Mark scheme – SI Units

Question			Answer/Indicative content	Marks	Guidance
1			B	1	**Examiner's Comments** This was an easy starting question for all the candidates. It was testing knowledge of S.I. units used in a range of topics. The majority of the candidates got the correct answer B. The most popular distractor was D, followed closely by A.
			Total	**1**	
2			A	1	
			Total	**1**	
3			A	1	
			Total	**1**	
4			C	1	**Examiner's Comments** About three quarters of all candidates recognised that the volt is not an S.I. base unit.
			Total	**1**	
5			B	1	
			Total	**1**	
6			B	1	
			Total	**1**	
7			A	1	
			Total	**1**	
8			B	1	
			Total	**1**	
9			D	1	
			Total	**1**	
10			A	1	
			Total	**1**	
11			D	1	
			Total	**1**	

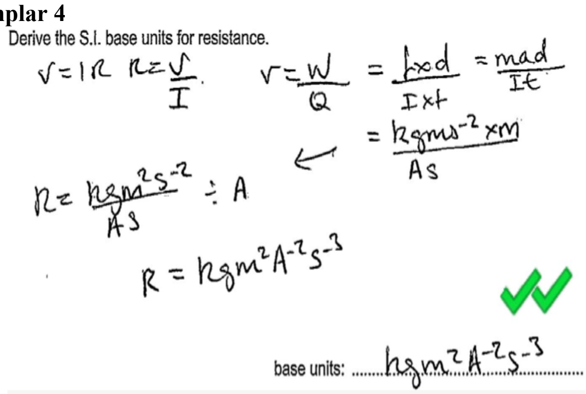
12			B	1	
			Total	**1**	
13			B	1	
			Total	**1**	
14			$\sqrt{\frac{T}{\mu}} \to \sqrt{\frac{\mathbf{kg\,m\,s^{-2}}}{\mathbf{kgm^{-1}}}}$ clearly leading to m s^{-1} Homogeneous because v and $(T/\mu)^{1/2}$ have same units	**M1** **A0**	**Examiner's Comments** The proof for the homogeneity required careful progression and no omission of any key step. About half of the candidates showed sufficient rigour to score the mark. Those who lost the mark, invariably did so because of the poor manipulation of m divided by m^{-1}.
			Total	**1**	
15	a		Any <u>one</u> from: current, temperature, light intensity and amount of substance / matter	**B1**	**Not:** ampere, kelvin, candela and mole **Not** correct quantity with its unit, e.g. current in A or current (A) **Examiner's Comment** Most candidates could not state an unambiguous base quantity. There was no credit for a correctly named quantity accompanied by its S.I. unit, e.g. *'current in ampere'.* Some answers were just wrong; these include *force, charge, energy* and *kelvin.*
	b	i	$R = \frac{\rho L}{A}$ **and** $A = \pi\left(\frac{d}{2}\right)^2$ $R_X = \frac{4\rho L}{\pi d^2}$ and $R_Y = \frac{8\rho L}{\pi d^2}$ Clear steps leading to $R = \frac{12\rho L}{\pi d^2}$	**M1** **A1**	**Examiner's Comment** Most candidates were familiar with the equations $R = \rho L / A$ and $A = \pi d^2/4$. The modal score here was two marks. Most scripts had well-structured answers and demonstrated excellent algebraic skills. A variety of techniques were employed to determine the total resistance of the two resistors in series.
		ii	**1** Ruler / tape measure (for L) **and** micrometer (for d) **2** R = 2.3(4) (Ω)	**B1** **C1** **C1**	**Allow** (vernier / digital) calipers or travelling microscope for micrometer **Allow** other correct methods for getting 2.3 ± 0.1 (Ω) **Allow** 2 or more sf for this C1 mark

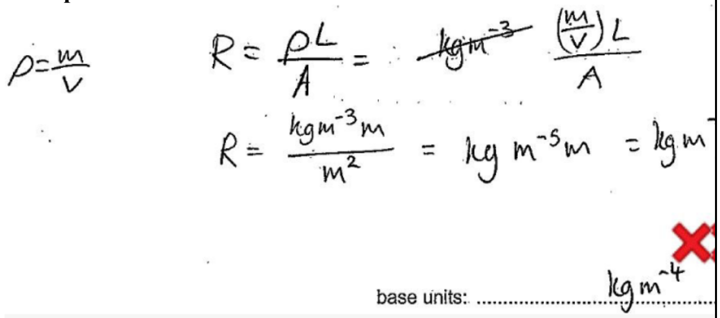
			$\frac{0.1}{9.5}$ or $2\times\frac{0.003}{0.270}$ $\frac{0.1}{9.5}+2\times\frac{0.003}{0.270}$ or 0.0327 or 3.27% absolute uncertainty in R = 0.0327 × 2.34 = 0.077 R = 2.3 ± 0.1 (Ω)	C1 A1 B1	**Note** 0.0105 or 1.05% or 0.0222 or 2.22% scores this mark, allow 2sf or more **Allow:** 2.34 ± 0.08 (Ω) **Note** use of R_X or R_Y instead of R can score the second and third C1 marks only **Allow:** The calculated R is small(er) **because** (the measured) A is large(r) or $R \propto 1/d^2$ **Examiner's Comment** Almost all candidates correctly identified the measuring instrument for L and d. Some answers were spoilt by mentioning both a ruler and a micrometer for measuring the length of the wire. This question produced a range of marks and discriminated well. According to the data shown in the table on page 13, the final value for the resistance R had to be given to 2 significant figures (SF), but an answer to 3 SF was also allowed. Top-end candidates produced flawless answers and quoted R as either 2.3 ± 0.1 Ω or 2.34 ± 0.08 Ω. Some candidates successfully calculated the maximum and the minimum values for R and then the absolute uncertainty from half the range. The most common mistakes being made were: • Omitting the factor of 2 when determining the percentage uncertainty in d^2. • Calculating the resistance of either resistor **X** or resistor **Y.** • Inconsistency between R and its absolute uncertainty, e.g. R = 2.3 ± 0.077 Ω. Some candidates realised that the actual value of R would be *'larger because d was smaller or R* ∝ 1/d^2'. On most scripts, it was difficult to follow if the resistance was the **actual** one or the **calculated** one.
			3 (The actual) R is large(r) **because** (the actual) d is small(er) or (the actual) A is small(er) or $R \propto 1/d^2$		
			Total	**9**	
1 6			C	1	
			Total	**1**	
1 7			power or P: kg m^2 s^{-3}	B1	power = force × distance / time = force × velocity
			Total	**1**	
1 8			A	1	
			Total	**1**	

19			D	1	**Examiner's Comments** The correct response is **D**. It was encouraging to see that a large number of candidates were able to select the correct answer. Although a relatively straightforward calculation, it does involve two unit conversions (mA to A, and hours to seconds), which if not done would generate one of the distractors. Many candidates showed their working here as they would in a structured question and this is always helpful when the calculation involves more than one stage.
			Total	**1**	
20			**A**	1	
			Total	**1**	
21			A	1	
			Total	**1**	
22			**D**	1	
			Total	**1**	
23			B	1	
			Total	**1**	
24			C	1	**Examiner's Comments** Since P = F/A, we need the units of force and area in base units. F = ma, so force has the base units of kg m s^{-2} . Area's unit in base units is m^2. Hence pressure has the base units kg m s^{-1}/m^2 = kg m^{-1} s^{-2}, which is answer C.
			Total	**1**	
25			A	1	
			Total	**1**	
26			A	1	
			Total	**1**	
27			C	1	
			Total	**1**	
28			L → [m] and A → [m^2] **or** L/A → [m^{-1}] kg m^3 s^{-3} A^{-2}	C1 A1	**Allow** $\frac{\text{kg m}^3}{\text{s}^3\ \text{A}^2}$ **or** kg m^3/s^3 A^2

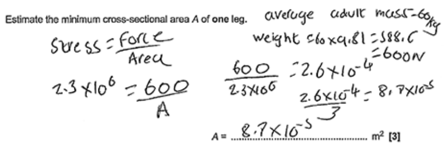
					Examiner's Comments The majority of the candidates effortlessly showed the base units for resistivity to be kg m^3 s^{-3} A^{-2}. The structure from most was immaculate. It was good to see shortcuts being used too. Some candidates went straight to the units for resistivity (Ω m), and then multiplied the units given for resistance multiplied by m. **Misconception** The most common misconception, mainly at the lower end, was that the A in the resistance equation was the unit for current, the ampere A. This led to the incorrect answer kg ms^{-3} A^{-1}
			Total	**2**	
29	a		*F* / *N* — **e / cm** 0 — **0.0** 0.49 — **1.0** 0.98 — **1.8** 1.47 — 2.8 1.96 — 3.6 2.45 — 4.6	B1	**Note** Column heading required and values in table. **Allow** 0 for 0.0 **Not** 1 for 1.0 **Examiner's Comments** A surprisingly number of candidates either did not include the heading in the table or wrote "0.9" or "1" to one significant figure rather than "1.0".
	b		*y*-axis labelled correctly *e* / cm *y*-axis scale is simple and uses at least half the graph paper Data points plotted correctly. Straight line of best fit drawn with a straight edge / ruler	B1 B1 B1 B1	**Allow** extension / cm or *e* (cm) for *e* / cm **Note** axis tick labels must be at least every two large squares (4 cm) **Check** two data points (0.98, 1.8) and (2.45, 4.6) Thickness of each point must be less than half a small square **Not** freehand / wobbly line **Examiner's Comments** The graph was drawn well with most candidates labelling the axis and using a simple scale which covered more than half the y-axis. Occasionally candidates lost a mark because of a miss-plot.
	c		Gradient in the range 1.80 to 1.94 OR 0.0180 to 0.0194	B1	**Allow** 1.8 or 1.9 OR 0.018 or 0.019 **Not** 2 OR 0.02 **Ignore** POT errors **Ignore** significant figures **Examiner's Comments** This question was well answered. It was pleasing to see that the majority of the candidates clearly indicated the points on their line used to determine the gradient.

	d		$k_2 = \frac{1}{\text{gradient}} = \frac{1}{\text{(c)}}$ Correct value for k_2 <u>and</u> correct unit N cm^{-1} or N m^{-1} and given to 2 or 3 significant figures	C1 A1	**Note** expect about 0.55 (N cm^{-1}) or 55 (N m^{-1}) **Note** unit must be with correct power of ten **Examiner's Comments** In this question candidates were required to use the gradient value to determine a value for the spring constant. Many candidates did not realise that the spring constant was the inverse of the gradient value. A common error was determining *k* and then dividing it by two. This question also required candidates to include a suitable unit and give the answer to an appropriate number of significant figures. Some candidates made a power of ten error by not converting centimetres to metres; other candidates either gave the answer to one significant figure or four or five significant figures.
	e		Hooke's law: Extension is (directly) proportional to the load (provided elastic limit not exceeded) Graph is not a <u>straight</u> line <u>passing through the origin</u> so Hooke's law is not obeyed OR Graph is a <u>straight</u> line <u>passing through the origin</u> so Hooke's law is obeyed	B1 B1	**Examiner's Comments** A good number of candidates quoted Hooke's law; candidates should be encouraged to define any symbols used. Many candidates stated that to prove a directly proportional relationship a straight line should be produced but omitted to state that the straight line should pass through the origin.
	f		k_1= 2 × **(d)** or springs in series = k / n $\frac{2}{3}$	C1 A1	**Allow** $F = k_1e = k_2 2e = k_3 3e$ **Note** 2:3 scores one mark **Allow** 0.66, 0.67 **Examiner's Comments** Candidates found this part difficult; it was often omitted and where candidates did attempt it they ended up with the inverse ratio of 1.5.
			Total	**12**	
30			$h \rightarrow$ J s / $\frac{h \rightarrow \text{N m}}{\text{s}}$ / J → kg m^2 s^{-2} base unit = kg m^2 s^{-1}	C1 A1	
			Total	**2**	
31			1.2 × 10^6 = $^1/_2$ × (mass per second) × 8.0^2 mass per s = 3.8 × 10^4 (kg s^{-1})	C1 A1	Answer is 3.75 × 10^4 (kg s^{-1}) to 3sf **Note:** 3.8 × 10n (kg s^{-1}) scores 1 for PoT error. **<u>Examiner's Comments</u>**

					A large majority of candidates got this right. Those that did not usually forgot to square the velocity.
			Total	**2**	
3 2			**D**	1	
			Total	**2**	
3 3			$(R = \frac{V}{I} = \frac{W}{QI}$; $Q = It)$ charge → A s **or** energy → kg m s^{-2} × m **or** kg m^2 s^{-2} (base units) kg m^2 A^{-2} s^{-3}	**C1** **A1**	**Allow** other correct methods **Allow** *Q* or *C* **or** coulomb for 'charge'; *E* **or** *W* **or** joule **or** J **or** work done for 'energy' **Allow** 1 mark for J s^{-1} A^{-2} **Allow** $\frac{\text{kg m}^2}{\text{A}^2\,\text{s}^3}$ **or** kg m^2 /(A^2 s^3) **Not** kg m^2 / A^2 / s^3 **or** kg m^2 / s^3 / A^2 **<u>Examiner's Comments</u>** This was a challenging question, which provided the ideal opportunity for top-end candidates to use a variety of methods to get the correct S.I. base units of kg m^2 A^{-2} s^{-3} for resistance. A significant number of candidates secured 1 mark for a partial answer with either charge → A s, or energy → kg m^2 s^{-2}. The rules for exponents were a bit perplexing for the low-scoring candidates. Many also misunderstood S.I. units. **Exemplar 4**  This exemplar illustrates a flawless answer from a top-end candidate. The equations are clear to see and follow. The units of each physical quantities are clearly identified and the appropriate S.I. units for the quantities have been successfully manipulated to give the correct answer. Compare this with the exemplar below which illustrates a common misconception.

					Exemplar 5  This exemplar illustrates a common error made by some candidates across the ability spectrum. ? The resistivity ρ in the equation for resistance has been mistaken for density (which unfortunately has the same label). There can be no credit for wrong physics. It is vital to know your equations. **Key:** ? **Misconception**
			Total	**2**	
34	a		$\varepsilon = 7.2 \times 10^{-12} \times 1.2 \times 10^{-3} / 4.0 \times 10^{-4}$ permittivity = 2.2×10^{-11} (F m^{-1})	C1 A1	**Allow** any subject **Allow** ε_0 instead of ε **Note** answer to 3 sf is 2.16×10^{-11} (F m^{-1}) **Allow** 1 mark for bald 2.4; relative permittivity calculated **Examiner's Comment** Most candidates effortlessly used the equation $C = \varepsilon A / d$ to determine the permittivity *s* of the insulator between the capacitor plates. Once again, most answers were well-structured and showed good calculator skills. The most common errors were: • Taking the prefix pico (p) to be a factor of 10^{-9}. • Confusing permittivity ε and permittivity of free space ε_0. • Calculating relative permittivity (2.4).
	b	i	capacitance of two capacitors in series = 500 (πF) $C = 1000 + 500$ $C = 1500$ (μF)	C1 A1	**Examiner's Comment** The modal score here was two marks, with most scripts showing excellent understanding of capacitors in combination. Many

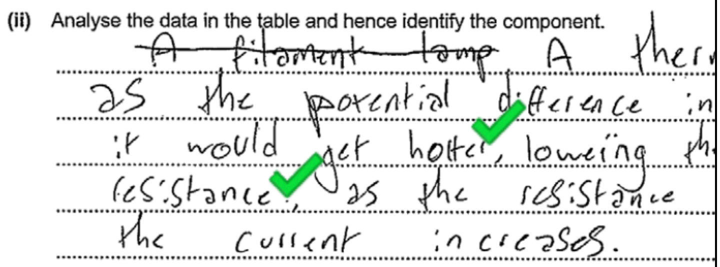
					candidates arrived at the final answer of 1500 μF without much calculation. A small number incorrect swapped the equations for series and parallel combinations and arrived at the incorrect answer of 670 μF.
		ii	$V = 1.5 \times e^{-12/15}$ $V = 0.67$ (V)	C1 A1	Possible ecf from **(i)** **Allow** 1 mark for 0.83 V, $V = 1.5[1 - e^{-12/15}]$ used **Examiner's Comment** Many candidates correctly calculated the time constant of the circuit and then either determined the p.d. across the capacitors (0.83 V) or the resistor (0.67 V) - the latter being the correct answer. The most common mistake was calculating e^{-12115} rather than $1.5 \times e^{-12/15}$. Weaker candidates got nowhere by attempting to use $V = IR$ and $Q = VC$.
			Total	**6**	
35	a		work done = 400 × 0.80 work done = 320 (J)	C1 A1	**Examiner's Comments** This was answered correctly by most candidates; a tiny number did not convert from cm to m correctly.
	b		ratio of speeds = ratio of distances (since same time) **or** ratio = 80 / 2 ratio = 40	C1 A1	**Allow** 40:1 **Allow** 2 marks for ratio 29.4 (assuming p same) **Not** 1:40 for A1 **Examiner's Comments** Unsuccessful candidates tried to employ 'suvat' equations, although many candidates realised that the required ratio was also the ratio of the distances travelled in the same time period. Some credit was given for those candidates that assumed constant pressure and 100% efficiency.
	c		work done = 1200 × 9.81 × 0.02 (= 235.4) efficiency = 235.4 / 320 × 100 efficiency = 74 %	C1 A1	**Note:** Using g =10 N kg^{-1} gives 75%: allow 1 mark max Possible ECF from **(a)** **Note:** 0.74 scores 1 mark **Allow** 2 marks for using 235/320 × 100 = 73% **Allow** use of 9.8 N kg^{-1} gives 73.5% for 2 marks **Allow** 1 mark for 71%, force = (1200g − 400) N used **Allow** 1 mark for 76%, force = (1200g + 400) N used **Examiner's Comments** The majority of candidates successfully calculated the work done on the car and hence the efficiency of the system.
			Total	**6**	
36			(Mass of adult =) 50 kg to 150 kg or W = 500N to 1500 N	B1 C1	**Allow** use of 10 for g (since estimate) **Allow ECF** for incorrect weight

			$\text{Area} = \dfrac{\text{weight}}{2.3 \times 10^{n}}$ $\text{Area} = \dfrac{1}{3} \times \dfrac{\text{weight}}{2.3 \times 10^{6}} = \text{value for area } (\text{m}^2)$	A1	**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 $2.3\times10^6 = \frac{600}{A}$ $\frac{600}{2.3\times10^6} = 2.6\times10^{-4}$ $\frac{2.6\times10^{-4}}{3} = 8.7\times10^{-5}$ 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**	
3 7			$x = \dfrac{TL}{EA}$ $x = \dfrac{460 \times 1.73}{210 \times 10^{9} \times 11 \times 10^{-6}}$ *x* = 3.45 × 10^{-4} (m)	C1 C1	**Note** *x* must be the subject **Allow** alternative methods e.g. determines stress (4.18 × 10^7 Pa) C1 determines strain (1.99 × 10^{-4}) C1 determines *x*

				A1	**Allow** 3.4, 3.5, 3.43, 3.44 **Allow** 2 marks for 3.45 × 10^n **Examiner's Comments** This question required candidates to carry out several calculations. Good candidates would start by combining the definitions of stress and strain with the definition of Young modulus to give $$x = \frac{TL}{EA}$$ A significant number of candidates made a power of ten (POT) error either with 210 GPa or with the area of 11.0 mm^2. Many candidates wrote the latter as 11 × 10^{-3} m^2. Other lower ability candidates tried calculating the area from this value. Some candidates correctly determined the stress, then the strain and then the extension.
			Total	**3**	
38			wavelength = 60 (cm)	C1	**Ignore** POT
			v = 0.30/2.5 × 10^{-3} = 120 (m s^{-1})	C1	
			f = 120/0.60 = 200 (Hz)	A1	Possible ECF from incorrect value of speed v
			Total	**3**	
39			$E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{480\times10^{-9}}$ or E = 4.1(4) × 1	C1	
			$N = \frac{1.2\times10^{-3}}{4.1(4)\times10^{-19}}$	C1	
			N = 2.9 × 10^{15} (s^{-1})	A1	**Examiner's Comments** The term 'photon' and the 480 nm wavelength should have prompted most candidates to calculate the energy of a single photon. The most common answer was to divide the 1.2 mW by 480 nm. Once again, it was the top-end candidates who correctly arrived at the answer of 2.9 × 10^{15} photons per second. About 1 in every five candidates omitted this question.
			Total	**3**	
40			(1 C =) (1) A s	C1	**Allow** alternative methods
			(1 J =) (1) kg m s^{-2} × m or (1) N = (1) kg m s^{-2}	C1	

			$V = \frac{\text{kg ms}^{-2} \times \text{m}}{\text{As}} = \frac{\text{kgm}^2\text{s}^{-2}}{\text{As}}$ $\text{kg m}^2\text{A}^{-1}\text{s}^{-3}$	M1 A0	**Note** this mark is for clear substitution and working **Examiner's Comments** Some candidates were not clear on what was meant by base units. Most realised that the quantity of electric charge is measured in As. Weaker candidates had difficulty deriving work done.
			Total	**3**	
4 1		i	($\lambda = \frac{3.00\times10^8}{11\times10^9}$) λ = 0.027 (m)	**B1**	**Note** answer to 3 SF is 0.0273 (m) **Possible** SF penalty for 0.03 (m)
		ii	Diffraction / spreading of the waves (occur at the narrow slit.) This is because the wavelength is similar / comparable to the width / size / length of the slit (ORA)	**M1** **A1**	**Allow** 'wavelength is same as the gap (size)' AW
			Total	**3**	
4 2		i	There is friction. GPE is transferred to KE and heat or thermal (energy).	B1	
		ii	work done = (0.50 − 0.36) (J) or work done = 0.14 (J)	C1	
		ii	F × 0.90 = 0.14, therefore resistive force = 0.16 (N)	A1	
			Total	**3**	
4 3			(μ = mass / length) Use (digital) balance / scales for mass Use ruler / measuring tape for the length Any one from: 1. Measure mass to the nearest gram / 0.1 g / 0.01 g / 0.001 g / 'high resolution' 2. Measure length to (the nearest) mm	**B1** **B1** **B1**	**Not** 'weight', but **allow** 'weigh using scales to get mass' **Allow** for $\mu = T / v^2$ route: T is measured using a newtonmeter **or** determine T using mg by measuring (hanging) mass m using a balance / scales **Allow** for $\mu = T / v^2$ route: Determine v by measuring length using a ruler / tape measure (and also either stopwatch or stroboscope) **Allow** any other sensible suggestion **Ignore** incorrect use of the terms accuracy and precision **Not** 'repeat measurements' for 3 **Allow** 'determine gradient of mass against length graph' or 'determine gradient of T-v^2 graph' for 3

			3. Repeat for different length / mass (and determine average value for the mass per unit length) 4. Use a longer length of wire (reduce the percentage uncertainty) 5. Ensure there is no zero-error for the balance / scales **or** use calibrated balance / scales (AW)		**Examiner's Comments** About half the candidates scored two or more marks for this practical based question. It is good to report that many candidates were familiar with the idea of measuring mass using a balance and using a ruler to measure length. A good number of candidates mentioned plotting a graph of mass against length of wire and determining the gradient or μ. In this instance examiners ignored the incorrect use of the terms *precise* and *accurate.* A significant number of candidates spoilt their answers by referring to *weight* being measured by a balance. Alternative approaches describing the analysis of measured values of tension *T* and speed *v* were allowed if the physics was correct.
			Total	**3**	
4 4		i	Microwave: 2 cm X-ray 200 pm	B1 B1	
		ii	Any two from: May be reflected / refracted / diffracted / interference May be polarised Travel in a vacuum (at a constant speed / 3 x 108 m s-1) Oscillation of electric and magnetic fields.	B1 × 2	**Allow** speed of light
			Total	**4**	
4 5		i	(P = VI = 10.0 × 0.030) power = 0.30 (W)	**B1**	**Allow** 0.3 (W) without any SF penalty **Allow** 300 <u>**m**</u>(W)
		ii	The component is (an NTC) thermistor. (As V or I increases the) resistance of the component decreases Any <u>one</u> from: Component cannot be a diode / LED because of current in one direction only (AW) (As V or I increases the) component gets warmer / increase in number density (of free charge carriers)	**B1** **B1** **B1**	**Allow** calculations at 5 V and 10 V to support this, **ignore** POT errors <u>**Examiner's Comments**</u> The question was effective in two parts. Use the data to determine the resistance of the component at different potential difference, and then use this data to make judgement in identifying the component. Most candidates gained two or more marks. Some descriptions went astray with mention of Ohm's law or I-V characteristics. A significant number of candidates gave good reasoning but spoilt their answers by opting for a diode, an LDR or a filament lamp.

					Exemplar 10  (ii) Analyse the data in the table and hence identify the component. ~~A filament lamp~~ A ther as the potential difference in it would get hotter, lowering th resistance, as the resistance the current increases. This exemplar illustrates how a brief answer can score maximum marks. This answer is from a grade C candidate. Answers from top'end candidates were verbose and supported by values of resistances.
			Total	**4**	
46			$\lambda = \frac{\ln 2}{6600} = 1.050 \times 10^{-4}$ (s^{-1})	C1	Correct use of $A = \lambda N$
			$N = \frac{400 \times 10^6}{1.050 \times 10^{-4}} = 3.809 \times 10^{12}$	C1	
			mass of FDG = $\frac{3.809 \times 10^{12}}{6.02 \times 10^{23}} \times 0.018 \div 0.099$	C1	
			mass of FDG = 1.15×10^{-12} (kg) or 1.2×10^{-12} (kg)	A1	
			Total	**4**	
47			speed = $2 \times 1.5 \times 10^{-2}/19 \times 10^{-6}$ (= 1579 m s^{-1})	C1	
			$Z = \rho c = 1070 \times 1579$	C1	
			$Z = 1.7 \times 10^6$	A1	**Allow** 2 marks for 8.4×10^5; factor of 2 omitted
			unit: kg m^{-2} s^{-1}	B1	
			Total	**4**	
48	a	i	40 (mV)	B1	**Examiner's Comments** This was well answered. A few candidates gave an answer of 80 mV.
		ii	(T =) 3 × 0.5 = 1.5 (ms)	C1	
		ii	f = 670 (Hz)	A1	**Note**: Answer to 3 SF is 667 (Hz) **Note**: 0.67 or 0.667 scores 1 mark **Examiner's Comments** This was also well answered although some candidates did not allow for the milliseconds.
		iii	(330 = 670 x λ)		**Possible** ECF from **(ii)** **Note**: λ = 0.495 (m) if 667 Hz is used, therefore allow

		iii	$\lambda = 0.49$ (m)	B1	0.50 or 0.5 (m) here **Examiner's Comments** Most candidates correctly rearranged the formula and used their answer to (ii). Some candidates truncated their answer to one significant figure which was not penalised this year.
	b		Amplitude / height (of trace / signal) is smaller	B1	
			$I \propto A^2$ <u>and</u> amplitude (of sound or signal) is halved / amplitude is 2 div / amplitude is 20 (mV)	B1	**Note** this will also score the first B1 mark **Examiner's Comments** Most candidates understood that the new amplitude would be less than the original. Many thought it would be 1 / 16th of the original. The second mark was only gained by stronger candidates who explained why it would be 20 mV.
			Total	**6**	
49			5.0 eV = 8.0×10^{-19} (J) and 2.0 eV = 3.2×10^{-19} (J)	B1	**Allow** correct answers in terms of threshold frequency / wavelength for the metals and the frequency / wavelength of the photon
			photon energy = $\dfrac{6.63\times10^{-34}\times3.0\times10^{8}}{300\times10^{-9}} = 6.6(3)\times10^{-19}$ (J)	B1	**Allow** first two B1 marks for photon energy quoted as 6.6×10^{-19} J and 4.1 eV
			energy of photon > work function of **X** Or energy of photon < work function of **Y**	B1	
			Hence electrons emitted from **X** with speed / KE from zero to a maximum value and no electrons are emitted from **Y**	B1	
			Total	**4**	
50			(intensity $I = I_0e^{-\mu x}$) = $4.6 \times 10^3 \times e^{-0.85 \times 2.1}$ Either: (power =) $4.6 \times 10^3 \times e^{-0.85 \times 2.1} \times 3.4 \times 10^{-4}$ Or (energy per unit area =) $4.6 \times 10^3 \times e^{-0.85 \times 2.1} \times 30$ energy = $4.6 \times 10^3 \times e^{-0.85 \times 2.1} \times 3.4 \times 10^{-4} \times 30$ energy = 7.9 (J)	C1 C1 C1 A1	intensity = 772 (W m^{-2}) power = 0.262 (W) energy per unit area = 23160 J m^{-2} energy at surface = 47 (J) 2 marks **<u>Examiner's Comments</u>** There were many routes to a final answer in this question. Those candidates who set out their working carefully, used letters to represent the calculated quantity, and set this out in several stages tended to be the most successful. Some calculated the energy at the surface before going on to apply the attenuation formula, and others carried out the attenuation on the intensity. Each method can be credited at various stages, but it is important that a clear structure is shown. Many candidates attempted to change cm^{-1} to m^{-1} by dividing by 100, whereas the better candidates appreciated that the units of distance and attenuation

					constant would cancel in the exponent. Several candidates used the incorrect formula energy = power / time which can be a common misconception. The correct formula is in the data booklet if required.
			Total	**4**	
5 1			(CR =) 2000 × 10^{-6} × 120 × 10^{3} 1.00 = 1.48 × [1 – $e^{-t/240}$] **or** 0.48 = 1.48$e^{-t/240}$ (t =) - 240 × ln(0.48/1.48) t = 270 (s)	C1 C1 C1 A1	CR = 240 (s) Special case: 94 (s) for use of discharging equation. Max 2 marks **Examiner's Comments** This question comes from the learning outcome 6.1.3(c) in the use of an equation in a capacitor-resistor circuit. Candidates are required to determine the time at which a potential difference is met, which involves the use of logarithms. It was noted that many candidates were confident in their use of logarithms and were able to make some progress through their solution. Most candidates calculated the time constant correctly, taking into account the unit prefixes, and substituted this into an equation. However a large proportion used the discharging (rather than the charging) equation to calculate the time and some credit could be allowed for this. Less than one fifth of candidates scored all marks on this question. **Misconception** Many candidates seemed uncertain which equation to use, applying the simpler discharging equation. While the charging and discharging equations are given in the data booklet, it is not stated which is which, so candidates must make sure they know which to apply.
			Total	**4**	
5 2		i	($v = f\lambda$) 340 = 20 × 10^{3} × λ wavelength = 1.7 × 10^{-2} (m)	C1 A1	**Allow** 1 mark for 17 (m); 20 Hz used **Examiner's Comments** This question should be a relatively simple introduction to the section, using a familiar formula to calculate a wavelength. Nearly all candidates were able to correctly make wavelength the subject of the equation, and the majority were able to select the correct frequency to use. Those that chose the other frequency could score 1 mark if correctly followed through.
		ii	Loudspeaker and signal generator Frequency increased until limit of hearing frequency determined using $f = 1/T$	B1 B1 B1	**Allow** this mark for a labelled diagram **Do not allow** t for time period **Examiner's Comments**

					This question was poorly answered in general; very few candidates appreciated the need to use a signal generator to produce varying frequencies and seemed to think that the oscilloscope would do this. Many candidates used diagrams (yet not always labelled) to show their apparatus. Although many did appreciate that the upper limit is reached when the hearing stops, few also then went on to say how the frequency could actually be determined.
			Total	**5**	
5 3		i	(surface area =) 4π × (1.4 × 10⁹)² **or** 2.46 × 10¹⁹ (m²) (intensity = $\frac{P}{4\pi r^2}$) intensity = $\frac{2.7\times10^{27}}{4\pi\times(1.4\times10^{9})^{2}}$ intensity = 1.1 × 10⁸ (W m⁻²)	**C1** **C1** **A0**	**Allow** 2.5 × 10^{19} (m²) **Note**: Using π × (1.4 × 10^9)² is wrong physics; hence no marks in this show question **Examiner's Comments** This was a demanding question designed for middle and top-end candidates. The radiant intensity is equal to the power transmitted per unit cross–sectional area. The area being that of a sphere of radius 1.4 × 10^9 m. The equation 4πR² was appropriate here. The common errors, mainly from the low–scoring candidates, were using πR² and $\frac{4}{3}\pi R^3$. All the key steps in the calculations had to be structured well for
		ii	$E = \frac{3.00\times10^{8}\times6.63\times10^{-34}}{5.0\times10^{-7}}$ E = 4.0 × 10^{-19} (J)	**C1** **A1**	**Note**: Answer to 3 SF is 3.98 × 10^{-19} (J) **Allow** 4 × 10^{-19} (J) without any SF penalty **Examiner's Comments** Most candidates were familiar with the equation for the energy of the photon. Answers were generally well–structured and calculations were undertaken without much error in either rearranging the equation or powers of ten. The answer to two significant figures was 4.0 × 10^{-19} J, as in the general rule with such answers, 4 × 10^{-19} J was acceptable without any significant figure penalty.
		iii	(number per second = $\frac{2.7\times10^{27}}{4.0\times10^{-19}}$) number per second = 6.8 × 10^{45} (s⁻¹)	**B1**	Possible ECF from **(b)(ii)** **Examiner's Comments** This was a successful end for the top–end candidates, who correctly divided the total output power of Procyon of 2.7 × 10^{27} W by the energy of each photon from **(b)(ii)**. The two common errors were dividing the intensity by the photon energy and changing the photon energy from joule (J) to electron–volt (eV).
			Total	**5**	

5 4		i	$\Delta\lambda = \frac{\lambda v}{c}$ = $\frac{486\times10^{-9}\times960\times10^{3}}{3.00\times10^{8}}$	C1	
		i	Δλ = 1.56 (nm)	C1	
		i	λ = 486 + 1.56 = 488 (nm)	A1	
		ii	d = 1.25 × 10^{-6} m $\theta = \sin^{-1}\left(\frac{2\times486\times10^{-9}}{1.25\times10^{-6}}\right)$	C1	
		ii	θ = 51°	A1	**Allow** 1 mark $\theta = \sin^{-1}\left(\frac{2\times488\times10^{-9}}{1.25\times10^{-6}}\right)$ = 51° ; incorrect 488 nm used instead of 486 nm.
			Total	**5**	
5 5		i	(g →) [m s^{-2}] **and** (t →) [s] **or** (gt^2 →) [m s^{-2} × s^2] Clear evidence of working leading to m on both sides	M1 A1	
		ii	s / distance measured with a ruler / tape measure Timer mentioned for measuring t / time Measure distance from bottom of ball to (top of) trapdoor Any <u>one</u> from: • Take repeated readings (for t for same s) to determine average t • Avoid parallax error when using the ruler	B1 B1 B1 B1	
			Total	**6**	
5 6		i	(E =) $\frac{4000}{0.080}$ (F =) $\frac{4000}{0.080}\times1.6\times10^{-19}$ (a =) $\frac{8.0\times10^{-15}}{9.11\times10^{-31}}$ **or** 8.78 × 10^{15} a = 8.8 × 10^{15}	C1 C1 C1 A0	E = 5.0 × 10^4 (V m^{-1}) F = 8.0 × 10^{-15} (N) **Allow** this mark if the working is shown. If only value is given, then the answer must be 3SF or more <u>**Examiner's Comments**</u> This question asks for a calculation to show the value of the vertical acceleration in an electric field. The magnitude of the electric field strength first needs to be calculated, followed by the acceleration from Newton's second law. Candidates are reminded that a **show** question needs to be answered in detail and that each stage should be clear. Roughly equal numbers of candidates scored full marks or zero on this question.

		ii	$(t =)\ \frac{0.12}{6.0\times10^{7}}$ ($t = 2.0 \times 10^{-9}$ s)	M1 A0	**Examiner's Comments** As with the previous question, there is the need to make sure that the calculation leading to the given answer is clearly set out.
		iii	(x =) ½ × 8.78 × 10^{15} × $(2.0 \times 10^{-9})^2$ $x = 1.8 \times 10^{-2}$ (m)	C1 A1	**Allow** $a = 8.8 \times 10^{15}$ **Examiner's Comments** Most candidates appreciated the need to use an equation of motion in their solution, but a significant number of candidates used an initial horizontal velocity in the expression, leading to an incorrect answer. There were also an unusually large number who gave no response. Candidates should appreciate that if they have been given show questions, then it is likely that these values will be used in alter questions. **Misconception** Many candidates included an initial vertical velocity – it may be helpful to think of this process as analogous to that of projectile motion.
			Total	**6**	
57			**Level 3 (5–6 marks)** Clear description and clear calculations of energy per kg *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)** Clear description **OR** Clear calculations of energy per kg **OR** Some description **and** some calculations *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description **OR** Limited calculations *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	B1×6	**Indicative scientific points may include:** **Description** • Energy is produced in both reactions • More energy produced (per reaction) in fission • The (total) binding energy of 'products' is greater • In fusion, nuclei repel (each other) • Fusion requires high temperatures / high KE • Fission reactions are triggered by (slow-)neutrons • Chain reaction possible in fission **Calculations** • 1 kg of uranium has 4.26 mols / 2.56×10^{24} nuclei • 1 kg of deuterium has 500 mol / 3.01×10^{26} nuclei / 1.50×10^{26} 'reactions' • 200 MeV = 3.2×10^{-11} J • 4 MeV = 6.4×10^{-13} J • Uranium: ~ 10^{14} (J kg^{-1}) (actual value 8.2×10^{13}) • Deuterium: ~ 10^{14} (J kg^{-1}) (actual value 9.6×10^{13}) • The energy per kg is roughly the same **Examiner's Comments** This is the second LoR question. This is designed to assess knowledge of the two nuclear energy reactions and to calculate energy release using some given data. The differences between

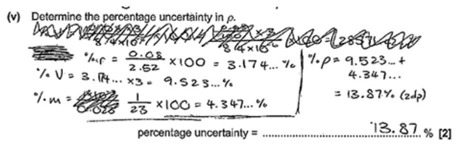
			0 marks No response or no response worthy of credit		the fission and fusion reactions were generally well answered although many candidates explained differences in design, operation and waste more than the reactions. The similarities were often not as clear however several candidates gave excellent responses in terms of binding energies and mass differences. Candidates were also expected to complete a calculation to show which produces more energy output per kilogram. This is challenging calculation to follow through fully, but most candidates were able to make some attempt, even if it was only converting MeV to J. Only better candidates realised 2 nuclei of deuterium were used for one fusion reaction. While a small number of candidates did correctly calculate the energy per kilogram, they tended to state that fusion produced more energy rather than a feeling that they are basically equivalent. As usual with LoR questions, a holistic approach is taken to the marking and candidates can access higher levels without necessarily reaching all the marking points. Even so, relatively few candidates were able to access Level 3, generally due to poor calculations and/or descriptions.
			Total	**6**	
58		i	$\underline{A =}$ 470/8.8 × 10^{-13} = 5.3 × 10^{14} (Bq) λ = ln 2/(88 × 3.16 × 10^{7}) (= 2.5 x 10^{-10} s^{-1}) ($A = \lambda N$); N (= 5.3 x10^{14} / 2.5 x 10^{-10}) = 2.1 x 10^{24}	C1 C1 A1	Mark is for correct calculation of A (in Bq **or** decays per s) Mark is for correct working to give λ in s^{-1}
		ii	$P = P_o \exp(-\lambda t)$ P = 470 exp (− ln 2 x 100 / 88) P = 210 (W)	C1 C1 A1	**Allow** formula in terms of N or A **Allow** calculation in terms of N or A; **allow ECF** for N or A
			Total	**6**	
59	a		(initial charge) $Q = EC_0$ **or** (Q conserved so final) $Q = V(C + C_0)$ (as capacitors are in parallel) so $EC_0 = V(C + C_0)$ (and hence $V = C_0 E / (C + C_0)$)	M1 A1	At least one correct expression for Q for first mark The two correct expressions equated for the second mark **Examiner's Comments** Some candidates obtained $Q = EC_0$ by applying the definition of capacitance at A, but then did not realise that charge would be conserved on switching from A to B. Some chose the wrong formula for capacitors in parallel or attempted to use the potential divider equation.
	b	i	$1/V = 1/E + C/EC_0$ (and compare to $y = c + mx$)	B1	Mark is for rearrangement into linear equation **Examiner's Comments** Some candidates correctly took the reciprocal of both sides of the

					given equation but were then unable to show a rearrangement into the standard linear form. A common difficulty was an inability to expand the bracket in $\frac{1}{E} \times \frac{(C + C_0)}{C_0}$ to give $\frac{C}{EC_0} + \frac{C_0}{EC_0}$
		ii	$1/EC_0 = 51 = 1/(9.1\ C_0)$ giving $C_0 = 1/(51 \times 9.1)$ F $C_0 = 2.2$ (mF)	B1 B1	$C_0 = 2.1547 \times 10^{-3}$ F Answer must be correct, rounded correctly and given in mF Candidate's answer must be given to 2 SF **Examiner's Comments** Some candidates gave their response to 2 d.p. instead of to 2 s.f. as required.
		iii	(at least) one correct worst fit line drawn gradient calculated correctly using a large triangle uncertainty = C_0 – 1/(wfl gradient x 9.1) uncertainty given is to the same number of decimal places as C_0	B1 B1 B1 B1	Top and bottom points chosen must be from opposite extremes of uncertainty limits, accurate to within half a small square $\Delta x \geq 1.5 \times 10^{-3}$; **expect** 59±1 or 44±1 (**or** 0.059 **or** 0.044); **allow ECF** from poorly drawn line; readings must be accurate to within half a small square **ECF** from **b(ii)**; **expect** uncertainty of up to 0.4(mF) **ECF** from **b(ii)** **If** no value for C_0 given in b(ii), **allow** any answer given to 1dp **Examiner's Comments** Most candidates gained the mark for using a large triangle (spanning more than 1.5 on the x–axis) to determine the gradient of the worst-fit line. Lower ability candidates were unable to gain credit for finding the gradient of their line because they read the scales on the axes incorrectly. Candidates should take a ruler into the examination and be careful about the positioning of the ruler for drawing a worst-fit straight line. A worst-fit line should join opposite extremes of uncertainty limits and pass between all the uncertainty limits. The Practical Skills Handbook is helpful on this topic. Several candidates performed the unnecessary step of calculating the fractional (or percentage) uncertainty instead of using $\Delta C_0 = \pm \lvert C_{0\ best} - C_{0\ worst} \rvert$ directly.
	c		Only effect is to slow the charging and / or discharging (of capacitor(s)) <u>and so</u> the final charges are unchanged / the values for *V* are unchanged / the graph is unchanged / the gradient is unchanged / there is no effect on the experiment (results)	B1	**Allow** and so the experiment takes longer
			Total	**10**	
60		i	tension = 850 kg × 9.81 = 8300 N	B1	

		ii	work done = mgh = 850 × 9.81 × 12	C1	
		ii	work done = 100 kJ	C1	
		ii	output power = 100 × 10^3 / 40 (=2501 W)	C1	
		ii	input power (= 2501 / 0.6) = 4200 (W)	A1	
		iii	Suggestion to reduce heat losses through friction in moving parts e.g. oil, bearings	B1	
		iii	Use a stiffer / stronger cable to reduce energy loss through stretching	B1	
			Total	**7**	
61		i	Velocity determined by Doppler shift of spectral lines	B1	
		ii	Suitable straight line of best fit though origin	M1	
		ii	Appropriate pair of values (d, v) taken from line, $H_0 = v/d$	M1	
		ii	400 km s^{-1} Mpc^{-1} ≤ H_0 ≤ 600 km s^{-1} Mpc^{-1}	A1	
		iii	H_0 = 500 × 10^3 / 10^6 × 3.1 × 10^{16} = 1.6 × 10^{-17} s^{-1}	C1	
		iii	t = 1 / H_0 = 1 / 1.6 × 10^{-17} = 6.2 × 10^{16} s	C1	
		iii	age = 2.0 × 10^9 (years)	A1	Accept answers between 1.6 × 10^9 (years) and 2.5 × 10^9 (years) CF
			Total	**7**	
62		i	energy of blue light / photon of blue light > 2.3 eV / work function or energy of red light / photon of red light < 2.3 eV / work function Energy of photon is independent of intensity (energy of photon given by equation) $E = hf$ / $E=hc/\lambda$ One photon interacts with one electron	B1 B1 B1 B1	**Not** blue light has frequency > threshold frequency Or red light has frequency < threshold frequency **Allow** intensity linked to <u>rate</u> of photons / <u>rate</u> of electrons emitted per second **Allow** E proportional f / E proportional to $1/\lambda$ **<u>Examiner's Comments</u>** The question is clear that the response needs to be given in terms of photons and energies. Many candidates discussed threshold frequencies, and although often correct, does not answer the question. The link between photon energy and frequency needs to be clear and not just a simple dependency – the simple solution for this is to state the equation. The final marking point requires the candidate to appreciate that only one photon can be absorbed by one electron. Standalone statements such as "there is a 1:1 relation" is meaningless in this context unless qualified. Many good candidates were able to score at least 3 marks on this question and it was clear that this is a well understood aspect. There is sufficient space for a fully clear

					answer and candidates are always to be reminded of the need for conciseness in such a response. **Misconception** Some candidates missed opportunities for marks by describing the effect wholly in terms of frequency, rather than energy.
		ii	(ϕ =) $2.3 \times 1.6 \times 10^{-19}$ **or** (E =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{320\times10^{-9}}$ (KE_{max} =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{320\times10^{-9}} - 2.3\ \times 1.6\times 10^{-19}$ (v =) $\sqrt{\frac{2\times2.5356\times10^{-19}}{9.11\times10^{-31}}}$ (wavelength =) $\frac{6.63\times10^{-34}}{9.11\times10^{-31}\times7.46\times10^{5}}$ wavelength = 9.8×10^{-10} (m)	C1 C1 C1 A1	ϕ = 3.68 × 10-*19* (J); E = 6.2156 × 10-*19* (J) $KE_{max} = 2.5356 \times 10^{-19}$ (J) $v = 7.46 \times 10^{5}$ (m s^{-1}) **Examiner's Comments** This is a novel development on what is a common calculation of kinetic energy and as such created some challenge for some candidates. Many were able to score the first marking point, either by converting from eV to joules, or by the calculation of the photon energy. Few candidates scored 2 or 3 marks, as generally an error such as using the speed of light for the electrons occurred. However, a good number of stronger candidates were able to achieve all 4 marks and set out their solutions clearly. It should be noted that the first 3 marks are for setting up the calculations and not the evaluations. This is to not penalise candidates too early for calculational errors and as always highlights the clear need for setting out working as well as possible.
			Total	**8**	
63	a	i	(Vernier) Calliper or micrometer (screw gauge)	B1	**Not** rule(r) **Examiner's Comments** 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 **Examiner's Comments** 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 = $\frac{4}{3}$ × π × (1.26 × $10^{-2})^3$ = 8.379 × 10^{-6} 8.4×10^{-6} m^2	M1 A0	$\frac{1}{6} \times \pi \times (2.52 \times 10^{-2})^3$ or $\frac{4}{3} \times \pi \times \left(\frac{2.52 \times 10^{-2}}{2}\right)^3$ **Examiner's Comments** 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	$\frac{0.023}{8.4 \times 10^{-6}}$ 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}) **Examiner's Comments** 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] **Examiner's Comments** 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**	
6 4		i	$a = F / m$ / $a = 8700 / 2300$	C1	
		i	$a = 3.8$	A1	**Note** answer is 3.78 to 3 s.f.
		ii	$D_{thinking} = u \times t = 22 \times 0.97 = 21.3$ (m)	C1	Allow 21.34
		ii	$D_{braking} = u^2 / 2a$ or $22^2 / (2 \times 3.8) = 64.0$ (m)	C1	Allow 63.98
		ii	stopping distance = $D_{thinking} + D_{braking}$ or 21.3 + 64.0	C1	Allow ecf
		ii	stopping distance = 85.3 (m)	A0	Allow 85.32
		iii	22 × 3600 / 1600 (= 49.5 mph)	B1	
		iv	Thinking distance for truck longer than in chart	B1	
		iv	Suggested reason e.g. tired	B1	Allow any relevant factor
		iv	Braking distance for truck longer than in chart	B1	
		iv	Suggested reason e.g. truck more massive than a car, truck's brakes are poor quality	B1	Ignore reference to road conditions
			Total	**10**	
6 5		i	$\frac{61000}{3600} = 16.944$ 17 ms^{-1}	**M1** **A0**	**Note** v must be the subject **Examiner's Comments** This question was the first 'show' question of the paper. It is important that candidates show clearly their working. In this case it was expected to see 61 multiplied by 1000 and divided by 3600. Most candidates came up with an answer of 16.9.
		ii	**1** $\frac{1}{2} \times 1.9 \times 10^5 \times 17^2$ 2.7(5) × 10^7(J)	**C1** **A1** **C1** **C1** **A1**	**Allow** use of 16.9 gives 2.7 × 10^7(J) **Allow** $v^2 = u^2 + 2as$ with values stated correctly **Ignore** negative sign **Allow** use of 16.9 gives 0.46

			$0 = 17^2 + 2a \times 310$ OR $\boldsymbol{t} = \frac{\mathbf{310}}{\mathbf{8.5}} = \mathbf{3}$ **2** $a = (-)\frac{17^2}{2\times310} = (-)\frac{289}{620}$ OR $\boldsymbol{a} = \frac{\mathbf{17}}{\mathbf{36.5}}$ 0.47 (m s^{-2}) 3 $1.9 \times 10^5 \times 0.47$ **3** 89000(N)	C1 A1	**Not** 0.5 **Allow** ECF from **(b) (ii) 1** and **(b) (ii) 2** **Allow** $\frac{2.7\times10^7}{310}$ **Allow** $1.9 \times 10^5 \times 0.46$ **Allow** $\frac{1.9\times10^5\times17}{36.5}$ **Allow** alternatives 87100, 87400, 88000 **Examiner's Comments** Most candidates were able to correctly write down the equation for kinetic energy and substitute the numbers into it. Where mistakes were made, it was normally with candidates not squaring the speed. It was hoped that candidates would use a speed of 17 m s^{-1} from the previous part. Good candidates clearly indicated which equation they were going to use and then clearly showed the substitution of the numbers, with the acceleration as the subject of the formula. Some candidates attempted to determine the time taken for the train to stop. Often when this method was attempted, candidates incorrectly assumed that the speed of 17 m s^{-1} was the average speed and not the initial speed. A few candidates round their answer inappropriately to one significant figure. Candidates answered this question in a number of different ways. The majority of the candidates substituted in their answer to the previous part into $F = m\,a$. Other candidates either used their answer for kinetic energy and the distance travelled or determined the time for the train to stop and used force equals the rate of change of momentum.
		iii	Component of train's <u>weight</u> acts against the motion / down the incline / same direction as braking force OR some KE transferred to GPE <u>Smaller distance</u> because larger opposing forces / net force or greater deceleration or less work done by braking force	B1 B1	**Not** gravity will slow it down **Not** down, parallel **Examiner's Comments** Candidates found this question requiring an explanation tough. There were many vague answers referring to "gravity" as opposed to the "force due to gravity" or

					“weight”. Candidates should be encouraged to use correct scientific terms. There was also occasional reference to “faster” deceleration. Some candidates correctly answer this question in terms of the kinetic energy being transferred to an increase in gravitational potential energy. Few candidates were precise in discussing the component of the weight parallel to the incline.
			Total	**10**	