Mark Scheme

Q1.

Question Number	Answer	Mark
	The correct answer is **C** A is incorrect because area represents work done per unit volume B is incorrect because area represents work done per unit volume D is incorrect because the breaking point is outside the linear region	**1**

Q2.

Question Number	Answer	Mark
	The correct answer is B (The second wire had a longer length) A is incorrect because the wire would break at the same extension C is incorrect because the wire would break at the same extension D is incorrect because the wire would break at a smaller extension	**1**

Q3.

Question Number	Answer	Mark
	The correct answer is B A is not the correct answer because the mass is not needed C is not the correct answer because radius cannot be directly measured and the mass is not needed D is not the correct answer because radius cannot be directly measured	**1**

Q4.

Question Number	Answer	Mark
(a)	Use of $\sigma = F / A$ (1) $\sigma = 3.8 \times 10^8$ Pa [accept N m^{-2}] **Or** $F_b = 170$ N **Or** $A_{min} = 3.6 \times 10^{-7}$ m^2 (1) Valid comparison in consistent units and conclusion (1) <u>Example of calculation</u> $\sigma = 150$ N ÷ 3.97×10^{-7} m^2 = 3.78×10^8 Pa 3.78 < 4.20 ∴ will not break	3
(b)(i)	Determine gradient of straight line section [straight line ends at 5 mm] (1) [$\Delta x \geq 3$ mm for gradient][Allow use of tangent at origin] (1) $k = 1.30 \times 10^4$ (N m^{-1}) [acceptable range to be determined at pre-stand] [1.27 to 1.33][need to see third s.f.] <u>Example of calculation</u> gradient = 60 / 4.6 = 13.0 gradient = k / N mm^{-1} k = 13.0 N mm^{-1} = 1.30×10^4 N m^{-1}	2
(b)(ii)	Use of $k = EA/x$ (1) $E = 1.3 \times 10^{11}$ Pa [or N m^{-2}](ecf from (b)(i))[their (b)(i) × 1.01×10^7 + unit] (1) <u>Example of calculation</u> $E = k\,x / A$ $E = 1.3 \times 10^4$ N m^{-1} × 4.00 ÷ 3.97×10^{-7} m^2 $E = 1.3 \times 10^{11}$ Pa	2
	Total for question	7

Q5.

Question Number	Answer	Additional Guidance	Mark
(a)	Adding the mass causes the string to be straight / taut **(1)**	Allow so the string is under tension	1
(b)	Increase x **Or** Position the marker further from the clamp **(1)** (absolute) uncertainty will remain the same **(1)** (and) percentage uncertainty is calculated by dividing uncertainty by x / length **(1)** **OR** Position metre rule adjacent to string **Or** Use a set square between metre rule and string **(1)** **Or** View perpendicular to the string / ruler **(1)** To reduce parallax error (dependent on MP1) **(1)** Which decreases (absolute) uncertainty (dependent on MP1)	Allow use a longer length of string (between the clamp and the marker) Ignore decreases percentage uncertainty	3

(c)	Use of $\sigma = \frac{F}{A}$ **(1)** Use of $\varepsilon = \frac{\Delta x}{x}$ **(1)** Use of $E = \frac{\sigma}{\varepsilon}$ **(1)** $E = 4.8$ (GPa) ≈ 5.0 (GPa) so the string is nylon **(1)** **Or** $E = 4.8$ (GPa) which is closest to the value for nylon	<u>Example of calculation</u> $\sigma = \frac{15\ \text{N}}{1.2 \times 10^{-6}\ \text{m}^2} = 12.5 \times 10^6\ \text{Pa}$ $\varepsilon = \frac{4.2 \times 10^{-3}}{1.6} = 2.63 \times 10^{-3}$ $E = \frac{12.5 \times 10^6\ \text{Pa}}{2.63 \times 10^{-3}} = 4.75 \times 10^9\ \text{Pa}$ 4.75×10^9 Pa ≈ 5.0 GPa so the string is nylon	4
	Total for question		**8**

Q6.

Question Number	Answer		Mark
(a)	• Ratio of stress to strain (for a material). **Or** stress per unit strain. **Or** σ / ε with symbols defined. **Or** $\frac{F\,x}{A\,\Delta x}$ with symbols defined.	(1)	(1)
(b)(i)	• Mean diameter = 0.234 mm (rounds to) • Use of $A = \pi r^2$ • $A = 4.3 \times 10^{-8}\,m^2$ **or** $0.043\,mm^2$ <u>Example of calculation</u> Mean diameter = ¼ (0.230 + 0.235 + 0.230 + 0.240) = 0.234 mm Area = $\pi \frac{(0.234 \times 10^{-3}\,m)^2}{4} = 4.30 \times 10^{-8}\,m^2$	(1) (1) (1)	(3)
(b)(ii)	• Use of $W = m\,g$ • Use of gradient = $m / \Delta x$ in Young Modulus formula i.e. E = gradient × g × x /A • $E = 1.6 \times 10^{11}$ Pa e.c.f. from (b)(i) <u>Example of calculation</u> Young modulus = $195 \times 9.81\,N\,kg^{-1} \times \frac{3.50\,m}{4.30 \times 10^{-8}\,m^2}$ $= 1.56 \times 10^{11}$ Pa	(1) (1) (1)	(3)
(b)(iii)	Shorter wire gives greater gradient. Young modulus the same.	(1) (1)	(2)

Q7.

Question Number	Answer	Mark
(a)	Vertical component of tension = $T \cos 76°$ **(1)** Use of 650 N = 2 × vertical component of tension **(1)** $T = 1.34 \times 10^3$ (N) **(1)** <u>Example of calculation</u> 650 N = 2 $T \cos 76°$ T = ½ × 650 N ÷ cos 76° = 1 343 N	3
(b)(i)	Use of sin76° or cos 14° to find new length of cord **(1)** Use of $\varepsilon = \Delta x \div x$ **(1)** ε = 0.03 or 3% **(1)** <u>Example of calculation</u> $(x + \Delta x) \div 2$ = 60 m ÷ sin 76° = 61.8 m Δx = (61.8 × 2) m − 120.0 m = 3.7 m ε = 3.7 m ÷ 120 m = 0.031	3
(b)(ii)	Use of $\sigma = F \div A$ with F = tension from (a) **(1)** Use of $E = \sigma \div \varepsilon$ **(1)** $E = 1.4 \times 10^8$ Pa (ecf from (a) and (b)(i)) **(1)** <u>Example of calculation</u> $\sigma = 1.34 \times 10^3$ N ÷ 3.14×10^{-4} m^2 = 4.28 MPa E = 4.28×10^6 Pa ÷ 0.031 = 1.38×10^8 Pa	3
	Total for question	**9**

Q8.

Question Number	Answer	Mark
(a)*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

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Indicative content

IC1 Measure the original length (from clamp to marker)

IC2 Measure distance moved by marker from original position to determine extension.
Or Measure new length and subtract original length to determine extension

IC3 Calculate weight of masses using $W = mg$
Or Use a newtonmeter to measure weight of masses

IC4 Use diameter to calculate cross-sectional area

IC5 Calculate stress using $\frac{\text{force}}{\text{area}}$ **and** calculate strain using $\frac{\text{extension}}{\text{original length}}$ (allow symbol equations if terms defined)
Or plot a graph of stress against strain
Or plot a graph of force against extension

IC6 Calculate Young Modulus using $\frac{\text{stress}}{\text{strain}}$ (allow symbol equations if terms defined)
Or Correctly relate gradient of (straight section of) graph to Young Modulus.

(b)	Calculates cross-sectional area **(1)** Use of $\sigma = \frac{F}{A}$ **(1)** Use of $E = \frac{\sigma}{\varepsilon}$ **and** use of $\varepsilon = \frac{\Delta x}{x}$ **(1)** $\Delta x = 4.6 \times 10^{-4}$ m **(1)** <u>Example calculation</u> $A = \pi \times \left(\frac{0.56\times10^{-3}\text{ m}}{2}\right)^2 = 2.46 \times 10^{-7}\text{m}^2$ $\sigma = \frac{5.0\text{ N}}{2.46\times10^{-7}\text{m}^2} = 2.03 \times 10^7$ Pa $\varepsilon = \frac{2.03\times10^7\text{Pa}}{1.1\times10^{11}\text{Pa}} = 1.85 \times 10^{-4}$ $\Delta x = 1.85 \times 10^{-4} \times 2.5 = 4.61 \times 10^{-4}$ m	**4**
	Total for question	**10**

Q9.

Question Number	Answer	Mark
(a)	Measure (diameter) at several positions along the wire **(1)** Measure (diameter) at several orientations **(1)**	**2**
(b)(i)	(Safety) goggles should be worn **(1)** (Because) the wire could break. **(1)**	**2**
(b)(ii)	The vernier scale has a better resolution **Or** The vernier scale has a resolution of 0.1 mm **(1)** There is a smaller (percentage) uncertainty (when using the vernier scale). **(1)**	**2**

(c)	**EITHER** Use of $A = \pi r^2$ (1) Use of $\Delta\sigma = \frac{\Delta F}{A}$ with initial force greater than 0 N (1) Use of $\Delta\varepsilon = \frac{\Delta x}{x}$ (1) Use of $E = \frac{\Delta\sigma}{\Delta\varepsilon}$ (1) E = 107 (GPa) ≈ 106 (GPa) so material is brass (1) **OR** Use of $A = \pi r^2$ (1) Determines gradient of graph (1) Calculates $\frac{x}{A}$ (1) Use of $E = \frac{\Delta\sigma}{\Delta\varepsilon}$ (1) E = 107 (GPa) ≈ 106 (GPa) so material is brass (1) <u>Example of calculation</u> $A = \pi \times \left(\frac{0.17 \times 10^{-3}\ \text{m}}{2}\right)^2 = 2.27 \times 10^{-8}\ \text{m}^2$ $\Delta\sigma = \frac{14\ \text{N}}{2.27 \times 10^{-8}\ \text{m}^2} = 6.17 \times 10^8\ \text{Pa}$ $\Delta\varepsilon = \frac{0.0104\ \text{m}}{1.80\ \text{m}} = 5.78 \times 10^{-3}$ $E = \frac{6.17 \times 10^8\ \text{Pa}}{5.78 \times 10^{-3}} = 1.07 \times 10^{11}\ \text{Pa}$ 107 GPa ≈ 106 GPa so material is brass.	5
	Total for question	**11**

Q10.

Question Number	Answer	Mark
(a)	• Use a micrometer (screw gauge) **Or** (vernier)digital calipers (1) • At different orientations **and/or** positions along the wire (1) • Calculate/determine/take/find a mean/average value (1)	3
(b)	• Use of $A = \pi\left(\frac{d}{2}\right)^2$ (1) • Calculate gradient of linear section (up to 3×10^{-3} m, 6.8 N) of graph **Or** use of a corresponding pair of points for F and Δx from the linear region of the graph (1) • Use of $\sigma = \frac{F}{A}$ and $\varepsilon = \frac{\Delta x}{l}$ **Or** use of $E = \frac{Fl}{A\Delta x}$ **Or** Use of $E =$ gradient $\times \frac{l}{A}$ (1) • $E = (1.2 - 1.3) \times 10^{11}$ Pa (1) (MP4 conditional on scoring MP1 & MP2 & MP3) <u>Example of calculation using gradient</u> $A = \pi\left(\frac{2.3 \times 10^{-4}\text{ m}}{2}\right)^2 = 4.15 \times 10^{-8}\text{ m}^2$ Gradient $= \frac{6.5\text{ N}}{2.9 \times 10^{-3}\text{ m}} = 2.2 \times 10^3\text{ N m}^{-1}$ $E = 2.2 \times 10^3\text{ N m}^{-1} \times \frac{2.4\text{ m}}{4.15 \times 10^{-8}\text{m}^2} = 1.27 \times 10^{11}$ Pa	4

*(c)	• This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. • Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. • The following table shows how the marks should be awarded for indicative content.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

• The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2 (a minimum of at least 5 IC points including: IC1 and IC2/IC5 **and** IC3 and IC4/IC5
Answer is partially structured with some linkages and lines of reasoning	1 (a minimum of 3 IC points including: **either** IC1 and IC2/IC5 **Or** IC3 and IC4/IC5)
Answer has no linkages between points and is unstructured	0

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning

	Indicative content • For long(er) wire, the extension will be large(r) • (For the same load) extension is proportional to the original length **Or** $\frac{\text{extension}}{\text{original length}} = \text{constant}$ • For a thin(ner) wire, the extension will be large(r) • (For the same load) extension is inversely proportional to cross-sectional area (may be explained in terms of E, σ and ε) • The percentage uncertainty in the extension/length will be lower (although this will be greater for the cross-sectional area) • A small(er) load can be used with a long/thin wire	6
	Total for question	**13**

Q11.

Question Number	Answer	Mark
(a)	• Micrometer (screw gauge) **Or** digital (not Vernier) calliper(s) **(1)**	1
(b)(i)	• Attempt to calculate gradient **(1)** • Use of linear section, or tangent at origin, with use of large triangle **(1)** • $E = 1.2 \pm 0.05 \times 10^{11}$ Pa **(1)** <u>Example of calculation</u> Extending straight section to 1% 120×10^6 Pa ÷ 0.01 = 1.2×10^{11} Pa	3
(b)(ii)	• Breaking stress read from graph **(1)** • Use of $A = \pi r^2$ **(1)** • Use of $\sigma = F/A$ **(1)** • $F = 2.6 \times 10^4$ N **(1)** <u>Example of calculation</u> Area = $\pi \times (2.525 \times 10^{-3})^2 = 2.00 \times 10^{-5}$ m^2 Force = $1\,280 \times 10^6 \times 2 \times 10^{-5} = 2.56 \times 10^4$ N	4
(b)(iii)	• Use of area under graph = ½σε **(1)** • Substitution of $F = \sigma A$ and $\Delta x = \varepsilon x$ **(1)** • Substitution of $Ax = V$ and $\Delta W = ½ F\Delta x$ **(1)** <u>Example of calculation</u> Area = ½σε = ½ $(F / A)(\Delta x / x)$ = ½ $F\,\Delta x / (A\,x)$ = $\Delta W / V$	3
(b)(iv)	• Calculation of area under graph by a valid method. **(1)** • Area in range 60 to 64 (MJ m^{-3}) **(1)** • Calculation of volume of sample **(1)** • Energy = 500±20 J **(1)** <u>Example of calculation</u> One large square = $200 \times 10^6 \times 0.01 = 2 \times 10^6$ J m^{-3} 31 large squares Volume of sample = 0.40 m $\times 2.0 \times 10^{-5}$ m$^2 = 8.0 \times 10^{-6}$ m^3 Work = $31 \times 8 \times 10^{-6}$ m$^3 \times 2 \times 10^6$ J m$^{-3} = 4.96 \times 10^2$ J	4
	Total for question	15