Mark scheme - Materials

Question			Answer/Indicative content	Marks	Guidance
1			**B**	1	**Examiner's Comments** This question was based on the simple understanding of compression of material in the form of a concrete slab. About two thirds of the candidates opted for the correct answer B. The majority of the remaining candidates opted for C. Point C of the slab would be under maximum tension. Only a very small number of candidates, mainly from the lower quartile, went for either A or D.
			Total	**1**	
2			C	1	
			Total	**1**	
3			**C**	**1**	
			Total	**1**	
4			C	1	
			Total	**1**	
5			**D**	**1**	**Examiner's Comments** The tension for both wires is the same, yet wire X has half of the cross-sectional area. This means the stress for X will be twice that of Y. Strain = stress/Young modulus, so with half of the stress and (120/200) of the Young modulus, the strain for X will be 2 × (200/120) or times that of the strain for Y. The original lengths for X and Y are the same, so the extension of X will be 3.3 times that of Y.
			Total	**1**	
6			D	1	
			Total	**1**	
7			C	1	
			Total	**1**	
8			D	1	
			Total	**1**	
9			B	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must

					endeavour to use a variety of quick techniques when answering multiple choice questions.
			Total	**1**	
10			D	1	
			Total	**1**	
11			D	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.
			Total	**1**	
12			D	1	
			Total	**1**	
13			1.6 (× 10^{-3} m).	B1	
			Total	**1**	
14			The **maximum** (tensile) **stress** a material can withstand (before it breaks)	B1	**Examiner's Comments** Ultimate tensile strength is the maximum stress a material can withstand without breaking or failing. The most common incorrect answer included descriptions of force rather than stress.
			Total	**1**	
15			**D**	1	
			Total	**1**	
16	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.	**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

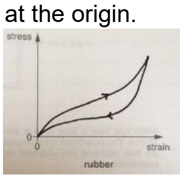
			Straight line of best fit drawn with a straight edge / ruler	B1	**Not** freehand / wobbly line **Examiner's Comments** The graph was drawn well with most candidates labelling the axis and using a simple scale which covered more than half the y-axis. Occasionally candidates lost a mark because of a miss-plot.
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			$k_1 = 2 \times$ **(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.

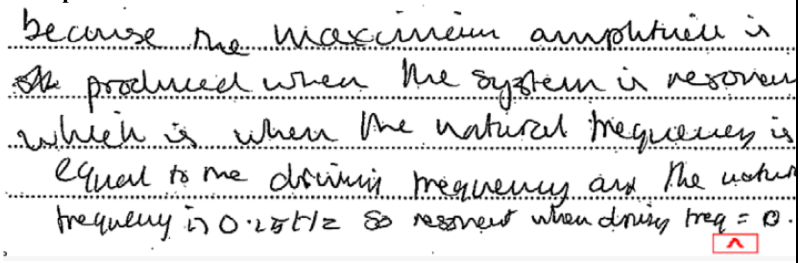
			Total	**12**	
17	a		arrow down through centre of ball labeled weight **or** W **or** mg **or** 1.2 N	B1	zero if any other arrows or forces present **Examiner's Comments** There were some carelessly drawn arrows on the diagram but otherwise this was done well. There were some arrows labelled *centripetal force.*
	b	i	(horizontally) mv^2/r **(or** $mr\omega^2$) = T sin θ **and** (vertically) W **or** mg = T cos θ (tan θ = v^2/rg **or** rw^2/g) tan θ = 0.045 × 4 × 9.87 × 2.2 / 9.81 **or** 0.48 / 1.2 (= 0.40) θ = 22°	M1 A1 A0	**accept** figures in place of algebra, r = 0.045 m v = 0.42 m s^{-1} ω = 3π rad s^{-1}; $r\omega^2$ = 4.0 m s^{-2} ; W = 1.2 N and m = 0.12 kg and $mr\omega^2$ = 0.48 N **accept** labelled triangle of forces diagram **N.B.** this is a *show that Q* ; sufficient calculation must be present to indicate that the candidate has not worked back from the answer
		ii	k = (mg / x_0 = 1.2 / 0.050) = 24 (N m^{-1}) (T = mg / cos θ = kx giving) x = 1.2 / 24 cos 22 x = 0.054 (m)	C1 C1 A1	**or** solution by ratios **Examiner's Comments** About half of the candidates completed the angle calculation successfully with a slightly smaller number finding the correct extension of the string.
	c		(y = ½gt^2 =) 0.18 = 0.5 × 9.81 × t^2 giving t = 0.19 (s) (x = vt =) 0.42 × 0.19 = 0.08 (m) distance = √(r^2 + x^2) = √(0.0020 + 0.0064) = 0.092 (m)	C1 C1 C1 A1	**alt:** projectile motion: x = vt, y = ½gt^2 y = ½g$(x / v)^2$ **ecf (b)i** for v; x^2 = $2yv^2/g$ = 2 × 0.18 × 0.42^2/9.81 **Examiner's Comments** About half of the candidates found the time for the ball to fall to the bench. Most then managed to find the horizontal distance from the point of release, but half forgot that the point of reference in the question was the centre of rotation so failing to complete the calculation.
	d		T increases **or** string stretches **or** angle θ increases to provide / create a larger centripetal force	M1 A1	**allow** mv^2/r **or** $mr\omega^2$ in place of *centripetal force* causality must be implied to gain the A mark **Examiner's Comments** About half of the candidates appreciated that the tension in the string increased or that the angle of the string to the vertical increased. Most answers gave the impression that the *centripetal force* was a *real* force rather than its provision being necessary for the ball to follow a circular path
			Total	**12**	

18			D	1	
			Total	**1**	
19			The extension of each spring is halved because the force in each spring is halved. (Hence the force constant is *2k*.)	B1	**Allow** *F* = kx, *x* is halved for the same *F*, hence *k* doubles.
			Total	**1**	
20			B	1	
			Total	**1**	
21			**B**	1	**Examiner's Comments** This question was slightly more challenging.
			Total	**1**	
22			A	1	
			Total	**1**	
23			C	1	
			Total	**1**	
24			**C**	1	
			Total	**1**	
25			**C**	1	
			Total	**1**	
26			D	1	**Examiner's Comments** The Young modulus is found by calculating the initial gradient of the material's stress-strain graph. The initial portion appears to be a straight line from the origin to the point (0.1, 120). The units on this graph are megapascals and %. This means the co-ordinates of the chosen point are in fact (0.1×10^{-2}, 120×10^{6}). Many candidates forgot to convert the strain into a decimal and left it as a percentage. Their answer was a factor of a 100 out, ie answer B. The correct answer is 120×10^{6} / 0.1×10^{2} = 1.2×10^{11} Pa. This is answer D.
			Total	**1**	
27			C	1	
			Total	**1**	

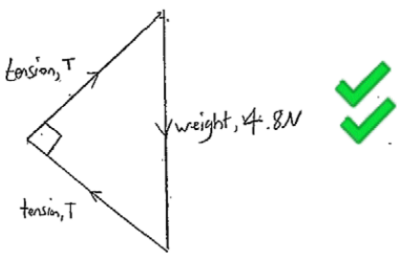
28			C	1	
			Total	**1**	
29			**B**	1	**Examiner's Comments** This question proved particularly straightforward and accessible to nearly all candidates.
			Total	**1**	
30			**A**	1	**Examiner's Comments** This question proved particularly straightforward and accessible to nearly all candidates.
			Total	**1**	
31			**B**	**1**	
			Total	**1**	
32			C	1	
			Total	**1**	
33			D	1	
			Total	**1**	
34			(*A* =) π x 0.0021^2 or 1.39 x 10^{-5} (m^2)	C1	
			(σ) = 2200 / π x 0.0021^2		
			σ = 1.6 π 10^8 (Pa)	A1	**Allow** 1 marks for 4(.0) x 10^7; diameter used as radius Answer is 1.59 x 10^8 Pa to 3sf
			Total	**2**	
35	a		GPE loss = mgh = 0.60 × 9.81 × 0.050 = 0.29 J	A1	
	b		EPE = ½ F × = 0.50 × 5.88 × 0.05	M1	**Allow** answers to 2 s.f.
			= 0.147 J	A1	
			(or k = F / × = 5.88 / 0.050 = 118 N/m, EPE = ½ k x^2 = ½ × 118 × 0.050^2		
			= 0.147 J)		
	c		GPE → EPE + KE (when falling)	B1	
			EPE → GPE + KE (when rising)	B1	

			Some energy dissipated as heat as oscillates (because of air resistance / friction)	B1	
			Total	**6**	
36			Greater area under the graph (from 3 mm to 4 mm) / greater **average** force from (3 mm to 4 mm) Mention of work done = **average** force x distance or work done = area under graph	B1 B1	ORA **Allow**: labelled/annotated diagram **Allow** energy (transferred) instead of work done **Allow** 2 marks for arguments including reference to $W = ½ kx^2$ **and** constant k **and** greater average x **<u>Examiner's Comments</u>** This question is best answered by referring to the graph in the question. Exemplars 1 and 2 indicate the difference between a low level and a high level response. **Exemplar 1** Work is the force aplied over a distance. If initial distance is larger then the work will be larger. [2] This exemplar shows a response that contains broadly true statements yet is only loosely linked to the context and so scored zero marks. **Exemplar 2** work done is equal to the area under the force extension graph and this area is larger for the area between 3 + 4 mm than 1 + 2 mm. [2] This response is clearly and specifically about this context and uses the graph as supporting evidence. The link to the graph is that the area gives the work done and that a larger area for one region means a larger amount of work done for that region.
			Total	**2**	
37	a	i	Missing data point and error bar plotted correctly.	B1	**Allow** ½ square tolerance.
		ii	Force measured by pulling back plate with a newton−meter.	B1	
		ii	Extension measured with a ruler (placed close to the transparent plastic tube).	B1	
		iii	Best fit line drawn correctly and gradient determined correctly.	B1	**Ignore** POT for this mark; gradient = 50 ± 4 (N m^{-1})

		iii	Worst fit line drawn correctly and its gradient determined correctly.	B1	**Note**: The line must have a greater/smaller gradient than the best fit line and must pass through all the error bars. **Ignore** POT for this mark.
		iii	$2k = 50$ (N m^{-1}), therefore $k = 25$ (N m^{-1})	B1	Possible ECF.
		iii	Absolute uncertainty determined correctly.	B1	Possible ECF within calculation.
		iv	$F \propto x$ / straight line passing through the origin.	B1	
		v	energy stored = ½ × 50 × 0.12^2	C1	Possible ECF from **(iii)**
		v	½ × 50 × 0.12^2 = ½ × 0.39 × v^2	C1	**Allow** 1 mark for v = 0.96 m s^{-1}; used k for single spring
		v	v = 1.4 (m s^{-1})	A1	
	b		force constant of spring arrangement) = $\frac{2k}{3}$ $\frac{2k}{3}x = ma$	M1	
			$a = \frac{2}{3 \times 0.39}kx$	M1	
			a = 1.7 kx	A0	
			Total	**13**	
38			Glass: A straight line from the origin.	B1	**Ignore** arrows
			Rubber: A correct sketch for loading and unloading sections, with the graph starting and finishing at the origin. 	B1	**Allow** either arrows or labelled curves **Examiner's Comments** Candidates needed to indicate the loading and unloading directions on the rubber curve. For the rubber curve, a number of candidates indicated that the rubber was increasing its strain when the load was being removed. Where a straight line is intended, a ruler should be used.
			Total	**2**	
39			Maximum energy is transferred between tower (driver) and sphere when sphere (driven) is at/close to the natural frequency <u>of the tower</u> **or** in this forced oscillation/resonance situation	**B1** **B1**	**allow** causes maximum damping <u>of the tower</u> **or** maximum amplitude <u>of the sphere</u>/AW **allow** AW e.g. sphere must be driven close to/at the natural/resonance frequency <u>of the tower</u> <u>**Examiner's Comments**</u> The answers gave a clear indication as to how well the candidates understood a resonance situation. Many omitted to explain which of the three oscillating elements were acting as drivers and which were driven. The candidate who wrote the answer (exemplar 3) shown here has some understanding of the situation but has failed to communicate it clearly to

					the reader. **Exemplar 3**  because the maximum amplitude is produced when the system is resonan which is when the natural frequency is equal to the driving frequency and the natur frequency is 0.28Hz so resonant when driving freq = 0. The ball was often quoted as just acting against the tower to reduce the amplitude rather than using the clue at the end of the initial paragraph about the energy drawn from the tower being absorbed by the dampers. Hence the requirement for the ball to be given a large amplitude or absorb the maximum amount of energy.
			Total	**2**	
40			Area increases by a factor of four / extension decrease by factor of four Elastic strain energy decreases by a factor of four	M1 A1	
			Total	**2**	
41	a		$2 \times T^2 = 4.8^2$ **or** $2T\sin 45° = 4.8$ **or** $T = 4.8 \sin 45°$ **T** = 3.39(4)(N)	**B1** **B1**	**Note**: sin45° = cos45° **Note**: *T* must be given to at least 3 SF **<u>Examiner's Comments</u>** This question was good discriminator, where the top–end candidates could demonstrate their powers of analysis. The success in **(c)** was very much dependent on a well–annotated triangle of forces in **(b)**. Most triangle of forces were workable but lacked detail. Missing labels and incorrect direction of the force arrows were the main misdemeanours. As expected, candidates used a range of methods to show the force in the extended spring was 3.4 N. In order of popularity, the techniques were using Pythagoras' theorem, using trigonometry, resolving forces in the vertical direction and sine (or cosine) rule. It is sensible to show the final answer to more significant figures than required in a 'show' question. **Exemplar 6**

(b) Sketch a **labelled** triangle of forces diagram for the three forces acting at point **X**. You do not need to draw this diagram to scale.



(c) Show that the tension T in each extended spring is 3.4 N.

$T^2 + T^2 = 4.8^2$

$2T^2 = 23.04$

$T^2 = 11.52$

$T = 3.39\,N$

$\rightarrow 3.4\,N$

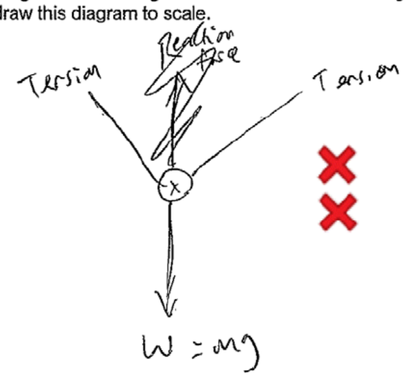
This exemplar illustrates a flawless answer from a top–end candidate.

The triangle of forces of perfect – all labels clear and the pivotal angle 90° between the two tensions marked. The calculation in **(c)** makes an excellent use of this triangle to show that the force is 3.39 N and hence 3.4 N.

Contrast the above excellent solution with the exemplar shown below from a grade C candidate.

Exemplar 7

(b) Sketch a **labelled** triangle of forces diagram for the three forces acting at point **X**. You do not need to draw this diagram to scale.



(c) Show that the tension T in each extended spring is 3.4 N.

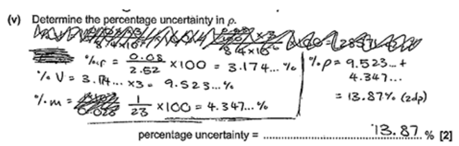
$4.8 \sin(45) = 3.39\,N$

$\approx 3.4\,N$

The triangle of forces in **(b)** is simply not right.

However, in **(c)**, the analysis is correct and shows another plausible

					method for securing the 2 marks. Again, it is good to see the penultimate value for the force given to **more** than two significant figures.
	b		$3.4 = 24x$ **or** $(x =) \frac{3.4}{24}$ **or** (x=) 0.14(17)(m) (E = ½ × 24 × 0.1417^2 **or** E = ½ × 3.4 × 0.1417) energy = 0.24 (J)	**C1** **A1**	**Allow** the C1 mark for $E = 3.4^2/(2 \times 24)$ **Allow** 3.39(4) N No ECF from **(c)**
			Total	**4**	
4 2	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 = $\frac{4}{3} \times \pi \times (1.26 \times 10^{-2})^3$ $= 8.379 \times 10^{-6}$ 8.4×10^{-6} m^2	M1 A0	$\frac{1}{6} \times \pi \times (2.52 \times 10^{-2})^3$ or $\frac{4}{3} \times \pi \times \left(\frac{2.52 \times 10^{-2}}{2}\right)^3$ **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	$\frac{0.023}{8.4\times10^{-6}}$ 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**  The candidate's answer is logically structured showing the percentage

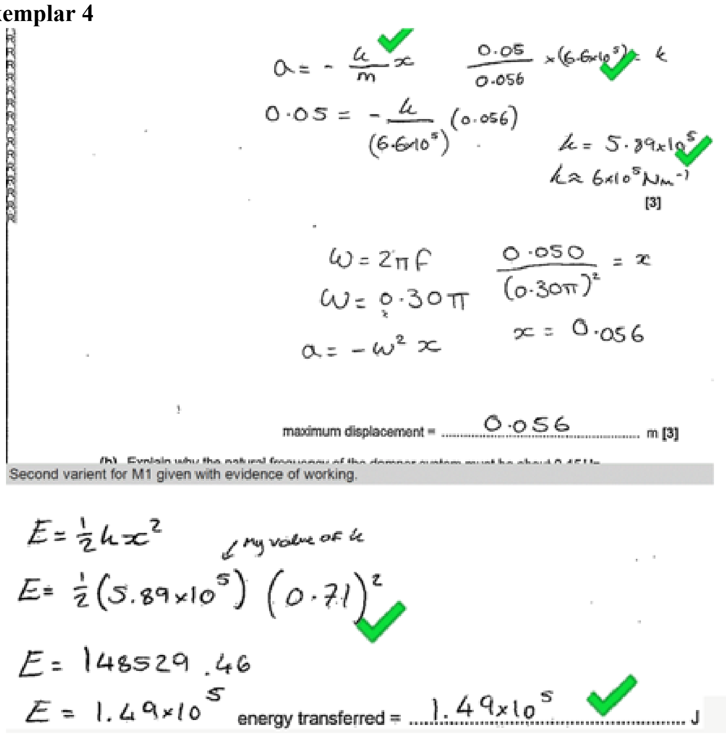
					uncertainty in the mass and volume and then adding them together so gaining both marks. An answer of 14% would have been acceptable.
	b		Extension = 0.096 – 0.078 or 0.018 m Weight = 0.023 x 9.81 or 0.22563 13 (N m^{-1})	C1 C1 A1	**Allow ECF** for incorrect mass conversion from **(iv)** **Allow** 12.6 (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**	
43	a		Arrow vertical down <u>and</u> an arrow opposite to the frictional force. Both arrows labelled correctly.	M1 A1	**Allow** weight / *mg* / W for the downward arrow <u>and</u> tension / *T* / 'force in rod' / 'force in tow bar' /'driving force' for the 'upward' arrow
	b		(W_s =) 1100 × 9.81 × sin 10° **or** 1100 × 9.81 × cos 80° (W_s = 1874 N or 1900 N)	C1 A0	**Allow** *g* instead of value
	c		force = 1900 + 300 force = 2200 (N)	A1	**Allow** 1870 + 300 = 2170 (N)

	d		(distance =) 120 / sin 10° **or** 691 (m)	C1	
			(work done =) 2200 × 691	C1	**Allow** ECF from **(c)** **Allow** ECF from an incorrect attempt at first mark.
			work done = 1.5×10^{6} (J)	A1	
	e		(A =) π × 0.006^2 **or** 1.1×10^{-4} (m^2)	C1	
			(stress =) $\frac{2200}{\pi \times 0.00}$ an d $2.0 \times 10^{11} = \frac{stre}{stra}$	C1	**Allow** ECF from **(c)** **Allow** x (=FL/EA) = $\frac{2174 \times 0.5}{2.0\times10^{11} \times 1.1 \times 10^{-4}}$ **Allow** 2 marks for 1.2×10^{-5}; 1.2×10^{-2} m used as radius
			$x = 4.8 \times 10^{-5}$ (m)	A1	**Allow** answer between 4.7 and 5.1 × 10^{-5} (m)
			Total	**10**	
44	a	i	Data point plotted to within ± ½ small square and correct line of best fit though all the data points.	B1	
		ii	Gradient of line determined.	M1	
		ii	E = gradient = (8.8 ± 0.1) × 10^{10} (Pa).	A1	Allow 1 mark for (8.8 ± 0.1) × 10^{n} Pa; where $n \neq 10$
	b		The actual cross-sectional area will be smaller.	B1	
			The actual stress values on the graph will be larger (because stress ∝ $area^{-1}$)	B1	
			The gradient of the graph will be larger; hence the Young modulus of the metal must be larger than the student's value.	B1	
			Total	**6**	
45			$1.4\times10^{10} = \frac{1.1\times10^{5}}{strain}$ (Any subject) / strain = 7.86×10^{-6}	**C1**	Possible ECF from **(a)**
			$x = \frac{1.1\times10^{5}}{1.4\times10^{10}} \times 2.3$	**C1**	
			$x = 1.8 \times 10^{-5}$ (m)	**A1**	
			or $1.1 \times 10^{5} = \frac{6500}{A}$ / A = 0.059 (m^2)		

			$(F = \frac{EAx}{L})$; $6500 = \frac{1.4\times10^{10}\times0.059\times}{2.3}$ (Any subject) x = 1.8×10^{-5} (m)	C1 C1 A1	**Examiner's Comments** This was a notable success for most of the candidates. Examiners were pleased to see a range of techniques being used to get to the correct answer of 1.8×10^{-5} m. Most of the answers were well-structured and showed good use of calculators. A small number of candidates correctly calculated the strain but then struggled to rearrange the expression for strain to determine the compression.
			Total	**3**	
46			$x = \frac{TL}{EA}$ $x = \frac{460 \times 1.73}{210 \times 10^9 \times 11 \times 10^{-6}}$ $x = 3.45 \times 10^{-4}$ (m)	C1 C1 A1	**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 **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**	
47	a	i	points on the line read to the nearest half square	B1	**Allow** Δy for $y_2 - y_1$ and Δx for $x_2 - x_1$

			size of triangle is greater than half the length of the drawn line and Δy / Δx	B1	$\Delta x \geq 0.1625$
		ii	$\left(\frac{9.81}{0.12}\right) = 81.75$ 82 N m^{-1} given to 2 or 3 significant figures	C1 A1	**Allow** ECF from (a)(i) **Allow** 81.8 N m^{-1} **Note** POT must be correct for given unit **Allow** kg s^{-2}
	b	i	steepest or shallowest line that passes through all the error bars	B1	
		ii	gradient determined: 0.10 m kg^{-1} or 0.13 m kg^{-1}	B1	**Allow ECF** from (b)(i)
		iii	Δgradient (0.13 - 0.12 or 0.12 - 0.10) $\frac{\Delta\text{gradient}}{\text{gradient}} \times 100 = 8.3\%$ or 17% OR Δk (82 – 75 or 98-82) $\frac{\Delta k}{k} \times 100 = 8.5\%$ or 20%	C1 A1 C1 A1	**Allow ECF** from (b)(i) and (ii) **Not** 10% without justification **<u>Examiner's Comments</u>** In this question, most candidates clearly identified the points on the line that were to be used for the gradient calculation. High achieving candidates clearly showed their working when determining the percentage uncertainty.
			Total	**8**	
48	a	i	a = (−) $4\pi^2f^2x$ = 4 × 9.87 × 4900 × 0.004	C1	**allow** 774 (m s^{-2})
		i	a = 770 (m s^{-2})	A1	
		ii	**1** sketch showing one wavelength and 140 (Hz)	B1	both sketch and value required for 1 mark
		ii	**2** driving force is around nodal point / AW;	B1	**max** 3 of the 4 marking points
		ii	points either side of nodal point try to move in opposite directions when force in one direction / AW;	B1	
		ii	move magnet to antinodal point; ¼ of distance between clamps	B1	**not** increase current
	b	i	$f \alpha \sqrt{T}$ so f = 70/√2 = 49 or 50 Hz	B1	
		ii	**1** μ increases / goes up by 0.4%	B1	**allow** +0.4% NOT 0.4%
		ii	**2** 0.2%,	B1	**or** half of answer to **(ii)1**
		ii	f is lower because μ is bigger and μ is on the bottom of the formula	B1	**or** greater inertia present with same restoring force / other physical argument
			Total	**10**	

49		i	Elastic: material returns to original dimensions when load is removed.	B1	
		i	Plastic: material has permanent change of shape when load is removed.		
		ii	The material is elastic because the removal of force returns the rubber to its original length.	B1	
		ii	The area under force-extension graph is work done.	B1	
		ii	Repeated stretching and releasing the rubber warms up the rubber because not all the strain energy is returned back. The area enclosed represents the amount of thermal energy. During landing, some of the aeroplane's kinetic energy is transferred to thermal energy and therefore the aeroplane does not "bounce" during landing; hence this minimises the risk to passengers.	B1	Mentioning 'hysteresis' is not enough to gain this mark.
			Total	**4**	
50		i	(Area under graph =) energy / elastic potential energy	B1	**Allow** work done on the elastic band
		ii	(Area of) 1 cm^2 is 0.025 × 2.5 J or 0.0625 J (31 × 0.0625 =) 1.9 (J)	C1 A1	**Allow** other alternatives. **Do not accept** $0.5Fx$
		iii	Energy transferred to the surroundings / heating the rubber	B1	
			Total	**4**	
51		i	R (= $\rho L/A$) = 1.8 × 10^{-8} × 1500/1.1 × 10^{-4} R = 0.25 (Ω)	C1 A1	
		ii	$E = \sigma/\varepsilon = T/A\varepsilon$ (so $T = EA\mathcal{E}$) T = 1.2 x 10^{10} x 1.1 x 10^{-4} x 0.013 T = 1.7 x 104 (N) or 17 (kN)	C1 C1 A1	**or** calculation of σ =1.56 x 10^8 (Nm^{-2}) **or** T = 1.56 x 10^8 x 1.1 x 10^{-4}
			Total	**5**	
52		i	$\omega^2 = k/m$ **or** $(2\pi f)^2 = k/m$ **or** $kA = ma_{max}$ k =($m4\pi^2f^2$)= 6.6 × 10^5 × (2π ×	**C1** **M1**	**allow** ω or ω^2 = 0.88 or 0.89 quoted from **(a)** **ecf** value of A from **(a)**

			0.15)^2 **or** ($k = ma_{max}/$**A**) = 6.6 × 10^5 × 0.05/0.056 k = 5.9 × 10^5 (N m^{-1})	**A1**	as this is a 'show that' question some definite evidence of working must be shown. **not** k = 6 × 10^5 **allow** answer to 2 or more SF.
		ii	$E = ½kA^2$ = = 0.5 × 5.9 × 10^5 × 0.71^2 E = 1.5 × 10^5 (J)	**C1** **A1**	**allow** value from (c)(**i**) or 6; **or** a = (k/m)A , F = ma, E = ½FA **accept** 1.48 to 1.51 or value from **ecf** **special case:** give 1/2 for E = 3(.0) × 10^5 (J) where **it is clear that** 2k has been used as the spring constant **<u>Examiner's Comments</u>** The exercise in this section completed successfully by most candidates was to perform standard calculations stating correct formulae and showing clear working to determine the required quantities. The example (exemplar 4) shown here is of a typical neat script. The most common error was to forget to square quantities in part (ii) or to use the amplitude calculated part (a) rather than the figure given in the stem of this part. **Exemplar 4** 
			Total	**5**	
5	3	i	(230 ± 40) M Pa	B1	
		ii	Stress = 1.1 × 10^6 / (Π × 0.045^2) = 173 MPa	C1	
		ii	173 MPa < 230 MPa	A1	AW (ecf)

		ii	So will not stretch too much in use	B1	Allow any sensible contextual suggestion
		ii	Less chance of permanent deformation or fatigue	B1	
			Total	**5**	
54		i	Use a micrometer / (Vernier) caliper Measure the diameter along its length in different directions (to ensure uniform cross-section) AW	B1 B1	**Allow** either along length or in different directions
		ii	**1**. Any value between 0 and 2.0 (kN) **2**. Any value between 2.0 and 2.2 (kN)	B1 B1	
		iii	k = gradient $k = 5.0 \times 10^5$ (N m^{-1})	C1 A1	**Allow** 1 mark for 5.0×10^n; $n \neq 5$ **Allow** 5 x 105 (N m^{-1})
			Total	**6**	
55		i	(Sum of clockwise moments = sum of anticlockwise moments) 95 × 9.81 × 1.80 / 120 × 9.81 × 1.00 / 1.60 × T sin 30°	C1	
		i	(95 × 9.81 × 1.80) + (120 × 9.81 × 1.00) = 1.60 × T sin30°	C1	
		i	$T = 3.6 \times 10^3$ (N)	A1	**Note** answer to 3 s.f. is 3.57×10^3 (N)
		ii	$\sigma = \frac{3.6\times10^3}{\pi\times0.015^2}$	C1	Possible ECF from part **(i)**
		ii	$\sigma = 5.1 \times 10^3$ (kPa)	A1	**Allow** 1 mark for 5.1×10^6; POT error **Note** using 3.57×10^3 N gives 5.05×10^3 (kPa)
		iii	The clockwise moment increases and therefore T increases.	B1	
			Total	**6**	
56			**Level 3 (5–6 marks)** Clear correct explanation of terms **and** correct comparison of materials *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*	B1 x 6	***Indicative scientific points may include:*** ***Explanation of terms*** • elastic : material returns to original length (when load removed) • plastic: material permanently deformed (when load removed) • brittle: elastic behaviour (only) up to breaking point/ will not deform before breaking • ductile: elastic and plastic regions before the material breaks / able to be (permanently) deformed / stretched / bent without breaking

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Level 2 (3–4 marks)
Clear correct explanation of terms or correct comparison of materials or has some clear correct explanation of terms <u>and</u> some correct comparison of materials

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)
Has limited correct explanation of terms and limited correct comparison of materials

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.
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UTS: maximum (tensile) stress a material can withstand
Young modulus = stress /strain
Young modulus = gradient of stress-strain graph

Comparison of materials

Both have elastic regions
K is elastic
J has a plastic region, K does not have a plastic region
J is ductile
K is brittle
gradient of J is greater than K
Young modulus of J is greater than K
UTS of J is greater than K

<u>Examiner’s Comments</u>

This was the first level of response question. A good range of marks from zero to six were credited.

This type of question allows candidates to demonstrate structuring an answer logically using appropriate terms correctly. To achieve the highest marks, candidates needed to explain all six terms and compare the two materials using the terms. Some candidates in their answer included a discussion of Hooke’s law.

Candidates who did not achieve a Level 3 response, often did not include all the terms or incorrectly described some of terms. Often ultimate tensile strength was not understood. Answers could have been improved by explaining why the gradient was an indication of the Young modulus. Many candidates did not state that an elastic material returned to its original length when a load was removed.

Some candidates who did less well, attempted to describe the material in terms of named materials, often incorrectly, e.g. J was rubber.

Exemplar 3

Material J is ductile. This means the material undergoes a large amount of plastic deformation before breaking and so is used for things like wires. Material K is brittle because it does not undergo plastic deformation at all but it reaches its breaking point after only elastic deformation. Brittle materials like glass and cast iron have this graph because they obey hookes law. J obeys hookes law (force ∝ extension) up until its elastic limit. Elastic deformation means it returns to its original shape once the force is removed. Plastic deformation means it does not. Young modulus is the stress/strain and can be calculated from the directly proportional sections of the graph. J has a larger Young Modulus because the line is steeper, and has a larger breaking point. J also has a larger ultimate tensile strength which is the most stress a material can go under before breaking.

The candidate has explained all the terms and there is a comparison of the two materials. The reference to Hooke’s law is acceptable and does not detract from the answer and is not irrelevant.
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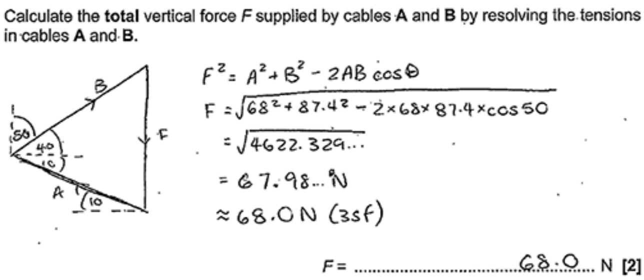
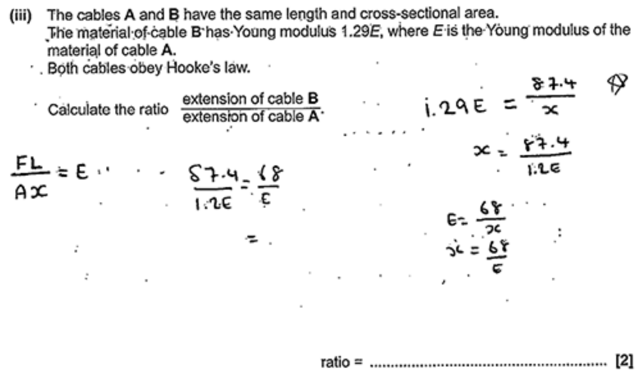
					The candidate's reasoning is clear and logically structured. This is a Level 3, 6-mark answer.
			Total	**6**	
5 7			*** Level 3 (5–6 marks)** All points E1, 2, 3 and 4 for equipment All points M1, 2, 3 and 4 for measurements For calculations expect C1, C2, C3 and C4 Expect at least two points from reliability *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect E1 and E2; E3 or E4 for equipment Expect M2 and two from M1, M3, M4 for measurements For calculations expect at least C3 and C4 Expect at least one point from reliability *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect at least E1 and E2 for equipment Expect at least two from measurements Expect C5 for the calculation No real ideas for obtaining reliable results *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	The complete plan consists of four parts: **Equipment used safety (E)** 1. Wire fixed at one end with load added to wire. 2. Suitable scale with suitable marker on wire. 3. Micrometer screw-gauge **or** digital / vernier callipers for measuring diameter of wire. 4. Reference to safety concerning wire snapping. **Measurements (M)** 1. Original length from fixed end to marker on wire. 2. Diameter of wire. 3. Measure load. 4. New length of wire when load increased. **Calculation of Young modulus. (C)** 1. Find extension (for each load) or strain (for each load). 2. Determine cross-sectional area or stress. 3. Plot graph of load-extension **or** graph of stress-strain. 4. Young modulus = gradient × original length / area **or** Young modulus = gradient. 5. Calculate Young modulus from single set of measurements of load, extension, area and length. **Reliability of results (R)** 1. Measure diameter in 3 or more places and take average. 2. Put on initial load to tension wire and take up 'slack' before measuring original length. 3. Take measurements of extension while unloading to check elastic limit has not been exceeded. 4. Use long wire (to give measurable extension). Scale or ruler parallel to wire.

			No response or no response worthy of credit.		
			Total	**6**	
5 8			**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 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.	B1 x6	**Indicative scientific points may include:** **Procedure** • labelled diagram • incremental increase in load / mass until wire breaks • method of attaching wire at fixed end • method of attaching load at other end • use of safety screen / goggles to protect eyes • method of securing retort stand **Measurements** • measurement of load / mass • measurement of diameter • use micrometer to measure diameter • averages diameter • repeats experiment **Analysis** • equation to determine force, e.g. mg • equation to determine cross-sectional area or $A = \pi r^2$ • (breaking) stress = (max) force / cross-sectional area or $\sigma = \frac{F}{A}$ **Examiner's Comments** This question was designed to test candidates' practical planning skills. It is expected that candidates should be able to apply the laboratory techniques that they have encountered to novel situations. This was the first LoR question. Candidates should explain their methods clearly and include any appropriate equations. Their account should be logical and the information given should be relevant to the experiment. In this particular question a number of candidates explained a Young modulus experiment and suggested that the breaking stress could be determined from a stress-strain graph. Good candidates clearly explained the procedure to be followed with a labelled diagram, the measurements to be taken (diameter, mass) and how the measurements would be used to determine the breaking stress.

			Total	**6**	
59		i	(stress =) $\frac{7.5}{8.2\times10^{-7}}$ **or** 9.15×10^{6} (Pa) (strain =) $\frac{7.5}{8.2\times10^{-7} \times 2.0\times10^{11}}$ **or** 4.57×10^{-5} $x = 2.8 \times 10^{-5}$ (m) **OR** $E = \frac{FL}{Ax}$ $2.0 \times 10^{11} = \frac{7.5 \times 0.62}{8.2 \times 10^{-7} \times x}$ $x = 2.8 \times 10^{-5}$ (m)	C1 C1 A1 C1 C1 A1	**Allow** full credit for alternative methods **Note** answer is 2.84×10^{-5} to 3 SF **Note** answer is 2.84×10^{-5} to 3 SF **Special case:** 1 mark for 2.8×10^{-4} (m) or 2.9×10^{-6} (m); 7.5g or 7.5g^{-1} (g = 9.81) used instead of 7.5
		ii	acceleration at **Y** / deceleration at **Z** At **Y** (tension is) greater / (T) > 7.5 (N) At **Z** (tension is) less / (T) < 7.5 (N)	B1 B1 B1	**Allow** increasing velocity / increasing speed at **Y** **Allow** decreasing velocity / decreasing speed / negative acceleration at **Z** / slowing down **Ignore** 'downward acceleration' at **Z** **Ignore** drag throughout **Allow** (T) > weight **Allow** (T) < weight
			Total	**6**	
60		i	87.4cos50° **or** 68.0sin10° F = 68.0 (N)	C1 A1	**Allow** 87.4sin40° or 68.0cos80° **Allow** cosine and sine rules being used, e.g. $F^2 = 68.0^2 + 87.4^2 - 2 \times 68.0 \times 87.4 \times \cos50°$ **or** $F = 87.4 \times \sin50°/\sin80°$ **or** $F = 68.0 \times \sin50°/\sin50°$ **Allow** 2 SF answer here __**Examiner's Comments**__ The question has a clue for making a start on this question. Most candidates did resolve the two tensions in the cables vertically. The majority of the responses were well-structured and demonstrated excellent understanding of vectors. Although not straightforward, many candidates used the correct angle when determining the vertical components of the forces. The correct answer of 68.0 N appeared on most scripts. A small number of candidates got 1 mark for just getting one of the components correct. A very small number of candidates got the correct answer by using trigonometry and triangle of forces. This is not what was expected, but full credit was given for this alternative approach. Correct responses will always score marks, even when the candidates choose not to go along the path designed by the examiners. This different approach is illustrated

					in the exemplar 6 below. **Exemplar 6**  Calculate the **total** vertical force *F* supplied by cables **A** and **B** by resolving the tensions in cables **A** and **B**. $F^2 = A^2 + B^2 - 2AB\cos\theta$ $F = \sqrt{68^2 + 87.4^2 - 2\times 68 \times 87.4 \times \cos 50}$ $= \sqrt{4622.329...}$ $= 67.98...$ N ≈ 68.0 N (3sf) *F* = ...68.0.... N **[2]** The candidate has used a triangle of forces and the cosine rule to determine the net downward. As it happens, the F in this calculation is the weight of the dolphin. However, it is numerically equal to the total upward vertical force. This concise and perfect alternative technique picked up the maximum marks.
		ii	68 = *m* × 9.81 *m* = 6.9 (kg)	C1 A1	Possible ECF from **(c)(i)** **Allow** 68 = *mg* **Note** answer to 3 SF is 6.93 (kg) **Allow** *g* = 9.8; this gives 6.94 (kg) **Not** *g* = 10; this gives 6.8 (kg). Only the first C1 mark can be scored **<u>Examiner's Comments</u>** Almost all candidates correctly used *W* = *mg* to determine the mass of the dolphin. Full marks were frequently picked up because of error carried forward (ECF) from **(c)(i)**. There were very few cases of *g* = 10 m s^{-2} being used; this was penalised because *g* = 9.81 m s^{-2} is given in the Data, Formulae and Relationship Booklet.
		iii	$E = \frac{\text{stress}}{\text{strain}}$ (Any subject) (Tension and E increase by the same factor of 1.29) ratio = 1.0	C1 A1	**Allow** $E = \frac{\sigma}{\varepsilon}$ **or** $E = \frac{FL}{Ax}$ (Any subject) **Allow** 1 SF answer **Allow** 1:1 **<u>Examiner's Comments</u>** This question on the equation for Young modulus E was well-answered with most candidates picking up one or more marks. The extension *x* of a wire is given by the expression $x = \frac{FL}{EA}$, where F is the tension in the wire, *L* its length and *A* its cross-sectional area. In this question, the extension $x \propto \frac{F}{E}$. Since both *F* and *E* increase by the same factor of 1.29, this meant that the ratio is 1.00. The most frequent incorrect answers were 1.29 and 1.29^{-1} or 0.78. The majority of the candidates in the upper quartile picked up 2 marks. Exemplar 7

					 (iii) The cables A and B have the same length and cross-sectional area. The material of cable B has Young modulus 1.29*E*, where *E* is the Young modulus of the material of cable A. Both cables obey Hooke's law. Calculate the ratio $\frac{\text{extension of cable B}}{\text{extension of cable A}}$ ratio = ... [2] This exemplar shows a response from a top-grade candidate. The solution is much more elaborate and the response of 0.996 is given to 3 significant figures. A perfect solution that earned this candidate 2 marks.
			Total	**6**	
6 1			**Level 3 (5–6 marks)** Clear description **and** clear 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 analysis **or** Clear description **or** Clear analysis *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description **or** Limited analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	B1× 6	Use level of response annotation in RM Assessor. **Indicative scientific points may include:** **Description** • Determine *T* by measuring several oscillations • Independent and dependent variables identified (e.g. *L* and *T*) • Variables kept constant (e.g. for L and T experiment, *m* is kept constant) • Repeating to determine average *T* • Measure length *L* and width *w* with ruler • Measure thickness t with a vernier (calliper) / micrometer • Use video/phone camera / stopwatch / data-logger and motion sensor / light gates and timer • Use top-pan balance / scales to measure *m* **Analysis** • Plot an <u>appropriate</u> graph, e.g. T^2 against L^3 **or** tabulate $T^2 \div L^3$ • Gradient of **best line** determined **or** average of $T^2 \div L^3$ • Use a large triangle to determine gradient • Gradient (or equivalent) related to E, e.g. gradient = $16\pi^2 m/wEt^3$ for T^2 against L^3 graph **<u>Examiner's Comments</u>** This part tested ideas about investigative experiments: there was a solid focus on elements of data-taking and instruments that should be used. Typically at A Level, analysis should include an appropriate graph and a comparison between the line of best fit and the equation under test. Putting the general equation below the given equation would make it much clearer how the candidate linked the gradient or y-intercept with the required property.
			Total	**6**	

62		i	$E = \frac{1}{2}kx^2$ or E = mgh or 0.080 ×9.81 × 0.20 or $\frac{1}{2} \times 60 \times x^2$ 0.080 ×9.81 × 0.20 = $\frac{1}{2} \times 60 \times x^2$ *x* = 0.072 (m)	C1 C1 A1	
		ii	Time of flight is independent of speed/AW **1** Because distance of fall is the same **and** initial velocity vertically is zero / velocity is horizontal at **X** *D* increases as speed at **X** increases because the time of flight is constant/AW **2** *D* is directly proportional to speed at **X**	B1 B1 M1 A1	**Allow** algebraic answers that assume initial vertical velocity is zero/velocity is horizontal at X. **Allow** d = vt idea "*D* is directly proportional to speed at **X** because the time of flight is constant" scores 2. **Examiner's Comments** This part showed that many candidates thought that the time of flight of the car depended on the take-off speed of the car. Since the car is travelling horizontally the time of flight only depends on the height of the car above the horizontal track.
			Total	**7**	
63		i	a = $4\pi^2f^2$ ×	C1	condition for SHM
		i	so k = $(m4\pi^2f^2)$ = $1.7 \times 10^{-27} \times 4 \times 9.87 \times 43.7 \times 10^{26}$	B1	substitution
		i	k = 292 ($N\ m^{-1}$)	A1	**ecf** if incorrect mass used
		ii	(N2 gives) $F_H = m_H a_H$ and $F_I = m_I a_I$	B1	**allow** total momentum = 0 at all times
		ii	(N3 gives) $F_H = F_I$ *can be implicit*	B1	SHM gives v = $2\pi f x_{max}$
		ii	SHM gives a α (−)x	B1	so $m_H X_H = m_I x_I$
		ii	hence $x_H/x_I = a_H/a_I = m_I/m_H = 127$	B1	**accept** 127 = $x_H/x_I \approx 10/0.08 = 125$
			Total	**7**	
64		i	$\frac{49}{1.4 \times 10^{-7}}$ 3.5×10^8 Pa	C1 A1	
		ii	$\frac{3.5 \times 10^8}{180 \times 10^9}$ 0.0019	C1 A1	**Allow ECF** from **(b)(i)** **Ignore** units
		iii	0.0019 × 2.2 0.0042 (m)	C1 A1	**Allow ECF** from **(b)(i)** and **(ii)** **Allow** 0.0043 (m)

		iv	$\frac{1}{2} \times 49 \times 0.0043$ 0.10 (J)	C1 A1	**Allow ECF** from **(b)(i)**, (ii) and **(iii)** **Do not accept** 1 sf
			Total	**8**	