (1.53 \times 10^7)^2}{4\pi \times (6.4 \times 10^6)^3 \times 6.67 \times 10^{-11}}$
			$= 5.49 \times 10^3$ (kg m⁻³)	A1	$= 5.50 \times 10^3$ kg m⁻³
			Total	**3**	
21					**Ignore** POT
			$\pi \times \frac{(32\times10^{-3})^2}{4} \times 100 \times 10^{-3}$ or 8.04×10^{-5}	C1	
					8881 2200 scores two marks
			$\frac{7.0}{9.81}$ or 0.714	C1	
			8900 (kg m⁻³)	A1	<u>**Examiner's Comments**</u> In part (a), most candidates answered this well although a significant minority confused the calculation of the volume.

					Answers such as 2√5 did not score in (b)(i); it is expected that decimal fractions should be used. In (b)(ii) high achieving candidates labelled the forces and correctly indicated the direction of the forces. Some candidates omitted to use the scale for their final response. In part (c), many candidates were confused in determining which forces and distances should be used.
			Total	**3**	
22			W of tube = upthrust (caused by submerged length) = A(0.30 − l) ρg	B1	Archimedes principle expressed in some form.
			W = 0.5 × 9.8 = 4.9 = π(2.5 × 10^{-2})^2 × (0.3 − l) × 1.0 × 10^3 × 9.8 = 19.2 (0.30 − l)	C1	
			0.30 – l = 0.255 giving l = 0.045 m = 45 (mm).	A1	
			Total	**3**	
23			Weight (of tube), <u>upthrust</u> (and tension / *F* are the forces acting on the tube) (For *t* < 60 s) the <u>upthrust</u> (on the tube) increases <u>One</u> detail point from: • <u>Upthrust</u> **increases** because <u>weight</u> of water displaced increases (up to 60s) **or** <u>upthrust</u> is constant (after 60s) because <u>weight</u> of water displaced is constant • Constant gradient (before 60 s) because upthrust **or** volume (of water displaced) **or** mass (of water displaced) **or** weight (of water displaced) increases at a constant <u>rate</u> • (After *t* = 60 s / eventually / finally the) upthrust is constant because tube is (fully) submerged / container is full (of water) • *F* = upthrust − weight / *F* = *U* − *W* (Any subject)	**B1** **B1** **B1**	**Allow** 'buoyancy <u>force</u>' for upthrust throughout, but not just 'buoyancy' **Not** 'mass' or 'volume' of water displaced **Not** upthrust = weight of fluid / water displaced **Allow** 'no more water is displaced after 60 (s) because tube is (fully) submerged' AW <u>**Examiner's Comments**</u> This question required understanding of upthrust and Archimedes principle. Many candidates gave explanation without mentioning any of the forces acting on the tube. Those candidates who read and focussed on the requirements of the question did better, but there were too many misconceptions and missed opportunities. The most common missed opportunities and errors were: • Not mentioning any of the two of the forces from the list of three (upthrust, tension and weight) • Stating Archimedes principle without reference to this specific question

					• Confusing mass and weight in the description of upthrust • Confusing the tension in the string with upthrust **key** **Misconception** **Exemplar 8**  There is a constant increase in force from 0-60 seconds. This is because as the water levels rise, the upthrust on the sealed hollow tube increase. At this point the weight of the tube + the force in the string is greater than the upthrust. After 60 seconds, the hollow tube is in equilibrium as the upthrust is equal to the force on the string + weight [3] This exemplar illustrates how correct use of technical language can score full marks. Here the marks were credited for • Identifying a minimum of two forces acting on the tube (weight and upthrust) ii • Mentioning that upthrust increases as the water level rises ii • Explanation that upthrust is equal to the force on the string (tension) and weight ii (The last mark was the toughest mark to gain, so this candidate has shown good understanding of this difficult topic.)
			Total	**3**	
24	a	i	$\pi \times \frac{(2.9\times10^{-2})^2}{4}$ or $\pi \times (1.45\times10^{-2})^2$ 6.605 × 10^{-4} m^2 ≈ 6.6 × 10^{-4}	M1 A0	
		ii	V = 6.6 × 10^{-4} × 12.0 or 7.92 × 10^{-5} (m^3) m = 400 × 7.92 × 10^{-5} or 0.03168 kg W = 0.31 (N)	C1 C1 A1	**Ignore** POT
	b		$V = \frac{0.31}{1000\times9.81}$ or 3.16×10^{-5} $y = \frac{3.16\times10^{-5}}{6.6\times10^{-4}}$ y = 0.048 (m)	C1 C1 A1	Mass of water displaced = $\frac{0.31}{9.81} = 0.316$ $y = \frac{0.316}{1000\times6.6\times10^{-4}}$
	c		y = 0.053 m Same weight / mass displaced of oil	B1 B1	

			Smaller density implies larger volume of oil displaced *y* is larger OR *y a* 1/p	B1 B1	
			Total	**11**	
2 5		i	The upthrust (on an object in a fluid) is equal to the <u>weight</u> of fluid (it displaces)	B1	**Note** 'fluid' or 'liquid' must be mentioned at least once. **Allow** a named fluid, e.g. water
		ii	($p = h\rho g$) $1.9 \times 10^3 = 0.15 \times \rho \times 9.81$ $\rho = 1.3 \times 10^3$ (kg m^{-3})	C1 A1	
			Total	**3**	
2 6	a	i	(Vernier) Calliper or micrometer (screw gauge)	B1	**Not** rule(r) <u>**Examiner's Comments**</u> This question was well answered with most candidates stating either Vernier calliper or a micrometer screw gauge.
		ii	2.52 ± 0.08	B1 B1	**Allow** (2.52-2.43 =) 0.09 or (2.59-2.52 =) 0.07 <u>**Examiner's Comments**</u> Most candidates correctly calculated the mean diameter of the ball. A much smaller proportion of the candidates determined the absolute uncertainty in the diameter correctly. In this case, the range was 0.16 cm, so the absolute uncertainty was 0.08 cm. Examiners allowed the maximum value minus average value or average value minus minimum value. **AfL** When measurements are repeated the absolute uncertainty is given by: Absolute uncertainty = ½ x range = ½ x (maximum value – minimum value)
		iii	Volume = $\frac{4}{3} \times \pi \times (1.26 \times 10^{-2})^3$ $= 8.379 \times 10^{-6}$ 8.4×10^{-6} m^2	M1 A0	$\frac{1}{6} \times \pi \times (2.52 \times 10^{-2})^3$ or $\frac{4}{3} \times \pi \times \left(\frac{2.52 \times 10^{-2}}{2}\right)^3$ <u>**Examiner's Comments**</u>

					This was another “show” question. Many candidates find dealing with standard form terms in their calculator difficult. Candidates needed to show clearly the conversion of the diameter in cm to radius in m. There was some evidence of candidate just adding a 10^{-6} power to their answer.
		iv	$\frac{0.023}{8.4\times10^{-6}}$ or 2738 2700 (kg m^{-3}) or 2.7 x 103 (kg m^{-3})	C1 A1	**Note** 2745 if using calculator value from **(iii)** **Note** must be two significant figures **Allow** one mark for 2.7 x 106 (kg m^{-3}) **<u>Examiner’s Comments</u>** In this question, most candidates were able to determine the density correctly although, a few candidates did not change the mass in gram to kilogram. A large number of candidates did not give their answer to an appropriate number of significant figures; the common answer being 2738 kg m^{-3}. In this case, the mass was given to two significant figures and the volume was calculated from data give to three significant figures, thus the final answer should be given to the same number of significant figures as the least significant data, i.e. to two significant figures.
		v	$\frac{1}{23}$ or $\frac{0.08}{2.52}$ or $\frac{0.24}{2.52}$ or 4.3% or 3.2% or 9.5% 14% (13.8%)	C1 A1	**Allow ECF** from **(ii)** – 3.6% or 10.7% for Δd = 0.09 **Allow** maximum/minimum methods **Note** 13% for Δd = 0.07 or 15% for Δd = 0.09 [ECF 5.5% for Δd = 0.01] **<u>Examiner’s Comments</u>** The majority of candidates were able to determine the percentage uncertainty in the mass correctly. Fewer candidates realised that the percentage uncertainty in the volume was three times the percentage uncertainty in the diameter. Candidates who did well, clearly showed their working. Some candidates tried to use a maximum/minimum method. This was a more complex method and more difficult for candidates to gain the correct answer. In this case, the maximum mass needed to be divided by the minimum volume or the minimum mass needed to be divided by the maximum volume **AfL** How to use percentage uncertainties. **Exemplar 5**

					 (v) Determine the percentage uncertainty in ρ. $\%r = \frac{0.08}{2.52} \times 100 = 3.174...\%$ $\%V = 3.174... \times 3 = 9.523...\%$ $\%m = \frac{1}{23} \times 100 = 4.347...\%$ $\%\rho = 9.523... + 4.347... = 13.87\%$ (2dp) percentage uncertainty = 13.87 % [2] The candidate's answer is logically structured showing the percentage uncertainty in the mass and volume and then adding them together so gaining both marks. An answer of 14% would have been acceptable.
	b		Extension = 0.096 – 0.078 or 0.018 m Weight = 0.023 x 9.81 or 0.22563 13 (N m^{-1})	C1 C1 A1	**Allow ECF** for incorrect mass conversion from **(iv)** **Allow** 12.6 (N m^{-1}) or 12.5 (N m^{-1}) **Examiner's Comments** The majority of the candidates clearly showed their working and calculated the force constant correctly. Some incorrectly used the energy stored equation.
	c	i	Apparent weight = 0.01 x 13 (= 0.13 N) (Upthrust = 0.226 - 0.13) = 0.10 (N)	C1 A1	**Allow ECF** from **(b)** **Allow** 0.008 x 12.5 **Allow** 0.1 (N) (1sf) **Examiner's Comments** In this question, many candidates calculated the apparent weight and then incorrectly assumed that this was the upthrust. Other errors included using the incorrect values for length to determine the extension. Some candidates correctly determined the upthrust by determining the change in extension.
		ii	$\rho = \frac{0.10}{9.81 \times 8.4 \times 10^{-6}}$ 1200 (kg m^{-3})	C1 A1	**Allow ECF** from **(i)** **Examiner's Comments** Candidates generally found this last question challenging. Some candidates who did less well, attempted to use the equation for liquid pressure. Candidates who did well again clearly showed their reasoning.
			Total	**15**	
27		i	volume = $7.0 \times 10^{-2} \times \pi \times (0.5 \times 10^{-2})^2$ or 5.5×10^{-6} (m^3) $p = 5.0 \times 10^{-3} / (7.0 \times 10^{-2} \times \pi \times (0.5 \times 10^{-2})^2)$ density = 910 (kg m^{-3})	**C1** **A1**	No ecf for incorrect volume. Answer to 3 s.f. is 909 **Allow** 1 mark for 230 (r = 1.0×10^{-2} m used) **Examiner's Comments** Examiners were delighted to see that nearly all candidates could successfully calculate the density of the wood block, although some candidates missed that the diameter rather than the radius

					was provided. A small number neglected to check the formula for the volume of a cylinder, which was provided in the Data, Formulae and Relationships booklet.
		ii	The density (of wood is) similar to human (AW) Less than density of water / it needs to float / otherwise it will sink	**B1** **B1**	**Allow** 'greater upthrust than weight when fully submerged' **Examiner's Comments** 18ai was intended as a guide to the candidates that the wood's density was relevant. Many candidates successfully saw the link between the wood's density and that of the diver, yet fewer realised the consequence of this i.e. that the wood would reach a deepest point in the water and then float back to the surface. Predominantly, candidates sought to describe a second physical property in ways beyond the scope of the specification, such as impermeability to water and shape retention.
			Total	**4**	
2 8	a	i	The upthrust is equal to the weight of the fluid / liquid / water / air displaced	B1	**Examiner's Comments** About one in every seven candidates omitted this question and only about a third of the candidates gave an acceptable statement of Archimedes' principle. It was clear from the answers that most candidates had not revised this topic. There were countless guesses, with many famous laws incorrectly linked to this principle.
		ii	(upthrust =) 9.0 − 7.8 (N) or (mass =) 9.0/9.8(1)	C1	**Note**: This C1 mark for determining the upthrust (1.2 N) or the mass (0.92 kg) of the cylinder
		ii	$V = \frac{(1.2/9.81)}{1000}$ or $V = 1.2(23) \times 10^{-4}$ (m^3 $\rho = \frac{(9.0/9.81)}{1.223 \times 10^{-4}}$	C1	
		ii	$\rho = 7.5 \times 10^3$ (kg m^{-3})	A1	**Allow** full credit for alternative methods, e.g: $\rho = \left(\frac{9.0}{1.2}\right) \times 1000 = 7.5 \times 10^3$ (kg m^{-3}) **Examiner's Comments** This proved to be a discriminating question that favoured those candidates who could apply, rather than just rote learn, Archimedes' principle. About a third of the candidates scored nothing in this question but many candidates did score one mark for determining the upthrust of 1.2 N. Most candidates stopped at this point. The top-end candidates correctly determined the volume of the displaced water and then went on to successfully calculate the density of the metal.
	b				**Note**: In this question any symbols used must be defined or previously mentioned **Note**: Allow full credit for alternative methods, e.g. using the equation pressure = height × density × *g*
			pressure = $\frac{\text{weight (of cylinder)}}{\text{area}}$	B1	**Allow** force / area

			Weight (of cylinder) determined using a newtonmeter or Measure mass (of cylinder) using balance / scale(s) and multiplying by *g* / 9.8(1 m s^{-2})	B1	**Not** 'gravity' for *g*
			Area determined by measuring the diameter with a ruler / vernier callipers / micrometer and then using (area =) π × r^2	B1	**Not** measure radius **Allow** other correct methods
			A sensible suggestion that reduces the % uncertainty: Use micrometer / (vernier) calipers / travelling microscope Use balance / newtonmeter with smaller division (AW)	B1	**Not** 'repeat readings (of diameter etc.)' because this procedure improves the accuracy and not the precision **Allow** balance / newtonmeter with 'high resolution' **Examiner's Comments** The majority of the candidates scored two or more marks for this practical based question. It is good to report that many candidates were familiar with instruments used to measure diameter and mass. Vernier calipers and micrometers were mentioned by some candidates for measuring the diameter of the metal cylinder. Instead of using the equation pressure = force / area, a small number of candidates successfully gained some marks by applying the equation $p = h\rho g$. A small number of candidates confused the terms *weight* and *mass*. Only a very small number of candidates realised that precision was linked to reducing the percentage uncertainty in the final value of the pressure. Answers such as '*Use a micrometer measuring to ± 0.01 mm instead of a ruler marked in mm*' or '*Use a digital balance giving mass to the nearest 0.01 g instead of 1 g*' were awarded the final mark. Most candidates however, confused accuracy with precision and went on to describe how the experiment could be made precise by taking multiple readings of diameter or mass. A significant number of candidates omitted answering the precision part of the question. It is worth reminding candidates that it is important to carefully examine the question before writing their answers.
			Total	**8**	
29		i	$\rho = m/V = m/Av$; so $m = A\rho v$	C1	
		i	$7.5 \times 10^{-5} \times 1000 \times v = 0.070$	A1	
		i	giving $v = 0.93$ (m s^{-1})	A0	
		ii	3.7 (m s^{-1})	A1	Accept 3.72
		iii	$F = \Delta(mv)/\Delta t = 0.070 \times (3.72 - 0.93)$	C1	**ecf (ii)**
		iii	$F = 0.195$ (N)	A1	accept 0.19 or 0.2(0)
		iv	arrow into the shower head perpendicular to its face.	B1	award mark for a reasonable attempt.
			Total	**6**	

30	a	i	Micrometer/(Vernier) caliper Repeat readings (in different directions) <u>and</u> average	B1 B1	**Not** ruler **Examiner's Comments** Most candidates were able to suggest the use of a micrometer or caliper. A significant number of candidates did not state that they would repeat readings in different directions and calculate the mean value.
		ii	$\frac{4}{3}\pi(0.014)^3$ OR 1.15×10^{-5} $m = 650 \times 1.15 \times 10^{-5} = 7.47 \times 10^{-3}$ 0.0075 (kg)	M1 M1 A0	**Allow** $\frac{4}{3}\pi(1.4)^3$ **Note** must see correct POT **Examiner's Comments** Candidates were able to use the formula for a volume of a sphere and rearrange the equation for density. Some candidates were confused with the power of tens. Again, clear working was needed for the award of both marks.
		iii	$1000 \times 1.15 \times 10^{-5} \times 9.81 = 0.11$ N OR $0.0075 \times 9.81 = 0.074$ N $F = 0.11 - 0.074 = 0.037$ (N) OR 9.81 (1000 − 650) or $1.15 \times 10^{-5} \times (1000 - 650)$ $F = 1.15 \times 10^{-5} \times 9.81\ (1000 - 650)$ = 0.039 (N)	C1 A1 C1 A1	**Allow** use of 7.47×10^{-3} kg from **a ii** **Allow** ecf from **a ii** **Examiner's Comments** Candidates found this question difficult. Many candidates gained one mark either for determining the weight of the sphere or for determining the upthrust correctly. Few candidates realised they needed to find the difference between the upthrust and the weight of the sphere.
	b		**Level 3 (5–6 marks)** Clear procedure, measurements **and** 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 procedure, some measurements and some analysis. *There is a line of reasoning presented with some structure. The information*	B1 x6	**Indicative scientific points may include:** **Procedure** • labelled diagram • long tube • method to determine <u>terminal</u> velocity • check for terminal velocity • safety precaution (tray to avoid spills / gloves / clamp tube) • method to remove sphere **Measurements**

			presented is in the most-part relevant and supported by some evidence. **Level 1 (1–2 marks)** Limited procedure and limited measurements **or** limited analysis *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		• measurement of diameter • use micrometer / calliper to measure diameter • averages diameter • measurements to determine *v*, e.g. stopwatch, ruler, light gate connected to timer, detailed use of video camera • repeats experiment for same *r* **Analysis** • $r = d / 2$ • determination of terminal velocity • plot a graph of *v* against r^2 • K = gradient. **Examiner's Comments** This question was the first level of response question on the paper. It involved candidates planning an investigation into the variation of terminal velocity and the radius of a sphere. Candidates were expected to draw a labelled diagram and there were many tubes with elastic bands drawn. To gain the highest marks candidates were expected to explain carefully how they would measure the terminal velocity and to include how they would check that the terminal velocity had been achieved. Candidates were also expected to explain how their results could be used to give to determine the constant K. Good candidates suggested an appropriate graph that should be plotted and explained how K could be determined from the gradient. In general answers were better this year than last year.
			Total	**12**	
3 1		i	weight / *W* / *mg* **and** downward arrow upthrust / *U* **and** upward arrow drag / *D* / friction **and** upward arrow	B1 B1 B1	**Allow** labels used in **(c)(i)** throughout **Ignore** arrow sizes. **Allow** '(water) resistance' for drag **Examiner's Comments** The forces referred to by name in module 3 of the specification are weight, drag, upthrust. tension, normal contact force and friction. Candidates should be aware that the three relevant forces in this example are upthrust, weight and drag (with friction as an acceptable alternative). A wide range of other options were provided by candidates, such as gravity, buoyancy, lift, pressure, impulse and air resistance, none of which were acceptable.
		ii	Resultant force decreases (with time or as cylinder descends) Upthrust remains constant / drag decreases (as speed decreases) / resultant force is upwards / At lowest	B1 B1	**Allow** 'At lowest point, upthrust > weight' **Note:** Any incorrect answer from the list will not score this point

			point, drag is zero At lowest point, resultant force is upwards	 **B1**	 **Not** 'resultant force = 0' **Note:** Resultant force is <u>always</u> upwards' scores B1×2 **Examiner's Comments** Examiners would like to see an improvement in the understanding of the forces acting on objects in motion as this item on resultant forces was not answered well. A large proportion of candidates misunderstood the scenario, believing it to be a terminal velocity problem. This meant that many responses included the notion that the block would speed up and eventually have zero resultant force acting upon it. In this case, that would mean that the block would continue at constant velocity downwards rather than return to the surface. This item prompted the candidates by asking about the resultant force at the lowest point of the motion, which tying in with the ideas in previous parts of the question about density and floatation, should have hinted that the resultant force at the lowest point was upwards. Those candidates that did realise this often contradicted themselves to ensure an upwards resultant at the bottom of the motion. Typically, this was by stating, incorrectly, that the upthrust or the drag increased, at which point only one mark was possible.
			Total	**6**	