1)

Question 1			
(a)	(i)	$F \propto \Delta L$ ✓ up to limit of proportionality ✓ accept 'elastic limit' $F = k\Delta L$ with terms defined gets first mark	**2**
(a)	(ii)	straight line ✓ through origin ✓	**2**
(a)	(iii)	working shown and $F \geq 200$ N ✓ (500/0.385) = **1290** ± 20 ✓ **N m^{-1} or** N/m kg s^{-2} ✓	**3**
(b)	(i)	($\Delta W = F\Delta s$) so area (beneath line from origin to ΔL) represents (work done or) energy (to compress/extend) ✓ **work done** (on or by the spring) linked to energy stored ✓ (area of triangle) = $\frac{1}{2} b \times h$ (therefore $E = \frac{1}{2} F\Delta L$) ✓	**3**
(b)	(ii)	F = **360** (N) used ✓ $P = \frac{\frac{1}{2} \times (360) \times 0.28}{1.5} = \frac{50.4}{1.5}$ ✓ = **34** (33.6) (W) ✓ ecf from wrong force	**3**
		Total	**13**

2)

(a)		returns to original length/shape/position/state/zero extension/no **permanent** extension ✓	**1**
(b)		(12 to 14 big squares/318 small squares ± 8 area of 1 big square = 10N × 0.05m = 0.50/small = 2 × 0.01 = 0.02) statement of method that refers to **area** ✓ accept triangle if **area** is mentioned 5.0 to 8.0 (J) or clear attempt to calculate correct area ✓ triangle OK here 5.1 (J) for single triangle is max 2 6.0 to 7.0 (J) ✓	**4**
(c)		$(E =) \frac{FL}{A\Delta L}$ ✓ $(=) \frac{10 \times 0.50}{5.0 \times 10^{-6} \times 0.04}$ ✓ also gets first mark incorrect values of *F* and *ΔL* get first mark only 2.5×10^{7} (Pa) ✓ **or** (stress = *F/A* =) $10/5 \times 10^{-6}$ ($= 2.0 \times 10^{6}$ Pa) ✓ (strain = *ΔL/L* =) 0.04/0.5 (= 0.08) ✓ $2 \times 10^{6}/0.08$ gets both marks *E* correctly evaluated from incorrect value of stress and incorrect value of strain gets 1 mark only use of 50 (N) and 0.04 (m) giving 1.25×10^{8} (Pa) gains 2 marks use of 5(N) and 0.4 (m) is max 2 2.5×10^{7} (Pa) ✓	**3**
(d)	(i)	straight line through origin finishing at the same point as the rubber ± 1 small division ✓	**1**
(d)	(ii)	**point beyond which** graph is no longer linear **or** force no longer proportional to extension **or** Hooke's law limit ✓	**1**
		Total	**10**

3)

(a)	(i)	force × perpendicular distance ✓ between line of action of force and the point ✓	**2**
(a)	(ii)	rear ✓ at rear + idea that centre of mass is closer to the rear wheel (than to the front wheel) ✓	**2**
(a)	(iii)	14000 × 1.4 = F × 2.5 ✓ F = 7840 (N) ✓ divides their final answer by 2 ✓ = 3900 (N) ✓ (3922)	**4**
(b)		$(F = k\Delta l)\ \frac{F}{k}$ or $(\Delta l =)\ \frac{\text{a(iii)}}{100000}$ ✓ = 0.039 (m) ✓ ecf	**2**
(c)		F = (100000 × 0.065 =) 6500 (N) ✓ F = (2 × 6500) = 13000 (N) ✓	**2**
		Total	**12**

4)

(a) QWC	the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication **descriptor**	**mark range**
good - excellent	(i) Uses accurately appropriate grammar, spelling, punctuation and legibility. (ii) Uses the most appropriate form and style of writing to give an explanation or to present an argument in a well structured piece of extended writing. [may include bullet points and/or formulae or equations] **Physics**: describes a workable account of making most measurements accurately. **For 6 marks**: complete description of the measurements required + **how to find the extension** + instruments needed + at least 2 accuracy points **For 5 marks**: all 4 quantities measured including **varying** load + 2 instruments, 2 accuracy points.	**5 - 6**
modest - adequate	(i) Only a few errors. (ii) Some structure to answer, style acceptable, arguments or explanations partially supported by evidence or examples. **Physics**: describes a workable account of making all or most of the measurements and has some correct awareness of at least one accurate measurement. **For 4 marks**: all 4 quantities measured including **varying** load + 2 instruments mentioned + 1 accuracy point. **For 3 marks**: 3 quantities (**load**, **extension**, **diameter** or **cross-sectional area**) may only omit original length + 1 instrument + 1 accuracy point.	**3 - 4**
poor - limited	(i) Several significant errors. (ii) Answer lacking structure, arguments not supported by evidence and contains limited information. **Physics**: unable to give a workable account but can describe some of the measurements. **For 2 marks**: load or mass + measure extension + one instrument mentioned. **For 1 mark**: applying a single load/mass + one other quantity or one instrument named or shown.	**1 – 2**
incorrect, inappropriate or no response		**0**

		Quantities to be measured • describe/show means of applying a **load/force** to a wire • measure **original length** • measure **extension** • measure **diameter** • extension = extension length – original length (needed for six marks) Measuring instruments • use of **rule**/ruler/tape measure • measure diameter with **micrometer** • use of **travelling microscope** to measure extension, or extension of wire measured with **vernier** scale for Searle's apparatus Accuracy • varying load/mass • repeat readings (of length or extension) • diameter measured in several places • Searle's 'control' wire negating effect of temperature change • change in diameter monitored (with micrometer) • original length of wire ≥ 1.0 m Additional creditworthy point • explain how cross-sectional area is found using $A = \pi (D/2)^2$ • showing how Young modulus is found is regarded as neutral	
(b)	(i)	good straight line through origin (within one square) up to stress = 5.1×10^7 and line that lies close to data points thereafter ✓	**1**
(b)	(ii)	evidence of use of gradient or stress/strain ✓ Δ strain used ≥ 3.2 ($\times 10^{-3}$) for correct gradient calculation ✓ $1.0 \pm 0.05 \times 10^{10}$ ✓ (0.95 to 1.05) allow 1 sf ecf form their line – may gain full marks Pa or $N\,m^{-2}$ or N/m^2 only ✓	**4**
(c)		originates at last point + parallel to their first line + straight + touches *x* axis ✓	**1**
		Total	**12**

5)

(a)	(i)	straight best fit line from 0 → (at least) extension of 4.0×10^{-3} m ✓ smooth curve near points after 5.0×10^{-3} m ✓	**2**
(a)	(ii)	$\left(k = \frac{\Delta F}{\Delta l} = \frac{2.55(\times 10^5)}{5.0\ (\times 10^{-3})}\right)$ their $\frac{\Delta F}{\Delta l}$ (ignore powers of ten) ✓ = 5.1×10^7 **and** x axis interval ≥ 3.0 ✓ (5.06 to 5.14×10^7 N m^{-1}) ecf from graph allow error in calculation ± 2%	**2**
(b)		load = 2.8×10^5 or $\left(stress = \frac{F}{A}\right) = \frac{2.8\ (\times 10^5)}{2.5 \times 10^{-3}}$ ✓ 2.8 only = 1.1×10^8 (Pa) 110 (MPa) ✓ (1.12×10^8) (M)Pa, pascals, N m^{-2} ✓	**3**
(c)		$\left(\Delta l = \frac{F}{k}\right) = \frac{150000}{5.1 \times 10^7}$ ✓ (= 2.94×10^{-3} m for 10 m) gives 0.29(4) (m) ✓ ecf or reads a reasonable extension for 150 kN from the graph ✓ and multiples by 100 (= 0.29) (ecf) ✓	**2**
		Total	**9**

6)

a		extension divided by its **original** length ✓ do not allow symbols unless defined ✓	**1**
b		1.9×10^8 (Pa) ✓	**1**
c		point on line **marked 'A'** between a strain of 1.0×10^{-3} and 3.5×10^{-3} ✓	**1**
d		clear evidence of gradient calculation for **straight section** eg 1.18 (1.2) × 10^8/1.0 × 10^{-3} ✓ = 120 GPa **and stress used ≥ 0.6×10^8 Pa** ✓ allow range 116 – 120 GPa **Pa or Nm^{-2} or N/m^2** ✓	**3**
e	i	clear attempt to calculate correct area (evidence on graph is sufficient) ✓ (32 whole squares + 12 part/2 = 38 squares) (38 × 10000 =) 380000 (J m^{-3}) ✓ allow range 375000 to 400000	**2**
e	ii	$V = m/\rho$ **or** 0.015/8960 **or** 1.674×10^{-6} (m^3) ✓ 380 000 × 1.674×10^{-6} = 0.64 (0.6362 J) ✓ ecf from ei	**2**
f		straight line passing through origin (small curvature to the right only above 160 MPa is acceptable) end at 176 MPa ✓ (allow 174 to 178) straight section to the left of the line for copper (steeper gradient) ✓	**2**
		Total	**12**

7)

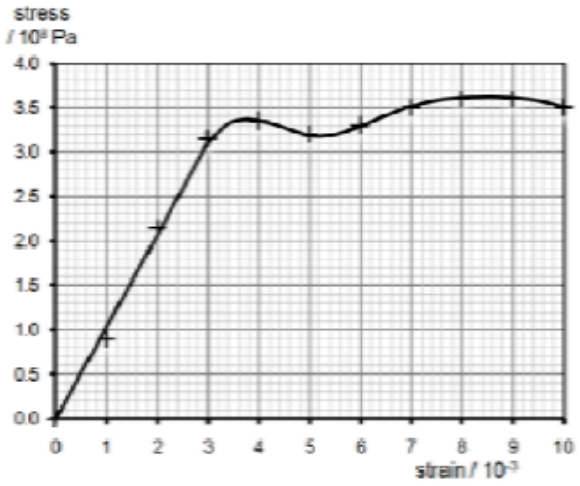
a		$(W = mg)$ $= 4.8 \times 35 \times 9.81$ ✓ $=1600$ (1648 N) ✓	2	Allow g=10 : 1680 (1700 N) g = 9.8 → 1646 N max 1 for doubling or halving. Max 1 for use of grammes
b		(stress = tension / area) $= (0.5 \times) 1.5\times10^{6} / 6.2\times10^{-4}$ OR $= 1.5\times10^{6} / (2 \times) 6.2\times10^{-4}$ ✓ $= 1.2\times10^{9}$ (1.21 GPa) ✓	2	For first mark, forgive absence of or incorrect doubling/ halving. Forgive incorrect prefix if correct answer seen.
c	i	(weight = stress × area) $= 400\times(10^{6}) \times 6.2\times10^{-4}$ (= 248 000 N) ✓ $(\times 2 =) 5.0\times10^{5}$ (496 000 N) ✓	2	max 1 mark for incorrect power of ten in first marking point max 1 mark for doubling or halving both stress and area Forgive incorrect prefix if correct answer seen. Look out for YM ÷ 400k Pa which gives correct answer but scores zero.
c	ii	$\Delta L = \frac{F\,L}{A\,E}$ **OR** correct substitution into a correct equation (forgive incorrect doubling or halving for this mark only) ✓ $= \frac{(\text{Ans } 4ci/2) \times 35}{6.2\times10^{-4} \times 2.1\times10^{11}}$ **OR** $\frac{\text{Ans } 4ci \times 35}{2 \times 6.2\times10^{-4} \times 2.1\times10^{11}}$ ✓ ecf from 4ci $(= \frac{(4.96\times10^{5}/2) \times 35}{6.2\times10^{-4} \times 2.1\times10^{11}} =) 6.7\times10^{-2}$ (6.667×10^{-2} m) ✓ ecf from 4ci	3	OR alternative method: strain = stress/ E then $\Delta L = L$ x strain If answer to 4ci is used, it must be halved, unless area is doubled, for this mark Any incorrect doubling or halving is max 1 mark. Allow 0.07
c	iii	$(k = \frac{F}{\Delta L})$ $= \frac{2 \times 248\,000}{6.667\times10^{-2}}$ OR correct substitution into $F=k\Delta L$ ✓ ecf ci and cii (answer 4c(i) ÷ answer 4c(ii)) $= 7.4(4)\times10^{6}$ ✓ (Nm^{-1})	2	Allow halving extension for force on one cable Correct answer gains both marks
c	iv	$(E = \frac{1}{2}F\Delta L$ or $E = \frac{1}{2}k\Delta L^{2})$ $= ½ \times 496\,000 \times 6.667\times10^{-2}$ OR $½ \times 7.4(4) \times 10^{6} \times (6.667 \times 10^{-2})^{2}$ ✓ ecf ci, cii, ciii $= 1.6(5) \times 10^{4}$ (J) ✓	2	Correct answer gains both marks Forgive incorrect prefix if correct answer seen. Doubling the force gets zero.
		total	13	

8)

(a)	(i)	weight of container (= mg = 22000 × 9.8(1)) = 2.16×10^{5} (N) ✓ tension (= ¼ *mg*) = (5.39) 5.4×10^{4} (N) or divide a weight by 4 ✓	**7**
	(ii)	moment (= force × distance) = 22000 *g* × 32 ✓ ecf weight in (a)(i) = 6.9 or 7.0×10^{6} ✓ **N m** or correct base units ✓ not J, nm, NM	
	(iii)	the counterweight ✓ provides a (sufficiently large) anticlockwise moment (about Q) or moment in opposite direction (to that of the container to prevent the crane toppling clockwise) ✓ **or** left hand pillar pulls (down) ✓ and provides anticlockwise moment **or** the centre of mass of the crane('s frame and the counterweight) is between the two pillars ✓ which prevents the crane toppling **clockwise**/to right ✓	

(b)	(i)	(tensile) stress (= $\frac{\text{tension}}{\text{csa}}$) = $\frac{5.4\times10^{4}}{3.8\times10^{-4}}$ ecf (a)(i) ✓ = 1.4(2) × 10^{8} ✓ **Pa** (or N m^{-2}) ✓	**5**
	(ii)	extension = $\frac{\text{length} \times \text{stress}}{E}$ or $\frac{FL}{EA}$ ✓ = $\frac{25\times1.4\times10^{8}}{2.1\times10^{11}}$ and (= 1.7 × 10^{-2}m) = 17 (mm) ✓	
		Total	**12**

9)

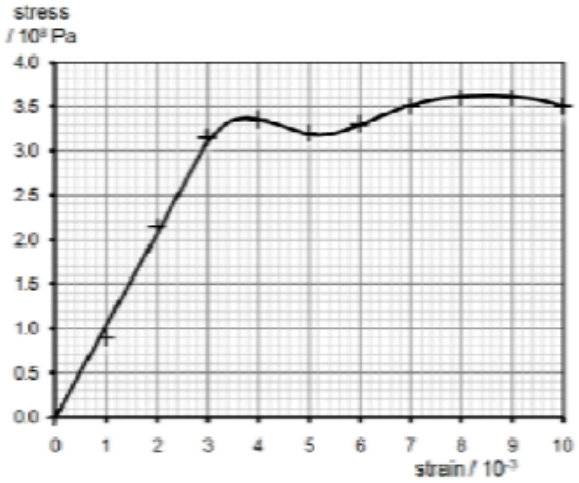
a	 suitable scale on both axes (eg not going up in 3s) **and** > ½ space used ✓ ≥ 8 points correct (within half a small square) ✓ line is straight up to at least stress = 2.5 × 10^{8} **and** curve is smooth beyond straight section ✓	**3**
b	understanding that *E* = gradient (= Δ*y*/Δ*x*) ✓ allow *y*/*x* if line passes through origin = 1.05 × 10^{11} (Pa) (allow 0.90 to 1.1) **ecf** from their line in (a) if answer outside this range **and** uses a y value ≥ 2.0 ✓ when values used from table; • two marks can be scored only if candidates line passes through them • one mark only can be scored if these points are not on their line	**2**

c	correct rearrangement of symbols or numbers ignoring incorrect powers of ten, eg $A = \frac{FL}{E\Delta L}$ ✓ correct substitution in any correct form of the equation, eg = $\frac{10(000)\times3.0}{1.90\ (\times10^{11})\times1.0\ (\times10^{-3})}$ ✓ allow incorrect powers of ten for this mark = 1.6 × 10^{-4} ✓ (1.5789) (m^{2})	**3**
	Total	**8**

10)

(a) (i)	the lines are not straight (owtte) ✓	
(ii)	there is no permanent extension ✓ (or the overall/final extension is zero or the unloading curve returns to zero extension)	**3**
(iii)	(area represents) **work done** (on or energy transfer to the rubber cord) or **energy** (stored) ✓ not heat/thermal energy	
(b)	the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication	
QWC	**descriptor**	**mark range**
good - excellent	The candidate provides a comprehensive and coherent description which includes nearly all the necessary procedures and measurements in a logical order. The descriptions should show awareness of how to apply a variable force. They should know that measurements are to be made as the force is increased then **as it is decreased**. In addition, they should know how to calculate/measure the extension of the cord. **At least five different masses/'large number' of masses are used. Minimum 7 masses to reach 6 marks**. The diagram should be detailed.	**5 - 6**
modest - adequate	The description should include most of the necessary procedures including **how to apply a variable force** and should include the necessary measurements. They may not have described the procedures in a logical order. They may not appreciate that measurements are also to be made as the cord is unloaded. They should know **that the extension** of the cord must be found and name a **suitable measuring instrument (or seen in diagram – label need not be seen)/how to calculate**. The diagram may lack some detail.	**3 - 4**
poor - limited	The candidate knows that the **extension or cord length** is to be measured for **different forces** – may be apparent from the diagram. They may not appreciate that measurements are also to be made as the cord is unloaded. They may not state how to calculate the extension of the cord. The diagram may not have been drawn.	**1 – 2**
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	**0**
	The explanation expected in a competent answer should include a coherent selection of the following physics ideas.	
	diagram showing rubber cord fixed at one end supporting a weight at the other end or pulled by a force ✓	
	means of applying variable force drawn or described (eg use of standard masses or a newtonmeter) ✓	
	means of measuring cord drawn or described ✓	
	procedure	
	measured force applied (or known weights used) ✓	
	cord extension measured or calculated ✓	
	repeat for increasing then decreasing length (or force/weight) ✓	
	extension calculated from cord length – initial length ✓	
	Total	**9**

11)

a	 suitable scale on both axes (eg not going up in 3s) **and** > ½ space used ✓ ≥ 8 points correct (within half a small square) ✓ line is straight up to at least stress = 2.5×10^8 **and** curve is smooth beyond straight section ✓	**3**
b	understanding that E = gradient (= $\Delta y/\Delta x$) ✓ allow y/x if line passes through origin $= 1.05 \times 10^{11}$ (Pa) (allow 0.90 to 1.1) **ecf** from their line in (a) if answer outside this range **and** uses a y value ≥ 2.0 ✓ when values used from table; • two marks can be scored only if candidates line passes through them • one mark only can be scored if these points are not on their line	**2**
c	correct rearrangement of symbols or numbers ignoring incorrect powers of ten, eg $A = \frac{FL}{E\Delta L}$ ✓ correct substitution in any correct form of the equation, eg = $\frac{10(000)\times 3.0}{1.90\ (\times 10^{11})\times 1.0\ (\times 10^{-3})}$ ✓ allow incorrect powers of ten for this mark $= 1.6 \times 10^{-4}$ ✓ (1.5789) (m^2)	**3**
	Total	**8**

12)

a		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Candidate must suggest: • drawing a graph of F vs ΔL (or *vice versa*) • AND that k is in some way linked to the gradient • AND use of a suitable named instrument to measure or determine extension • AND 1 further means of reducing uncertainty: repeats / minimum 8 different readings / use of vernier scale / check values of mass with balance / parallax elimination with set square, pointer in contact with scale, mirror. For 6 marks: must also give suitable range at least up to 10N but not beyond 20N (accept 'up to 20N' / 'not beyond 20N') AND minimum **8 different readings** OR **parallax** elimination must be included AND **repeats** must be included AND correctly explains how k is obtained from their graph. **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. Candidate must suggest: • to measure / determine extension OR initial and final length • AND to use $F = k\Delta L$ or $k = F / \Delta L$ OR drawing a graph of F vs ΔL (or *vice versa*) • AND use of suitable **instrument** to measure extension OR 1 means of reducing **uncertainty**: repeats / use of vernier scale / check values of mass with balance / parallax elimination with set square, pointer in contact with scale,	max 6

		mirror / minimum 8 different readings / graphical approach For 4 marks, **uncertainty** comment AND **instrument** required **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. Any relevant statement from the marking points above For 2 marks: must mention minimum two points including: • to measure / determine extension OR initial and final length	

b	i	($k = 2 \times 85 = 170$ (N m^{-1})) ($\Delta L = F / k =$) 15 / 170 (or 7.5 / 85) ✓ = 0.088 ✓ (m) (0.0882)	2

b	ii	($k = ½ \times 85 = 42.5$) ($\Delta L = F / k =$) 15/42.5 (or 2 x 15/85) ✓ = 0.35 ✓ (m) (0.3529)	2

b	iii	($W = ½ F\Delta L$ or $½ k\Delta L^2$) = ½ × 15 × 0.0882 (or 2 x ½ × 7.5 × 0.0882) ✓ ecf 5bi = 0.66 ✓ (J) (0.6615) ecf 5bi	2

b	iv	(series) **greater** ✓ ecf for answer 'less' or 'same' where candidates incorrect answers to 5bi and 5bii support this. extension is more (in series) and the **force is the same** (in both situations) ✓ **AND** quotes Energy stored = (½)Fs or $½ F\Delta L$ OR energy proportional to extension ✓	3

13)

a		Force proportional to extension ✓ up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark	2	Symbols must be defined Accept word equation allow '$F=k\Delta L$ (or $F \propto \Delta L$) up to the limit of proportionality' **for the second mark only** allow stress ∝ strain up to the limit of proportionality' **for the second mark only**
b		Gradient clearly attempted / use of $k=F/\Delta L$✓ correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200) OR 1154 ± 6 seen AND load used >= 15 ✓ (= 1100 or 1200 (2sf)) **Nm^{-1}** / N/m (newtons per metre) ✓ (not n/m, n/M, N/M)	3	k = 30/0.026 = 1154 or 31/0.027 = 1148 1100 or 1200 with no other working gets 1 out of 2 Do not allow 32/0.0280 or 33/0.0290 (point A) for second mark. 32/0.028 is outside tolerance. 32/0.0277 is just inside.
c		any area calculated or link energy with area / use of $1/2F\Delta L$ ✓ 35 whole squares, 16 part gives 43 ± 1.0 **OR** equivalent correct method to find whole area ✓ 0.025 Nm per (1cm) square x candidates number of squares and correctly evaluated OR (= 1.075) = 1.1 (J) (1.05 to 1.10 if not rounded) ✓	3	(or 0.001 Nm for little squares)
d		permanent deformation / permanent extension ✓	1	Allow: 'doesn't return to original length'; correct reference to 'yield' e.g. allow **'extension beyond the yield point'** do not accept: 'does not obey Hooke's law' or 'ceases to obey Hooke's law',
e		any line from B to a point on the x axis from 0.005 to 0.020 ✓ straight line from B to x axis (and no further) that reaches x axis for 0.010<=ΔL<= 0.014 ✓	2	
f		work done by spring < work done by the load	1	Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

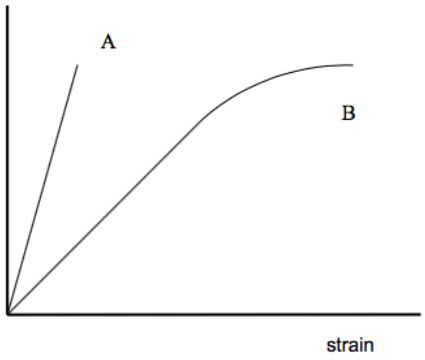
14)

a 5/6	Good/excellent	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Mentions **5** of the following: • Diagram (not necessarily labelled) showing a workable arrangement of suitable apparatus • measure diameter of wires • use a micrometer (for the diameter)* • apply range of loads or masses • measure original length • measure or calculate extension • (metre) rule (or equivalent) for the original length or extended length or extension* • Calculation of the weight of the mass \ use 'weights' in newtons And **2** of the following: • Measure diameter in several places • At least 7 different loads* • Repeat measurements for the same wire (or measure whilst unloading)	5/6		
		• Use of a travelling microscope or Searle's apparatus \ pointer touching scale \ set square (for parallax reduction) \ Vernier scale (not Vernier calipers) * • Monitor diameter change during experiment *These points may appear in a clear diagram			
3/4	Moderate	**Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. Mentions **4** points in total from the following 2 lists: • Diagram (not necessarily labelled) showing a workable arrangement of suitable apparatus • measure diameter of wires (must be stated) • use a micrometer (for the diameter)* • apply range of loads or masses • measure original length • measure or calculate extension • (metre) rule (or equivalent) for the original length or extended length or extension* • Calculation of the weight of the mass \ use 'weights' in newtons Accuracy • Measure diameter in several places • At least 7 different loads* • Repeat measurements for the same wire (or measure whilst unloading) • Use of a travelling microscope or Searle's apparatus \ pointer	3/4		

		touching scale \ set square(for parallax reduction) \ Vernier scale (not Vernier calipers)* • Monitor diameter change during experiment *These points may appear in a clear and suitably labelled diagram A **four mark answer** will have good QWC **OR** will exceed the specification above and will have at least one of the 5 points from the Accuracy list.			
1/2	Limited	**Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. **Two** valid points from the list For two marks, at least **3** points are required	1/2		
		Marking points: • Diagram (not necessarily labelled) showing a workable arrangement of suitable apparatus • measure diameter of wires • use a micrometer (for the diameter)* • apply range of loads or masses • measure original length • measure or calculate extension		**6 marks**	

		• (metre) rule (or equivalent) for the original length or extended length or extension* • Calculation of the weight of the mass \ use 'weights' in newtons • Measure diameter in several places • At least 7 different loads • Repeat measurements for the same wire (or measure whilst unloading) • Use of a travelling microscope or Searle's apparatus \ pointer touching scale \ set square(for parallax reduction) \ Vernier scale (not Vernier calipers) * • Monitor diameter change during experiment			

b	i	brittle ✓ allow misspellings allow: britle, brittleness,	1		

b	ii	stress  For stress- strain: Straight line labelled 'A' with greater gradient than other line and starting close to origin✓ allow small curve in correct direction at end of line. Line labelled 'B' with significant curve and decreasing gradient which may then undulate ✓ (**forgive one label to be missing**)	3		Allow full credit if strain plotted against stress correctly Allow reasonable free hand straight line. Tolerance for curve of A: no more than 10% of the total change in strain for their line.

		Both of the above AND axes labelled, y, 'stress' or symbol or F/A, and x, 'strain or symbol or deltaL / L' ✓ (disallow if incorrect units are included but forgive 'PA' etc) (Assume stress-strain if no labels are give – max 2) For strain – stress: Straight line labelled 'A' with lesser gradient than other line ✓ allow small curve in correct direction at end of line. Line labelled 'B' with significant curve and increasing gradient which may then undulate ✓ (allow one label to be missing) Both of the above AND axes labelled, x, 'stress' or symbol or F/A , and y, 'strain or symbol or deltaL / L' ✓ (disallow if incorrect units are included)			Line B must have a curved portion of 20% or more. It must have an initial straight section A correct force-extension graph gets max 2
c	i	(strain = $\Delta L / L$) strain = 0.24/100 (= 0.0024) OR correct calculation of extension (0.0036) ✓ (stress = E x strain) stress = 2.80 (x 10^{11}) x 0.0024 ✓ **ecf from first mark** = 6.7 x 10^{8} (Pa) ✓ ecf from first mark	3		Some working required for full marks. Correct answer only gets 2
c	ii	($A = \pi(D/2)^2$)	3		Some working required for full
		$\pi(1.4 (x10^{-3}) /2)^2$ OR = 1.539 x 10^{-6} (m^2) ✓ ignore incorrect powers of ten $F = E$ x A x $\Delta L / L$ **OR** = 280 (x 10^{9}) x 1.539 (x 10^{-6}) 0.0024 ecf 4ci (incorrect extension or strain) **OR** A x their stress from 4ci ✓ ecf 4ci for strain and ecf for incorrect area in 4cii but do not accept use of diameter or radius as the area = 1 000 ✓ (1034.46 N)			marks. Correct answer only gets 2 Use of diameter or radius for area gets zero for the question
		total		16	

15)

a	breaking stress ✓ stiffness constant, k tensile strain tensile stress Young modulus ✓		1
bi	Elastic limit✓	only one attempt at the answer is allowed	1
bii	(E = 300 x 10^{6} / 4 x10^{-2} = 7.5 x10^{9}) 7.5 (Pa) ✓ allow 7.4 to 7.6 (Pa) x 10^{9} ✓	first mark is for most significant digits ignoring the power of 10. Eg 7500 gains mark	2
c	straight line beginning on existing line at a strain of 0.10 and hitting the strain axis at a lower non-zero value ✓ line that ends on the x -axis with strain between 0.045 and 0.055✓(only allow if first mark is given)	ie accuracy required ± one division	2
d	8.99 x 10^{-3} (m^3)✓ condone 1 sig fig	allow 9.00 × 10^{-3}	1
e	0.9872 x 8.99 x 10^{-3} or = 8.8749 x 10^{-3} (m^3) ✓ allow CE from 4d ($m = \rho V$)= 2700 x 8.8749 x 10^{-3} = 24 (kg) ✓ (23.962 kg) allow CE from first part ,e.g. if 1.28% was used gives 0.311 kg	V =0.9872 × (d) m = 2.665 × (d) 1.28% of vol = 1.15 × 10^{-4} m^3	2

16)

(a)	the force (needed to stretch a spring is directly) is proportional to the extension (of the spring from its natural length) or equation with all terms defined ✓ up to the limit of proportionally ✓	**2**
(b) (i) **QWC**	**descriptor**	**mark range**
good - excellent	The candidate provides a comprehensive and coherent description which includes all the necessary measurements in a logical order. The description should show awareness of the need to use a range of standard masses. In addition, the use of the measurements is explained clearly, including an outline of a graphical method to find the mass of the rock sample, or calculation using two or more standard masses and averaging. For 6 marks there must be a description of how to make accurate measurements.	**5 - 6**
modest - adequate	The candidate's description includes the necessary measurements using one standard mass as well as the rock sample. The description may not be presented in a logical order and they show little consideration in relation to making the measurements accurately. A clear explanation is provided of how to find the mass of the rock sample from their measurements, including correct use of Hooke's law through calculations or inadequate graphical method.	**3 - 4**
poor - limited	The candidate knows the necessary measurements to be made using a standard mass and the rock sample. The explanation of how to find the mass of the rock sample may be sketchy.	**1 – 2**
	The explanations expected in a competent answer should include a coherent account of the following measurements and their use	
	measurements	
	(use a metre rule to) measure the length of the spring ✓	
	when it supports a standard mass (or known) mass (m) and when it supports the rock sample	
	repeat for different (standard) masses	
	accuracy – use a set square or other suitable method to measure the position of the lower end of the spring against the (vertical) mm rule or method to reduce parallax	
	use of measurements	
	either	
	plot graph of mass against length (or extension) ✓	
	read off mass corresponding to length (or extension) due to the sample ✓	
	or	
	the extension of the spring = length – unstretched length ✓	
	mass of rock sample = $\frac{\text{extension of spring supporting rock sample}}{\text{extension of spring supporting known mass}} \times M$ ✓	