Marking Scheme

#1

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			**Description and appropriate example given for each [3 × 1]** **Crystalline**- long range, regular (unit cell repeated) Accept 'lattice'. **Amorphous** - no order (accept: short range, irregular) **Polymeric** - long chain molecules (no order between, only within molecules)	3			3		
	(b)	(i)		At (A) molecules unravel (accept untangle) under the action of a force. [Accept – C-C bond rotates] [1] At (B) molecules fully stretched/ strong forces between atoms within molecule / stretching bonds (covalent) [1] Either: Small force (or stress) produces large extension (or strain) at A [hence shallow gradient] Or: Large force (or stress) produces small extension (or strain) at B [hence steep gradient] [1]	1 1	1		3		3
		(ii)	I	Hysteresis [1] Explanation: e.g. area between curves represents energy 'lost' in the cycle or energy is transferred to internal energy in the rubber and then lost as heat [1]	2			2		
			II	Correctly drawn curve, of the same shape but 'below' the extension curve at all points. Can return to origin or shown as small 'permanent set'	1			1		
				Question total	**8**	**1**	**0**	**9**	**0**	**3**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)	Ruler and micrometer or Vernier callipers	1			1		1
		(ii)	Area = $\pi \times (0.505 \times 10^{-3})^2 = 8.01 \times 10^{-7}$ [m^2] (1) $E = \frac{Fl}{\Delta l A} = \frac{7.5 \times 0.2}{(28 \times 10^{-6})(8.01 \times 10^{-7})}$ (1) $E = 6.6 \times 10^{10}$ Pa / N m^{-2} with units (1) Accept in N mm^{-2}	1	1 1		3	3	3
		(iii)	Hazard and Risk – thin glass could shatter and cut the skin (1) Control measure – handle with care / wear gloves or protective clothing (1) **Alternative:** Hazard and Risk – [broken glass is sharp] thin glass could shatter and enter the eyes (1) Control measure – handle with care / wear goggles (1)			2	2		2
		(iv)	Work done = energy stored = $\frac{1}{2} F \Delta l$ (1) $0.5 \times 7.5 \times 28 \times 10^{-6} = 1.05 \times 10^{-4}$ [J] (1)	1	1		2	2	2
	(b)		Surface cracks (1) All force concentrated on a single / few bonds below the crack (1) When under tension (1)	3			3		
			Question 1 total	**6**	**3**	**2**	**11**	**5**	**8**

#3

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
3	(a)		Force (of a spring) is directly proportional to its extension	1			1		
	(b)	(i)	$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$ (1) $k = 50$ [N m^{-1}] (1) $v = 3.0$ [m s^{-1}] (1)		3		3	2	
		(ii)	$a = \frac{kx}{m}$ (1) $a = 150$ [m s^{-2}] and assumption that g is ignored (1)		2		2	1	
	(c)	(i)	Use of $v^2 = u^2 + 2as$ and $v = 0$ (1) $h = \frac{v^2}{2g}$ (1) $h = 0.46$ [m] (1) **Accept alternatives** Equating energies (1) Rearranging (1) $h = 0.46$ m accept 0.46 + 0.06 = 0.52 m (1)	1	1 1		3	2	
		(ii)	Use of $v = u + at$ or $t = \frac{u}{a}$ (1) Total time = 2 × 0.306 = 0.61 [s] (1)	1	1		2	2	
			Question 3 total	**3**	**8**	**0**	**11**	**6**	**0**

#4

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
1	(a)	(i)	$\frac{\text{stress}}{\text{strain}}$ (1)	1			1		
		(ii)	Strain: no units (1) Stress: $\frac{\text{kg m s}^{-2}}{\text{m}^2}$ (1) Young modulus: kg m^{-1} s^{-2} (1)	1	1 1		3	3	
	(b)	(i)	's' shape on graph (1) Loading and unloading labelled (1) Hysteresis shown (1)	3			3		3
		(ii)	Weak (van de Waals) bonds between molecules / unravelling of long chain molecules (1) Easily broken / strong (metallic) bonds in metals (1)		2		2		
		(iii)	Molecules become more entangled / vibrations increase (1) Increase (1)	2			2		
			Question 1 total	**7**	**4**	**0**	**11**	**3**	**3**

#5

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		**Plastic Deformation:** P1 - Reference to dislocations or incomplete planes of atoms P2 - Applied forces break bonds near to dislocations P3 - Dislocations slip P4 - Original bonds permanently broken and do not reform or crystal does not return to original form when force removed **Increasing Strength:** S1- Foreign atom S2- Reduce grain size or increase number of grain boundaries S3- Further dislocations S4- Reason - how they work - inhibit dislocation movement **5-6 marks** Comprehensive description including both plastic deformation and increasing strength typically 6 or more points covered. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description of either plastic deformation or increasing strength or brief description of both plastic deformation and increasing strength typically 4 - 5 points covered. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Brief description of either plastic deformation or increasing strength 1 - 3 points covered. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*	6			6		
	(b)	(i)	CSA = $\pi \times (0.16 \times 10^{-3})^2$ = [8.0×10^{-8}] (1) Gradient from graph = 4 375 or use of a point from the straight portion (1) Young Modulus = grad $\times \frac{l}{A}$ shown to be 1.2×10^{11} Pa (1)			3	3	3	3
		(ii)	0.2% strain corresponds to an extension of 4.4 mm (1) Area under graph calculated = ½ × 4.4 × 10^{-3} × 18.5 (1) [W = 0.04 J]		2		2	2	2
		(iii)	Straight line from end of graph (between 6 – 8 mm) parallel to original line to x-axis. Tolerance: x-axis intercept between 0.4 - 4.0 mm.	1			1		1
			Question total	**7**	**2**	**3**	**12**	**5**	**6**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		capacitance = $\frac{\text{charge (on either plate)}}{\text{pd (between the plates)}}$ Accept charge per unit pd / voltage [between plates] (1) Accept $C = \frac{Q}{V}$ if Q and V defined	1			1		
	(b)	(i)	Q = - 75 nC, R = + 75 nC, S = - 75 nC All numerical values stated as 75 [nC] (1) Correct signs and unit, i.e. nC (1) One of: (1) • Capacitors in series carry equal charges when joined to common pd • Conservation of charge applies for series circuit [hence if +75 µC moves from A to plate P, the same moves from Q → R etc] • Opposite charge to P (accept R), since connected to negative potential [Accept: battery transfers electrons from P to Q]	3			3		
		(ii)	Total capacitance = 7.5 nF (1) $V = \frac{75 \times 10^{-9}}{7.5 \times 10^{-9}}$ **(ecf on total** C**)** V = 10 V (1) **Alternative:** Application and substitution into $\frac{Q}{C_1} + \frac{Q}{C_2}$ i.e. $\frac{75 \times 10^{-9}}{30 \times 10^{-9}} + \frac{75 \times 10^{-9}}{10 \times 10^{-9}}$ (1) V = 10 V (1)		2		2	2	
		(iii)	**Either:** Q same on both capacitors (1) $\frac{1}{2}\frac{Q^2}{C}$ is bigger on smaller capacitor (1) (Award 2 marks for correct numerical analysis) **Or:** $V \propto \frac{1}{C}$ so V bigger across smaller capacitor (1) ½ CV^2 bigger across smaller capacitor (V^2 factor) (1) (Award 2 marks for correct numerical analysis) **Or** Q same on both capacitors and $V \propto \frac{1}{C}$ so V bigger across smaller capacitor (1) ½ QV is bigger on smaller capacitor (1) (Award 2 marks for correct numerical analysis			2	2		
	(c)		New C = 0.47 pF (1) New $d = 3.0 \times 10^{-3}$ m (1) $\Delta d = 5.2 \times 10^{-3} - 3.0 \times 10^{-3} = 2.2 \times 10^{-3}$ m (1) (**ecf** from new d) Application of $F = k\Delta d$ ecf k = 91 N m^{-1} so spring of k = 90 N m^{-1} suitable [conclusion consistent with value of F](1) **Alternative 'Trial and Error' :** Application of $x = \frac{F}{k}$ for each spring constant, showing that for: k = 120 N m^{-1}, $x = 1.67 \times 10^{-3}$ m k = 150 N m^{-1}, $x = 1.33 \times 10^{-3}$ m k = 90 N m^{-1}, $x = 2.22 \times 10^{-3}$ m (All required for1) New C = 0.47 pF (1) Application of $C = \frac{\varepsilon_0 A}{d}$ for each value of x above to show that, for $x = 2.22 \times 10^{-3}$ m, $C = 0.475 \times 10^{-12}$ F, so k = 90 N m^{-1} suitable. (1)			4	4	3	
			Question 6 total	**4**	**2**	**6**	**12**	**5**	**0**

#7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*		A pattern of disturbances travelling through a medium and carrying energy with it (1) involving the particles of the medium oscillating about their equilibrium positions (1) [Accept answers appropriate to e-m waves: A travelling pattern of oscillating electric and magnetic fields (1) carrying energy with it (1)]	2			2		
	(b)	(i)	Phase difference between A and B = 90° or $\frac{\pi}{2}$ accept fractions of cycle i.e. ¼ (1) Phase difference between B and C = 0 or $n\ 2\pi$ or n 360°(1)		2		2	1	
		(ii)	Determining $f = \frac{1}{T} = \frac{1}{0.4} = 2.5$ Hz (1) Wavelength = 1.5 km (1) Using $v = f\lambda$ (1) 3.75×10^3 m s^{-1} accept 3.75 km s^{-1} (1)	1	1 1 1		4	4	
	(c)		Substituting values in Young modulus = $\frac{\text{stress}}{\text{strain}}$ (1) Rearranging strain = $\frac{900\text{ MPa}}{70\text{ GPa}}$ (1) Strain = 0.013 (1) (ecf power of 10)	1	1 1		3	3	
	(d)		Data can be used to determine locations/frequency of Earthquakes (hotspots) (1) Informs planning and sites for new builds or increases knowledge of structure of the Earth (1)			2	2		
			Question 1 total	**4**	**7**	**2**	**13**	**8**	**0**

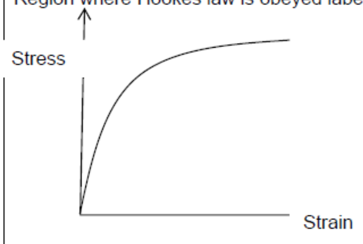
#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*		{Multiple passes of beam / reflection / keeps most of the light} for <u>more</u> amplification / stimulated emission or <u>increased</u> collimation (1) Some light (1%) transmitted by 99% mirror (1)	2			2		
	(b)		Increase of stimulated emission (1) Compared with absorption (1) [Exponential] increase in intensity or amplification or more power] (1) NB Stimulated emission > absorption → 2 marks	3			3		
	(c)	(i)	Energy of photon = 1.89×10^{-19} [J] seen or implied (1) $\frac{2 \times 10^{15}}{1.89 \times 10^{-19}}$ seen or implied (1.056×10^{34}) (1) [no e.c.f.]		2		2	2	
		(ii)	$p = \frac{6.63 \times 10^{-34}}{1.05 \times 10^{-6}}$ [kg m s^{-1}] seen or implied [= 6.314×10^{-28} N s]		1		1	1	
		(iii)	$1.06 \times 10^{34} \times 6.31 \times 10^{-28}$ [N] seen or implied (1) 2 × due to reflection stated (1) [→1.33×10^7 N] [Using the 'show that' figures → 1.2×10^7 N]		2		2	1	
		(iv)	$E = \frac{\text{stress}}{\text{strain}}$ used (1) [or by implication] Stress = $\frac{F}{A}$ used (1) [or by implication] Answer = 0.0083 or 0.011 (or 0.0105) seen (depends on (iii) but check) (1) [0.83% ✓]	1 1	1		3	3	
			Question 4 total	**7**	**6**	**0**	**13**	**7**	**0**

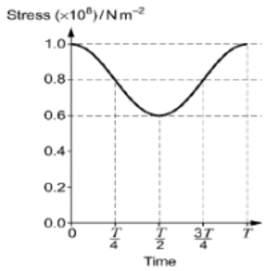
#9

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)	$\Delta x_{total} = \Delta x_A + \Delta x_{3A}$ (or by implication) [1] $\Delta x_{total} = \frac{FL_0}{AE} + \frac{FL_0}{3AE}$ [1] Convincing algebra e.g. $\frac{3FL_0}{3AE} + \frac{FL_0}{3AE}$ seen [1]		3		3	2	
		(ii)	Straight line from origin to (400 N, 4.0×10^{-6} m)		1		1		
		(iii)	**Using combination:** $Y = \frac{4FL_0}{3A\Delta x_{total}}$ and $\Delta x_{total} = 16 \times 10^{-6}$ [m] [1] Substitution - $E = \frac{4 \times 400 \times 1.2}{3 \times 2 \times 10^{-4} \times 16 \times 10^{-6}}$ [1] (gains first and second marks) $E = 2 \times 10^{11}$ Nm^{-2} or Pa **unit mark** [1] **Using bar of CSA A:** $E = \frac{FL_0}{A\Delta x_A}$ and $\Delta x_A = 12 \times 10^{-6}$ [m] [1] Substitution – $E = \frac{400 \times 1.2}{2 \times 10^{-4} \times 12 \times 10^{-6}}$ [1](gains first and second marks) $Y = 2 \times 10^{11}$ Nm^{-2} or Pa **unit mark** [1] **Using bar of CSA $3A$: - ecf** $E = \frac{FL_0}{3A\Delta x_{3A}}$ and $\Delta x_{3A} = 4 \times 10^{-6}$ [m] [1] Substitution – $E = \frac{400 \times 1.2}{3 \times 2 \times 10^{-4} \times 4 \times 10^{-6}}$ [1](gains first and second marks) $E = 2 \times 10^{11}$ Nm^{-2} or Pa **unit mark** [1]		3		3	3	
		(iv)	$E_{elastic} = \frac{1}{2}Fx_{total}$ and substitution: $E = \frac{1}{2} \times 400 \times 16 \times 10^{-6}$ [1] $E = 3.2$ m[J] [1] **Alternative:** $E_{elastic} = \frac{2F^2L_0}{3AE}$ used with substitution: $E_{elastic} = \frac{2 \times (400^2) \times 1.2}{3 \times 2 \times 10^{-4} \times 2 \times 10^{11}}$ [1] $E_{elastic} = 3.2$ m[J] [1] **Alternative: Area under graphs - ecf** ½ x 4 x 10^{-6} x 400 + ½ x 12 x 10^{-6} x 400 [1] $E_{elastic} = 3.2$ m[J] [1]	1	1		2	2	
	(b)	(i)	From graph, stress = 2.2×10^9 Pa [1] $F = 2.2 \times 10^9 \times \pi \times (0.1 \times 10^{-3})^2 = 69$ [N] [1] ecf for 2.1×10^9 Pa Mass = $\frac{69}{9.81} = 7.0$ k[g] [1]		3		3	2	
		(ii)	**Crack propagation** [around surface imperfection] - no details in terms of breaking bonds needed [1] **Thinner fibre contains fewer surface imperfections** [1] (mention of 'surface' required only once)	2			2		
			Question 5 total	**3**	**11**	**0**	**14**	**9**	**0**

#10

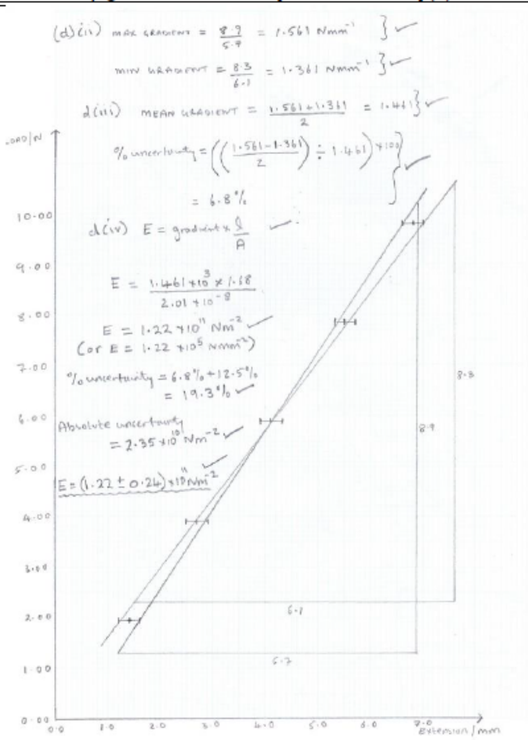
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Amorphous (1) [Short range and] long range order / regular lattice / regular array of planes / ordered layers (1) Long chain molecules (1)	3			3		
	(b)		Shape i.e. linear followed by curve flattening out (1) Yield point labelled (1) Elastic limit labelled (1) Region where Hookes law is obeyed labelled (1)  	4			4		
	(c)	(i)	Load/weight = mg = 5 × 9.81 [N] Stress = $\frac{F}{A}$ / substitution correct **ecf** for load (1) Area = 8.175 × 10^{-7} [m^2] (1) Diameter = 1.0[2] × 10^{-3} m / 1.0[2] mm with units (1)	1 1	1 1		4	4	
		(ii)	Strain = $\frac{\Delta l}{l}$ = 0.02 (1) E = 3.0 GPa with units **no ecf** (1)		2		2	2	
		(iii)	Diameter increases by $\sqrt{10}$ (1) Diameter = 3.2[2] mm with units (1)	1	1		2	2	
			Question total	**10**	**5**	**0**	**15**	**8**	**0**

#11

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
(a)	(i)		Substitution and re-arrange e.g. $\Delta x_{max} = \frac{(1.0 \times 10^8 \times 2.5)}{2.0 \times 10^{11}}$ [1] $\Delta x_{max} = 1.25 \times 10^{-3}$ m or 1.25 mm [1] Accept use of 1.25 mm to show $E_{steel} = 2.0 \times 10^{11}$ [N m^{-2}]		2		2	2	
	(ii)		Stress required to reach elastic limit will remain constant irrespective of radius e.g. If radius is doubled the tension is increased by factor 4 [1] Δx_{max} (of this wire) will be the same (depends only on stress) [1] Δx_{max} does not depend on the radius, Natalie correct (or Simon incorrect) [1]			3	3		
(b)	(i)		Re-arrangement and substitute: $F = \frac{EA\Delta x}{l}$ i.e. $F = \frac{2.0 \times 10^{11} \times 1.0 \times 10^{-6} \Delta x}{2.5}$ [1] $F = k\Delta x$ seen or implied [1] Correct algebra to show $k = 8 \times 10^4$ [N m^{-1}] [1] **Alternative:** At elastic limit $k = \frac{100}{1.25 \times 10^{-3}}$ (= 80 kN m^{-2}) - award 3 marks		3		3	3	
	(ii)		$mg = k\Delta x$ seen or implied [1] $m = \frac{8.0 \times 10^4 \times 1 \times 10^{-3}}{9.81}$ $m = 8.2$ k[g] [1]		2		2	1	
(c)	(i)		Substitution into $T = 2\pi\sqrt{\frac{m}{k}}$ [1] (**ecf** on m) $T = 0.06$[3 s] [1]	1	1		2	2	
	(ii)		Elastic limit must not be exceeded, so max possible displacement = 1.25 mm – 1.0 mm = 0.25 [mm] [1] Substitution into $v_{max} = A\omega$ or equivalent: e.g. $v_{max} = 0.25 \times 10^{-3} \times \frac{2\pi}{0.06}$ [1] (**ecf** on T and Δx_{max}) $v_{max} = 0.026$ [m s^{-1}] [1]	1	1 1		3	2	
	(iii)		Stress in equilibrium position calculated or seen on graph i.e. $= \frac{2.0 \times 10^{11} \times 1.0 \times 10^{-3}}{2.5}$ (= 0.8×10^8 N m^{-2}) [1] Appropriate stress scale e.g. as shown or in steps of 0.2×10^8 N m^{-2} [1] Correct general shape with no reference to time/ stress scales [1] Correct shape and stress and timings [1] 		4		4	2	
			Question total	**2**	**14**	**3**	**19**	**12**	**0**

#12

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*			Test wire and reference wire made from the same material (or identical) (1) Do not accept reference to common support. [Change in] temperature will affect both **equally** (1)			2	2		2
	(b)			$A = \pi\,(0.08 \times 10^{-3})^2$ and conversion to m^2 $A = 2.01 \times 10^{-8}$ [m^2] (1) % Uncertainty = $\frac{(0.01)\times 100}{0.16}$ (1) (= 6.25%) $\times$ 2 [doubling ecf] (= **12.5% / 13%**) (1) [accept 3 s.f.] (award 2 marks if 12.5% or 13% seen)		3		3	3	3
	(c)			Correct reference to uncertainty taken as ruler resolution i.e. 1 mm (or 1×10^{-3} m) (1) ecf on same mistake in resolution as *(b)* Calculation of % uncertainty: 0.059% (or 0.06%) (1) Answer gains both marks	1	1		2	1	2
	(d)	i	I	Error bars correctly included for all points ± 2 small divisions on extension axis		1		1	1	1
			II	Lines for steepest and least steep gradients drawn appropriately (1) [do not accept lines through the origin] Steepest gradient calculated: [1.5 to 1.6 N mm^{-1}] (1) Least steep gradient calculated: [1.3 to 1.4 N mm^{-1}] (1)		3		3	3	3



			(ii)	Mean gradient calculated correctly using answers to d(i): expect 1.4 to 1.5 N mm^{-1} (1) ecf % uncertainty in mean calculated: expect 6%-10% (1) ecf		2		2	2	2
	(e)			Understanding shown that E = gradient $\times \frac{l}{A}$ (1) [or by implication] [not awarded for use of data point rather than line] Substitution and value of E found to any sig fig and using any unit (does not need to be given).e.g. $E = 1.22 \times 10^{11}$ N m^{-2} (1) ecf on A. Total % uncertainty calculated from (b) [+ (c)] + (d)(ii) e.g. 7% + 12.5% = 19.5% (1) ecf Absolute uncertainty calculated: e.g. 2.38×10^{10} N m^{-2} (1) Answer and uncertainty to appropriate sig figs with correct unit: e.g. $E = (1.22 \pm 0.24) \times 10^{11}$ N m^{-2} or $(1.2 \pm 0.2) \times 10^{11}$ N m^{-2} (1)			5	5	4	5
	(f)			Diameter (1) Use 'thicker' wire or more accurate measuring instrument (or instrument with higher/greater resolution) (1) Apply ecf if candidate's gradient uncertainty greater than candidate's calculation of uncertainty in area: Extension (1); use a micrometer for extension			2	2		2
				Question 3 total	**1**	**10**	**9**	**20**	**13**	**20**