

Mark Scheme

Q1.

Question Number	Answer	Mark
	B $0.5 \times 0.15 \times 2.5$ $E = \frac{1}{2} F \Delta x$	1
	A - incorrect calculation	
	C – incorrect calculation	
	D – incorrect calculation	

Q2.

Question Number	Answer	Mark
	B	1

Q3.

Question Number	Answer	Mark
	C The stress beyond which the steel becomes permanently deformed.	1
	Incorrect Answers: A – The stress at which the steel undergoes an increase in strain with no increase in stress. B – The stress beyond which the stress and strain are no longer proportional. D – The stress at which the steel breaks.	

Q4.

Question Number	Answer	Mark
	B	1

Q5.

Question Number	Answer	Mark
	C $\frac{1}{2}mg\Delta x$	1
	Incorrect Answers: A – no factor of $\frac{1}{2}$ B – incorrect equation and no factor of $\frac{1}{2}$ D – incorrect equation	

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q7.

Question Number	Answers	Additional Guidance	Mark
	A		(1)

Q8.

Question Number	Answer	Mark
	A	1

Q9.

Question Number	Answer	Mark
	D	1

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	B		1

Q11.

Question Number	Answer	Mark
	B	1

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
	- Uses $\Delta F = k\Delta x$ with corresponding points up to F=60N (1) or calculates the gradient between F=0 and 60N (1) 1000 -1100 N m⁻¹	<u>Example of calculation</u> $k = \frac{\Delta F}{\Delta x} = \frac{60 \text{ N}}{0.06 \text{ m}} = 1000 \text{ N m}^{-1}$	2

Q13.

Question Number	Acceptable Answers	Additional guidance	Mark
	- Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ (1) 4.6 J (1)	<u>Example of Calculation</u> $\Delta E_{el} = \frac{1}{2} \times 29 \text{ N} \times 0.32 \text{ m} = 4.6 \text{ J}$	2

Q14.

Question Number	Acceptable Answers	Additional guidance	Mark
i	For the 30-year-old greater stress for a given strain Or greater Young Modulus Or stiffer Or max deformation of the 23-year-old lens is greater Or breaking stress of 30-year-old lens is greater (1)	Accept answers for the 23-year-old	1
ii	Reference to the graph consistent with their answer to (i) (1)		1

Q15.

Question Number	Answer	Additional Guidance	Mark
	- Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ (1) 0.026 J (1)	<u>Example of calculation</u> $\Delta E_{el} = \frac{1}{2} \times 130 \text{ N} \times 4.0 \times 10^{-4} \text{ m} = 0.026 \text{ J}$	2

Q16.

Question Number	Acceptable Answers	Additional Guidance	Mark
	- Uses graph to find full compression of spring at F=700 (N) (1) - ans = $6 \times 10^{-3} \text{ m}$ (1)	<u>Example of calculation</u> $d = 0.126 - 0.120 = 6 \times 10^{-3} \text{ m}$	2

Q17.

Question Number	Acceptable Answer	Additional guidance	Mark
	- Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ and $\Delta F = k \Delta x$ (1) $2.2 \times 10^{-14} \text{ J}$ (1)	<u>Example of calculation</u> $E = 0.5 \times 1195 \text{ N m}^{-1} \times ((18 - 12) \times 10^{-9} \text{ m})^2$ $= 2.15 \times 10^{-14} \text{ J}$	2

Q18.

Question Number	Acceptable Answers	Additional guidance	Mark
	- Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ - Or - Use of $F = kx$ and $\Delta E_{el} = \frac{1}{2} k \Delta x^2$ (1) 0.028 J (1)	<u>Example of Calculation</u> $\Delta E_{el} = \frac{1}{2} \times 14 \text{ N} \times (0.002 \times 2.0 \text{ m})$ $= 0.028 \text{ J}$	2

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
	- attempt to determine an area under the graph or use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ (1) - area between $F = 60$ and 220 used or average value for F used (1) - Ans 3.75J to 4.2 J (1)	For example: trapezium calculation or counting squares	3

Q20.

Question Number	Acceptable Answers	Additional guidance	Mark
	- Draws a line of best fit (1) - Calculates a gradient using at least half the graph (1) 19.4 – 20.6 N m⁻¹ (1)	<u>Example of calculation</u> Gradient = $\frac{5 \text{ N}}{0.25 \text{ m}} = 20 \text{ N m}^{-1}$	3

Q21.

Question Number	Acceptable Answers	Additional guidance	Mark
	- Steel had a lower fracture toughness due to the low temperature (1) - at low temperatures less energy is absorbed before fracture (1) - the (absorbed) energy was sufficient to cause fracture (1)		3

Q22.

Question Number	Answer	Mark
	The graph for sample A (for small extensions obeys Hooke's law as it) is a straight line (1) through the origin (1) The graph for B is not a straight line (through the origin) (1)	3
	Total for question	3

Q23.

Question Number	Answer	Additional Guidance	Mark
	Max three Elderly bone: • lower gradient showing the bone is under more strain for a given stress (1) • graph ends at a lower stress showing it has a lower breaking stress (1) • Area under graph is smaller as less energy is absorbed before fracture (1) • Graph is shorter showing less plasticity (1)	Accept answer with respect to healthy bone Accept more brittle	3

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	• X is brittle at greater stresses/forces (1) • Y will deform plastically at greater stresses/forces (1) • The Young modulus for X is greater than Y (1) • A screen made from material Y would be more suitable as it is more flexible (1)	Accept converse for MP3 and MP4 MP4: accept less stiff for flexible.	4

Q25.

Question Number	Acceptable Answers	Additional guidance	Mark								
	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. Indicative Content - Band does not obey Hooke's law (1) Or there is a non-linear relationship between force and extension (The band is elastic so) the extension returns to zero when the force is removed or size/shape is unchanged (1) - For a given force the extension when loading is less than when unloading or for the same extension more force required when loading (1) - Area under the loading curve is greater than the unloading curve Or Loading increases the elastic strain energy (of the band) (1) - The band absorbs more energy when being loaded than it releases when unloaded Or Unloading: some strain energy transferred by heating (1) - Energy released by heating represented by the area between the lines (1)	The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>		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	6
	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										

Question Number	Acceptable Answers	Additional guidance	Mark
	- Young modulus of steel > young modulus of wood Or steel is stiffer Or greater stress for a given strain (1) Or less strain under the same stress - So there are less changes in dimensions under a given force for steel (1) - Breaking stress of steel > breaking stress of wood Or steel is stronger Or steel withstands greater forces without breaking (1) - steel can withstand a larger force/weight than wood of the same (cross-sectional) area Or Under the same force/weight steel can have a smaller (cross-sectional) area than wood (1) - Steel coasters can be built that withstand the larger forces from faster cars Or (taller tracks can be built because) steel tracks can have smaller dimensions (1)	Answers must a comparison between steel and wood Accept deformation for changes in dimension MP3 accept UTS steel > UTS wood	5

Q27.

Question Number	Acceptable answers	Additional guidance	Mark
(a)(i)	$\sigma = 54-56$ (MPa) (1) - Use of $\sigma = \frac{F}{A}$ with their value of σ (1) $F = 64.5 \text{ N} - 67.5 \text{ N}$ (1)	do not penalise powers of 10 <u>Example of calculation</u> $F = 56 \times 10^6 \text{ Nm}^{-2} \times 1.2 \times 10^{-6} \text{ m}^2$ $F = 67 \text{ N}$	3

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	- Use of $\epsilon = \frac{\Delta x}{x}$ (1) - Extension = 1.0 cm (1)	<u>Example of calculation</u> $0.04 = \Delta x / 25 \text{ cm}$ $\Delta x = 0.04 \times 25 \text{ cm} = 1.0 \text{ cm}$ Allow 1 cm, 0.01 m, 10 mm	2

Question Number	Acceptable answers	Additional guidance	Mark
(b)	An answer that makes reference to the following: - Shrilk has less strain for same stress (1) Or Shrilk is stiffer - Shrilk breaks at a higher stress (compared to polythene) (1) Or Shrilk can withstand a greater stress/force/load/weight Or Shrilk is stronger - Shrilk doesn't stretch as much (for a given force) (1)	It should be clear from the student's answer that shrilk is the better material Ignore references to Young modulus, renewable, biodegradable, cost Accept converse arguments for polythene	3

Q28.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	- As graphene is only 1 atom thick so the CSA/thickness is far smaller than for a sample of steel (1) Or most applications need a thickness greater than one atom Or if more than one layer of graphene is used it will be weaker or the bonds between the layers will not be strong Or Graphene is difficult to manufacture because it has only one atomic layer (1) - Although graphene has a greater breaking stress it will break at a lower force (1)	MP1: accept graphene can only be 1 atom thick but steel can be any thickness (MP1, treat references to cost/energy as neutral)	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	- Use of depth of graphite = $100 \times$ diameter of 1 carbon atom (1) - Use of cross-sectional area = depth $\times$ (0.5×10^{-3} m) (1) - Use of $\rho = \frac{RA}{l}$ (1) $\rho = 3.6 \times 10^{-5} \Omega \text{ m}$ Or $36 \mu\Omega \text{ m}$ (1)	<u>Example of calculation</u> Depth of graphite = $100 \times 1.4 \times 10^{-10} \text{ m} = 1.4 \times 10^{-8} \text{ m}$ $\text{CSA} = 1.4 \times 10^{-8} \text{ m} \times 0.50 \times 10^{-3} \text{ m} = 7.0 \times 10^{-12} \text{ m}^2$ $\rho = \frac{1.029 \times 10^6 \Omega \times 7.0 \times 10^{-12} \text{ m}^2}{0.200 \text{ m}} = 3.6 \times 10^{-5} \Omega \text{ m}$	4

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	Max 3 • Silicon will only release a (photo) electron for a limited range of frequencies/wavelengths (1) • Silicon releases only one (photo) <u>electron</u> per incident photon (1) • Greater current (for the same illumination) in graphene (1) • Graphene (cells are) more efficient Or graphene cells could be smaller / cheaper / thinner	MP1: accept single frequency for limited range	3

Q29.

Question Number	Answer		Mark
(a)	Property of material Linked evidence from graph Brittle Breaks with no/little plastic deformation Or breaks soon after elastic limit Or breaks soon after limit of proportionality Or Large Young modulus Or stiff Gradient of stress/strain graph is high Or large stress for a small deformation /strain Or Strong Large breaking stress Or Obeys Hooke's law Straight line graph through the origin Or Stress is directly proportional to strain	(1) (1)	2
(b)(i)	Compressive would shorten the bone and tensile would stretch the bone	(1)	1
(b)(ii)	Gradient of the linear section of the graph Or stress divided by (the corresponding) strain in the linear part of the graph (accept alternative references to the linear section of the graph such as "where the graph obeys Hooke's law" Or "where the stress is proportional to the strain")	(1)	1
(b)(iii)	Use of $\text{Stress} = \text{Force} / \text{Area}$ Answer (62900 N) Use of $\text{weight} = mg$ Divide by $\text{weight} = 71$ times (allow 4 marks for arriving at a ratio $\frac{\text{maximum breaking stress}}{\text{stress of person's weight on the bone}} = 71$) (max 3 for any reverse show that e.g. $170 \text{ MPa} \times 3.76 \times 10^{-4} \text{ m}^2 = 62900 \text{ N}$ is approx equal to $883 \text{ N} \times 70 = 61\,810 \text{ N}$ Or $883 \text{ N} \times 70 / 3.76 \times 10^{-4} \text{ m}^2 = 167 \text{ (MPa)} \approx 170 \text{ (MPa)}$ (ratio= 68.3 comes from misreading graph and scores 3 marks) <u>Example of calculation</u> Force = stress $\times$ area Force = $170 \text{ MPa} \times 3.76 \times 10^{-4} \text{ m}^2 = 62900 \text{ N}$ Weight = $mg = 90 \text{ kg} \times 9.81 \text{ m s}^{-2} = 883 \text{ N}$ Force / weight = $62900 \text{ N} / 883 \text{ N} = 71$	(1) (1) (1) (1)	4
(b)(iv)	Part is trabecular Which is weaker Or has a lower maximum (compressive) stress Or lower breaking stress Or The effective area of <u>cortical</u> bone is less (than in (iii)) So the force is less (Reverse arguments may be given)	(1) (1) (1) (1)	2

Question Number	Acceptable Answers	Mark
(a)(i)	Use of $E_{\text{grav}} = mgh$ (1) $E_{\text{grav}} = 48 \times 10^3 \text{ J}$ (1) <u>Example of calculation</u> Work done = $810 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 6.0 \text{ m}$ Work done = 47 700 (J)	2

Question Number	Acceptable Answers	Mark
(a)(ii)	(useful) energy transferred = $0.4 \times \text{total energy transferred}$ (1) Use of work done against resistive forces of the ground = $F\Delta s$ (1) Force = $9.5 / 9.6 \times 10^4 \text{ N}$ (ecf) (ignore any -) (1) (It is possible to calculate v from K.E., then a and use $F = ma$) <u>Example of calculation</u> Useful energy transferred from driver = $\frac{40}{100} \times 47\,700 \text{ J} = 19\,100 \text{ J}$ Resistive force = $\frac{19100 \text{ J}}{0.20 \text{ m}} = 9.6 \times 10^4 \text{ N}$	3

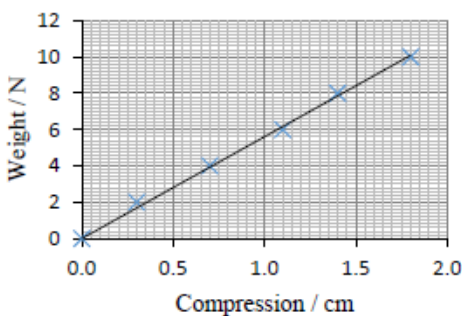
Question Number	Acceptable Answers	Mark
(b)(i)	Use of Stress = $\frac{\text{force}}{\text{area}}$ Or Use of Strain = $\frac{\text{extension}}{\text{original length}}$ (1) Correctly use $E = \frac{\text{stress}}{\text{strain}}$ with $E = 120 (\times 10^6)$, $F = 7(\times 10^5)$, $x = 0.4$ correctly substituted (1) (Use of $E = (F \times x) / (A \times \Delta x)$ scores MP1 for quoting formula and MP2 for 'use of') $\Delta x = 0.008(3) \text{ (m)}$ (1)	3
	<u>Example of calculation</u> $\sigma = \frac{7.0 \times 10^5 \text{ N}}{\pi \times (0.30 \text{ m})^2} = 2.48 \times 10^6 \text{ Pa}$ $\epsilon = \frac{\Delta x}{0.40 \text{ m}}$ $\Delta x = \frac{2.48 \times 10^6 \text{ Pa} \times 0.40 \text{ m}}{120 \times 10^6 \text{ Pa}}$ $\Delta x \text{ (compression)} = 0.0083 \text{ (m)}$	

Question Number	Acceptable Answers	Mark
(b)(ii)	Use of $E_{el} = \frac{1}{2}F\Delta x$ (1) Energy stored = $2.8 \times 10^3 \text{ J}$ or $2.9 \times 10^3 \text{ J}$ (ecf) (1) <u>Example of calculation</u> $E_{el} = \frac{1}{2} \times 7.0 \times 10^5 \text{ N} \times 0.0083 \text{ m}$ $E_{el} = 2.9 \times 10^3 \text{ J}$	2

Question Number	Acceptable Answers	Mark
*(b)(iii)1.	(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate) [Only apply if both 1. and 2. get full marks] <u>Graph:</u> Permanent/plastic compression/deformation Or does not return to its original length/shape (1) <u>Effect:</u> Becomes too thin Or will not compress Or no longer elastic Or becomes brittle (1)	2

Question Number	Acceptable Answers	Mark
*(b)(iii)2.	More work done in loading than unloading the wood Or more energy is absorbed/stored than released Or the area between the lines shows energy is dissipated Or the area while applying the force > the area while releasing Or (the area in) the hysteresis loop shows energy is dissipated (1) (these should be marked if written in 1. above)	1
	Total for question	13

Q31.

Question Number	Acceptable answers	Additional guidance	Mark														
(a)(i)	Processing of data to calculate change in length (1) Axes with labels & units (accept force for weight) (1) Scales (1) Plots (1) Line of best fit (1) <table><thead><tr><th>Weight/ N</th><th>Compression/ cm</th></tr></thead><tbody><tr><td>0.00</td><td>0.0</td></tr><tr><td>2.00</td><td>0.3</td></tr><tr><td>4.00</td><td>0.7</td></tr><tr><td>6.00</td><td>1.1</td></tr><tr><td>8.00</td><td>1.4</td></tr><tr><td>10.00</td><td>1.8</td></tr></tbody></table>	Weight/ N	Compression/ cm	0.00	0.0	2.00	0.3	4.00	0.7	6.00	1.1	8.00	1.4	10.00	1.8	 MP2: only award for a graph of weight against compression. Units may be in m or cm for compression. Allow paper to be landscape MP3: scales only in 1,2,4,5 and must cover at least half of paper MP4: a 2 mm square tolerance, check all points	5
Weight/ N	Compression/ cm																
0.00	0.0																
2.00	0.3																
4.00	0.7																
6.00	1.1																
8.00	1.4																
10.00	1.8																

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	- States that best fit line is through the origin (1) - So it fits Hooke's law because extension is proportional to force (1) - Uses corresponding values from best fit line from (a)(i) to determine gradient (1) - Spring constant = $10.0 \text{ N} / 0.0176 \text{ m} = 568 \text{ (N m}^{-1}\text{)}$ (which, 1 s.f., is the stated answer) (1)	If plunger position plotted in (a)(i) then only MP2 may be awarded for attempt at gradient MP3: values selected from at least half way along line or a triangle using over half the line is used MP4: conditional on MP3 and allow any value that rounds to 1 sf as 600	4

Question Number	Acceptable answers	Additional guidance	Mark
(b)	- Use of $\Delta F = k\Delta x$ (1) - Use of $\Delta E_{el} = \frac{1}{2} F\Delta x$ (1) - Use of $E_k = \frac{1}{2} mv^2$ (1) $v = 6.7 \text{ m s}^{-1}$ to 6.8 m s^{-1} (1)	<u>Example of calculation</u> $\Delta F = k\Delta x = 610 \text{ N m}^{-1} \times 0.054 \text{ m} = 32.94 \text{ N}$ $\Delta E_{el} = \frac{1}{2} F\Delta x = \frac{1}{2} \times 32.94 \text{ N} \times 0.054 \text{ m} = 0.90 \text{ J}$ $E_k = \frac{1}{2} mv^2$ so $0.90 \text{ J} = \frac{1}{2} \times (0.0041 + 0.0354) \text{ kg} \times v^2$ $v = 6.75 \text{ m s}^{-1}$	4

Question Number	Acceptable answers	Additional guidance	Mark
(c)	Work may be done against friction (by the spring/marble) Or KE is gained by the spring Or GPE gained by the piston and marble Or the light gate must be above the launch position so the marble is already accelerating downwards Or statement of friction between two specified parts in launch system (1)		1

Q32.

(a)(i)	Use of density = $\frac{\text{mass}}{\text{volume}}$ Or see upthrust = ρVg (1) Use of upthrust = mass of water displaced $\times g$ (1) Upthrust = 0.026 N (1) Idea that the effect of the upthrust is more significant for the nylon than for the copper (1) (e.g. a quantitative comparison made between the 2 net forces Or a sensible comment linking the upthrust to the 2 weights) Or Use of density = $\frac{\text{mass}}{\text{volume}}$ (1) Use of weight = mass $\times g$ (1) Density_{copper} = 8625 kg m⁻³ Or density_{nylon} = 1098 kg m⁻³ (1) Comparison of the densities of both copper and nylon to that of sea water (1) e.g. the density of nylon is only just greater than that of sea water so it almost floats whilst the density of copper is much greater than that of sea water so it will fall rapidly <u>Example of calculations</u> Mass of water displaced by either line = 1030 kg m⁻³ $\times$ 1.30 $\times$ 10⁻⁷ m² $\times$ 20.0 m = 2.68 $\times$ 10⁻³ kg Upthrust = 2.68 $\times$ 10⁻³ kg $\times$ 9.81 N kg⁻¹ = 0.0263 N Net downwards force on Copper = 0.220 N – 0.0263 N = 0.194 N Net downwards force on nylon = 0.0280 N – 0.0263 N = 0.00170 N	4
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(a)(ii)	Use of either stress = $\frac{\text{load}}{\text{cross sectional area}}$ Or strain = $\frac{\text{extension}}{\text{original length}}$ (1) Or see $E = \frac{Fx}{A\Delta x}$ Use of Young modulus = $\frac{\text{stress}}{\text{strain}}$ Or use of $E = \frac{Fx}{A\Delta x}$ (1) Extension = 0.0775 m (1) <u>Example of calculation</u> Stress = $\frac{65.0 \text{ N}}{1.30 \times 10^{-7} \text{ m}^2} = 5.00 \times 10^8 \text{ Pa}$ Or strain = $\frac{\text{extension}}{20.0 \text{ m}}$ $129 \times 10^9 \text{ Pa} = 5.00 \times 10^8 \text{ Pa} + \frac{\text{extension}}{20.0 \text{ m}}$ Extension = 0.0775 m	3
(b)(i)	Loading graph to include elastic(straight) line and some plastic(curved) section (1) Unloading line showing a permanent extension (1) Unloading line to be parallel to the loading line (1)	3
(b)(ii)	Line becomes more sensitive Or all work done is used to reel in fish Or no/less work done on extending the line Or all force supplied pulls in fish Or less force required (to reel in fish) Or less (elastic /plastic) stretch Or elastic limit increases (1)	1
	Total for question	11