

1)

<p>(a)</p>	<p>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 ✓</p>	<p><b>2</b></p>
<p>(b) (i)</p> <p><b>QWC</b></p> <p>good - excellent</p> <p>modest - adequate</p> <p>poor - limited</p>	<p style="text-align: center;"><b>descriptor</b></p> <p>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.</p> <p>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.</p> <p>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.</p> <p><b>The explanations expected in a competent answer should include a coherent account of the following measurements and their use</b></p> <p><b>measurements</b></p> <p>(use a metre rule to) measure the length of the spring ✓ when it supports a standard mass (or known) mass (<math>m</math>) 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</p> <p><b>use of measurements</b></p> <p><i>either</i></p> <p>plot graph of mass against length (or extension) ✓ read off mass corresponding to length (or extension) due to the sample ✓</p> <p><i>or</i></p> <p>the extension of the spring = length – unstretched length ✓</p> <p>mass of rock sample = <math>\frac{\text{extension of spring supporting rock sample}}{\text{extension of spring supporting known mass}} \times M</math> ✓</p>	<p><b>mark range</b></p> <p><b>5 - 6</b></p> <p><b>3 - 4</b></p> <p><b>1 – 2</b></p>

(ii)	<p>use a (G) clamp (or suitable heavy weight) to fix/clamp the base of the stand to the table ✓</p> <p>clamp (or weight) provides an anticlockwise moment (about the edge of the stand greater than the moment of the object on the spring)/ counterbalances (the load) ✓</p> <p><b>or</b> adjust the stand so the spring is nearer to it ✓</p> <p>so the moment of the load is reduced (and is less likely to overcome the anticlockwise moment of the base of the stand about the edge of the stand) ✓</p> <p><b>or</b> turn the base of the stand/rotate the boss by <math>180^\circ</math> ✓</p> <p>so the weight of the load acts through the base ✓</p>	
	<b>Total</b>	<b>10</b>

2)

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

	<p>Quantities to be measured</p> <ul style="list-style-type: none"> <li>describe/show means of applying a <b>load/force</b> to a wire</li> <li>measure <b>original length</b></li> <li>measure <b>extension</b></li> <li>measure <b>diameter</b></li> <li>extension = extension length – original length (needed for six marks)</li> </ul> <p>Measuring instruments</p> <ul style="list-style-type: none"> <li>use of <b>rule/ruler/tape</b> measure</li> <li>measure diameter with <b>micrometer</b></li> <li>use of <b>travelling microscope</b> to measure extension, or extension of wire measured with <b>vernier</b> scale for Searle's apparatus</li> </ul> <p>Accuracy</p> <ul style="list-style-type: none"> <li>varying load/mass</li> <li>repeat readings (of length or extension)</li> <li>diameter measured in several places</li> <li>Searle's 'control' wire negating effect of temperature change</li> <li>change in diameter monitored (with micrometer)</li> <li>original length of wire <math>\geq 1.0</math> m</li> </ul> <p>Additional creditworthy point</p> <ul style="list-style-type: none"> <li>explain how cross-sectional area is found using <math>A = \pi (D/2)^2</math></li> <li>showing how Young modulus is found is regarded as neutral</li> </ul>		
(b)	(i)	good straight line through origin (within one square) up to stress = $5.1 \times 10^7$ and line that lies close to data points thereafter ✓	<b>1</b>
(b)	(ii)	evidence of use of gradient or stress/strain ✓ $\Delta$ strain used $\geq 3.2 (\times 10^{-3})$ for correct gradient calculation ✓ $1.0 \pm 0.05 \times 10^{10}$ ✓ (0.95 to 1.05) allow 1 sf ecf from their line – may gain full marks Pa or $\text{Nm}^{-2}$ or $\text{N/m}^2$ only ✓	<b>4</b>
(c)		originates at last point + parallel to their first line + straight + touches x axis ✓	<b>1</b>
		<b>Total</b>	<b>12</b>

3)



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

4)

a	<p><b>The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.</b></p> <p>The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.</p> <p><b>High Level (Good to excellent): 5 or 6 marks</b></p> <p>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.</p> <p>Candidate must suggest:</p> <ul style="list-style-type: none"> <li>• drawing a graph of <math>F</math> vs <math>\Delta L</math> (or <i>vice versa</i>)</li> <li>• AND that <math>k</math> is in some way linked to the gradient</li> <li>• AND use of a suitable named instrument to measure or determine extension</li> <li>• 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.</li> </ul> <p>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 <b>8 different readings</b> OR <b>parallax</b> elimination must be included AND <b>repeats</b> must be included AND correctly explains how <math>k</math> is obtained from their graph.</p> <p><b>Intermediate Level (Modest to adequate): 3 or 4 marks</b></p> <p>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.</p> <p>Candidate must suggest:</p> <ul style="list-style-type: none"> <li>• to measure / determine extension OR initial and final length</li> <li>• AND to use <math>F = k \Delta L</math> or <math>k = F / \Delta L</math> OR drawing a graph of <math>F</math> vs <math>\Delta L</math> (or <i>vice versa</i>)</li> <li>• AND use of suitable <b>instrument</b> to measure extension OR 1 means of reducing <b>uncertainty</b>: repeats / use of vernier scale / check values of mass with balance / parallax elimination with set square, pointer in contact with scale,</li> </ul>	max 6
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		<p>mirror / minimum 8 different readings / graphical approach</p> <p>For 4 marks, <b>uncertainty</b> comment AND <b>instrument</b> required</p> <p><b>Low Level (Poor to limited): 1 or 2 marks</b></p> <p>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.</p> <p>Any relevant statement from the marking points above</p> <p>For 2 marks: must mention minimum two points including:</p> <ul style="list-style-type: none"> <li>to measure / determine extension OR initial and final length</li> </ul>	
b	i	$(k = 2 \times 85 = 170 \text{ (N m}^{-1}\text{)})$ $(\Delta L = F / k =) 15 / 170 \text{ ( or } 7.5 / 85 \text{ ) } \checkmark$ $= 0.088 \checkmark \text{ (m) (0.0882)}$	2
b	ii	$(k = \frac{1}{2} \times 85 = 42.5)$ $(\Delta L = F / k =) 15 / 42.5 \text{ ( or } 2 \times 15 / 85 \text{ ) } \checkmark$ $= 0.35 \checkmark \text{ (m) (0.3529)}$	2
b	iii	$(W = \frac{1}{2} F \Delta L \text{ or } \frac{1}{2} k \Delta L^2)$ $= \frac{1}{2} \times 15 \times 0.0882 \text{ ( or } 2 \times \frac{1}{2} \times 7.5 \times 0.0882 \text{ ) } \checkmark \text{ ecf 5bi}$ $= 0.66 \checkmark \text{ (J) (0.6615) ecf 5bi}$	2
b	iv	<p>(series) <b>greater</b> <math>\checkmark</math> ecf for answer 'less' or 'same' where candidates incorrect answers to 5bi and 5bii support this.</p> <p>extension is more (in series) and the <b>force is the same</b> (in both situations) <math>\checkmark</math></p> <p><b>AND</b> quotes Energy stored = <math>(\frac{1}{2})Fs</math> or <math>\frac{1}{2} F \Delta L</math> OR energy proportional to extension <math>\checkmark</math></p>	3

5)

(a)	(i)	It has maximum / large / increased <u>stress</u> at this point	B1	<b>Allow:</b> it has 'same force but thinner/smaller area' <b>Not:</b> Thin / small area
	(ii)	The tape has (permanent) extension / deformation when the force / stress is removed (AW)	B1	<b>Note:</b> Need reference to force or stress removed <b>Allow:</b> '.. does not return to original size / shape / length when force / stress is removed'
(b)		<p><b>Measurement:</b>   Diameter                      Any <u>two</u> from:</p> <ul style="list-style-type: none"> <li>• original / initial length (<b>Not:</b> final length)</li> <li>• extension / initial <u>and</u> final lengths</li> <li>• weight / mass</li> </ul> <p><b>Equipment:</b>   Micrometer / vernier (calliper) (for the diameter of the wire)                      Any <u>two</u> from:</p> <ul style="list-style-type: none"> <li>• Ruler / (metre) rule / tape measure (for measuring the original length / extension)</li> <li>• Travelling microscope (for measuring extension)</li> <li>• Scales / balance (for measuring the mass &amp; <i>mg</i> equation is used or for measuring weight) / Newtonmeter (for the weight of hanging masses) / 'known' weights used</li> </ul> <p><b>Determining Young modulus:</b></p> <ul style="list-style-type: none"> <li>• stress = force/(cross-sectional) area <u>and</u> strain = extension/original length</li> <li>• Young modulus = stress/strain / Young modulus is equal to the gradient from stress-strain graph (in the linear region)</li> </ul>	<p>B1 B1 X 2</p> <p>B1 B1 x 2</p> <p>B1 B1</p>	<p><b>The term <i>diameter</i> to be included and spelled correctly to gain the mark</b></p> <p><b>The term <i>micrometer / vernier (calliper)</i> to be included and spelled correctly to the gain mark. (ALLOW: Micrometer is used to measure area / radius / thickness – as BOD)</b></p> <p><b>Allow:</b> 'known masses &amp; <i>mg</i> equation' but <b>not</b> 'known masses'</p> <p><b>Allow:</b> stress = <math>F/A</math> <u>and</u> strain = <math>x/L</math></p> <p><b>Special case for determining Young modulus:</b>                      Gradient from force-extension graph is <math>\frac{EA}{L}</math> B1                      Young modulus = gradient <math>\times L/A</math> B1</p>
<b>Total</b>			<b>10</b>	


**Question 6 Analysis, conclusions and evaluation (15 marks)**

	Mark	Expected Answer	Additional Guidance						
<b>(a)</b>	A1	$\frac{4LF}{\pi E}$							
<b>(b)</b>	T1	$\frac{1}{d^2} / 10^6 \text{ m}^{-2}$							
	T2	<table border="1"> <tr><td>13 or 12.8</td></tr> <tr><td>9.8 or 9.77</td></tr> <tr><td>6.9 or 6.93</td></tr> <tr><td>4.7 or 4.73</td></tr> <tr><td>3.2 or 3.19</td></tr> <tr><td>1.9 or 1.93</td></tr> </table>	13 or 12.8	9.8 or 9.77	6.9 or 6.93	4.7 or 4.73	3.2 or 3.19	1.9 or 1.93	All values to 2 s.f. or 3 s.f. Allow a mixture of significant figures. Must be values in table.
13 or 12.8									
9.8 or 9.77									
6.9 or 6.93									
4.7 or 4.73									
3.2 or 3.19									
1.9 or 1.93									
	U1	From $\pm 2$ to $\pm 0.1$	Allow more than one significant figure.						
<b>(c) (i)</b>	G1	Six points plotted correctly	Must be within half a small square. Do not allow "blobs". ECF allowed from table.						
	U2	Error bars in $\frac{1}{d^2}$ plotted correctly	All error bars to be plotted. Must be accurate to less than half a small square.						
<b>(ii)</b>	G2	Line of best fit	If points are plotted correctly then lower end of line should pass between (3.2, 3.0) and (3.6, 3.0) <b>and</b> upper end of line should pass between (11.2, 10.0) and (11.6, 10.0).						
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through all the error bars.	Line should be clearly labelled or dashed. Examiner judgement on worst acceptable line. Lines must cross. Mark scored only if error bars are plotted.						
<b>(iii)</b>	C1	Gradient of line of best fit	The triangle used should be at least half the length of the drawn line. Check the read-offs. Work to half a small square. Do not penalise POT. (Should be about $9 \times 10^{-10}$ .)						
	U3	Absolute uncertainty in gradient	Method of determining absolute uncertainty Difference in worst gradient and gradient.						
<b>(d) (i)</b>	C2	$\frac{4LF}{\pi \times \text{gradient}} = \frac{60.479}{\text{gradient}}$	Do not penalise POT. (Should be about $7 \times 10^{10}$ .)						
	C3	$\text{Nm}^{-2}$ or Pa	Allow in base units: $\text{kg m}^{-1} \text{s}^{-2}$ .						
<b>(ii)</b>	U4	Percentage uncertainty in $E$	Must be larger than 3%.						


	Mark	Expected Answer	Additional Guidance
(e)	C4	$e$ in the range $15.5 \times 10^{-3}$ to $18.0 \times 10^{-3}$ and given to 2 or 3 s.f.	Allow mm.
	U5	Absolute uncertainty in $e$	Note $e = \frac{\text{gradient}}{d^2}$ is possible.

### Uncertainties in Question 2

#### (c) (iii) Gradient [U3]

uncertainty = gradient of line of best fit – gradient of worst acceptable line

uncertainty =  $\frac{1}{2}$  (steepest worst line gradient – shallowest worst line gradient)

#### (d) (ii) [U4]

$$\text{percentage uncertainty} = \left( \frac{\Delta \text{gradient}}{\text{gradient}} + \frac{0.01}{2.50} + \frac{0.5}{19.0} \right) \times 100 = \left( \frac{\Delta \text{gradient}}{\text{gradient}} \right) \times 100 + 3.03\%$$

$$\max E = \frac{4 \times \max L \times \max F}{\pi \times \min \text{gradient}} = \frac{4 \times 2.51 \times 19.5}{\pi \times \min \text{gradient}} = \frac{62.319}{\min \text{gradient}}$$

$$\min E = \frac{4 \times \min L \times \min F}{\pi \times \max \text{gradient}} = \frac{4 \times 2.49 \times 18.5}{\pi \times \max \text{gradient}} = \frac{58.652}{\max \text{gradient}}$$

#### (e) [U5]

$$\text{percentage uncertainty} = \left( \frac{0.5}{19.0} + \frac{0.01}{2.50} + 2 \times \left( \frac{0.02}{0.23} \right) \right) \times 100 + \%E = 20.4\% + \%E$$

$$\text{percentage uncertainty} = \left( \frac{\Delta \text{gradient}}{\text{gradient}} + 2 \times \left( \frac{0.02}{0.23} \right) \right) \times 100$$

$$\max e = \frac{\max \text{gradient}}{d_{\min}^2}$$

$$\max e = \frac{4 \times L_{\max} \times F_{\max}}{\pi \times E_{\min} \times d_{\min}^2}$$

$$\min e = \frac{\min \text{gradient}}{d_{\max}^2}$$

$$\min e = \frac{4 \times L_{\min} \times F_{\min}}{\pi \times E_{\max} \times d_{\max}^2}$$