PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 4: MATERIALS

SOLIDS

SCORE	PERCENTAGE
/444	%

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Mark Scheme

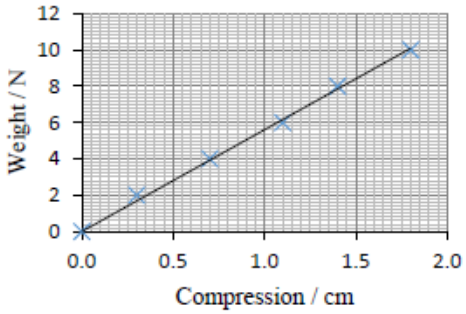
Q1.

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)	Example of calculation Gradient $= \frac{5\ N}{0.25\ m} = 20$ N m^{-1}	3

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Comment that a straight line graph through the origin (up to 5 N) is consistent with Hookes law / $F \propto x$ (1) • Comment that indicates that the max extended length 400 mm is not covered by the student's results (1) • Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ **and** $F = k\Delta x$ with $\Delta x = 0.4$ m **Or** Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ using extrapolated readings from graph (1) • Candidate's calculated energy value compared with 1.6 J and valid conclusion given (1) **Either** • Use of %U to determine the range in k (manufacturer's) (1) • Comparison of values for k with conclusion consistent with candidates calculated value (1) **Or** • Calculates % difference between candidate's calculated value for k and 21 N m^{-1} (1) • Comparison of calculated % difference with 5% and conclusion made (1)	<u>Example of calculation</u> $k = 21 \pm 1.05 = 19.95 - 22.05$ N m^{-1} $F = k\Delta x = 20$ N m^{-1} × 0.4 m = 8.0 N $\Delta E_{el}(\text{max}) = \frac{1}{2} \times 8.0$ N × 0.4 m = 1.6 J	**6**

Q3.

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) 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

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 N / 0.0176 m = 568 (N m^{-1}) (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 $\Delta E_{el} = ½ F\Delta x$ (1) • Use of $E_k = ½ mv^2$ (1) • v = 6.7 m s^{-1} to 6.8 m s^{-1} (1)	<u>Example of calculation</u> $\Delta F = k\Delta x$ = 610 N m^{-1} × 0.054 m = 32.94 N $\Delta E_{el} = ½ F\Delta x$ = ½ × 32.94 N × 0.054 m = 0.90 J $E_k = ½ mv^2$ so 0.90 J = ½ × (0.0041 + 0.0354) kg × v^2 v = 6.75 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**

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• new spring constant = 11 N m^{-1} **(1)** • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • Use of $f = 1/T$ **(1)** • f = 1.5 Hz **(1)**	Example of calculation: $k = 22/2 = 11\,\text{N m}^{-1}$ $T = 2\pi\sqrt{\frac{0.12\,\text{kg}}{11\,\text{N m}^{-1}}} = 0.66\,\text{s}$ $f = 1/0.66\,\text{s} = 1.5\,\text{Hz}$	**4**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because the gradient of this graph is change in length ÷ change in force and the change in length is the same as the change in extension, so the gradient is equal to stiffness A is not correct because a graph of extension against force will have a gradient of $1/k$ C is not correct because a graph of stress against strain will have a gradient equal to the Young modulus for the sample D is not correct because a graph of strain versus length is equivalent to a graph of extension versus (length)^2, so it does not have a gradient equal to k		1

Q6.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• If two springs are added in parallel the stretching force is shared between the springs	(1)	MP3: Allow parallel combination has a greater stiffness than a single spring MP5: Allow adding two resistors in parallel decreases the effective resistance of the combination Equivalent points for MP4 – MP6 • For two identical resistors in series, $R_{eff} = R + R$ • So adding two equal resistors in series doubles/increases the effective resistance • This is equivalent to parallel springs, so the student's statement is invalid (dependent upon MP3 and MP5)	6
	• Hence the extension for a given force is half of what it would be for a single spring	(1)		
	• So parallel combination has twice the stiffness of a single spring	(1)		
	• For two identical resistors in parallel $\frac{1}{R_{eff}} = \frac{1}{R} + \frac{1}{R}$	(1)		
	• So, adding two equal resistors in parallel halves the effective resistance of the combination	(1)		
	• This is in contrast to the springs and so the student's suggestion is invalid (dependent upon MP3 and MP5)	(1)		

Q7.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is C because for the original spring $F = kx$ so $x = F/k$, so $E = ½ Fx = ½ F^2/k$. For $2F$ and $2k$ the epe is $E \times 2^2 / 2 = 2E$ A is not correct because it is $E/2$ B is not correct because it is E A is not correct because it is $8E$	1

Q8.

Question Number	Answer	Mark
(a)(i)	The increase in extension is constant for a fixed increase in mass **Or** mass is proportional to extension **Or** extension is proportional to mass **Or** graph is a rising/increasing straight line (1) The wire obeys Hooke's law (1)	2
(a)(ii)	Use of area under the graph **Or** use of ½ $F\Delta x$ (with m or F) (1) Identify that the limit of proportionality is at 2.6 ± 0.1 kg (1) Elastic potential energy = 0.5 J (1) (accept 0.40 J to 0.50 J) Example of calculation Area under the graph = ½ × 3.5×10^{-2} m × 2.6 kg = 0.046 kg m Area × g = 0.046 kg m × 9.81 N kg^{-1} Elastic potential energy = 0.45 J	3
(a)(iii)	The wire will experience a large (increase in) extension/strain for a small (increase in applied) force/stress/mass (1) The wire will not return to its original length/shape (once the force is removed) **Or** the wire will be permanently deformed **Or** the wire will exhibit plastic deformation/behaviour (1)	2

(b)(i)	Thinner wire **Or** smaller CSA/ diameter/radius **Or** longer wire **Or** wire with a lower stiffness/k/spring constant **Or** wire that is more ductile **Or** wire with a lower Young modulus (1) (comments must be comparative)	1
(b)(ii)	**Max 2** Use a pointer on the wire/masses (1) Sensible suggestion to reduce parallax e.g. read at eye level **Or** place the rule as near as possible to the mass/wire (1) Use a set square to ensure rule is vertical (1) Wait for the extension to finish (1) Add masses gently (1)	2
	Total for question	10

Q9.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $F = k\Delta x$ (1) • 0.30 m (1)	Example of Calculation $\frac{29\text{ N}}{0.32\text{ m}} = \frac{27\text{ N}}{\Delta x}$ $\Delta x = 0.30$ m	2

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Attempt to calculate gradient **(1)** • $k = (24.0 \rightarrow 25.0)$ N m^{-1} **(1)**	Accept $k = (0.24 \rightarrow 0.25)$ N cm^{-1} Example of calculation: gradient $= \frac{(1.6\text{-}0)\text{ N}}{(6.5\text{-}0)\times 10^{-2}\text{ m}} = 24.6$ N m^{-1}	**2**

Q11.

Question Number		Mark
(a)	(The line) AB (extended)does not pass through the origin /initially **Or** the graph is curved as it passes through the origin **Or** the graph (before A) is not a straight line through the origin. (1) The device does not obey Hooke's law (conditional mark) (1)	**2**
(b) (i)	Reference to finding area (1) **Detail** count squares **OR** approximate the shape of the graph to a triangle **Or** reference to using a trapezium(could be described as rectangles and triangles) (1)	**2**
(b) (ii)	Identifies that force is the problem. (1) Explains why force used is an overestimate e.g. maximum force has been used (each time) **Or** average force was not used (each time) **Or** the force is changing (continuously) **Or** should have used the trapezium rule **Or** area of rectangle has been used (1)	**2**
(c)	Use of 25% of 540 kJ i.e. find the energy to be used (1) Use of $\frac{\text{total available energy (either 540 000 J or 135 000 J)}}{\text{energy per stretch or energy per unit time}}$ (1) Time = 612 min (1) Example of calculation 540 000 J x 25% = 135 000 J 135 000 J / 14.7 J = 9184 stretches 9184 / 15 stretches per minute = 612 minutes (36 720 s **Or** 10.2 h)	**3**
(d)	smaller extension **Or** will not stretch as much (1) less work with reference to either same force applied **Or** to work done being force x extension (1) (Do not accept displacement or distance in place of extension for MP1or MP2)	**2**
	Total for question	**11**

Q12.

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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**

Q13.

Question Number	Answer	Mark
	D	1

Q14.

Question Number	Answer	Mark
	A	1

Q15.

Question Number	Acceptable Answers	Reject	Mark
	C		**1**

Q16.

Question Number	Answer	Mark
	A kg s^{-2}	1
	Incorrect Answers: B – base units for N C – incorrect units and not base units D – correct units but not base units	

Q17.

Question Number	Answer	Additional Guidance	Mark
(i)	• Use of $\Delta F = k\Delta x$ (1) • 45 (N m^{-1}) [accept 0.45 N cm^{-1}] (1)	Example of calculation $k = \frac{2.5\text{ N}}{5.5 \times 10^{-2}\text{ m}} = 45.45\text{ N m}^{-1}$	2
(ii)	• Use of $w = mg$ (1) • Use of vertical component of spring forces (1) • Use of $\Delta F = k\Delta x$ (1) • $\Delta x = 0.050$ m [accept 5.0 cm] (1) (ECF from (a)(i))	Example of calculation $w = 0.400\text{ kg} \times 9.8\text{ N kg}^{-1} = 3.92\text{ N}$ $2T\cos 30° = 3.92\text{ N}\ \therefore$ $F = \frac{3.92\text{ N}}{2\cos 30°} = 2.26\text{ N}$ $\Delta x = \frac{2.26\text{ N}}{45.45\text{ N m}^{-1}} = 0.0498\text{ m}$	4

Q18.

Question Number	Answers	Additional Guidance	Mark
	A	5 cm	**(1)**

Q19.

Question Number	Answer		Mark
(a)	Use of $\Delta x = (1.12 \times \text{diameter} - \text{diameter})$ e.g. $\Delta x = 1.27 \times 10^{-11}$ m	(1)	
	Use of $F = k\Delta x$	(1)	
	$F = 1.4 \times 10^{-8}$ N	(1)	3
	Example of calculation $\Delta x = 0.12 \times 1.06 \times 10^{-10}$ m $= 1.27 \times 10^{-11}$ m $F = 1130$ N m$^{-1} \times 1.27 \times 10^{-11}$ N $F = 1.44 \times 10^{-8}$ N		
(b)(i)	**Max 3**		
	For positive force/extension the spring is in tension/stretched/extended (accept after/right of origin)	(1)	
	For negative force/extension the spring is in compression/squashed (accept before/left of origin)	(1)	
	From −0.7 (± 0.1) N to 1.5(± 0.1) N the spring obeys Hooke's law	(1)	
	At 1.5 (± 0.1) N the spring has reached its elastic limit (allow limit of proportionality, yield point) **Or** at −0.9 (± 0.1) N the spring is fully compressed (allow coils touching)	(1)	3
	(answers may be given in terms of extension 1.5 N →7.6 (± 0.4) cm, −0.9 N → −4.0 (± 0.4) cm and − 0.7 N → − 3.6 (± 0.4) cm)		
(b)(ii)	Use of gradient **Or** pairs of points from the graph within the linear region	(1)	
	$k = 20$ N m^{-1} Or 0.20 N cm^{-1} (allow 19 to 21 N m^{-1})	(1)	2
	Example of calculation gradient $= \frac{7.4 \times 10^{-4}\text{ m}}{1.5\text{ N}} = 0.0493$ m N^{-1} $k = \frac{1}{\text{gradient}} = \frac{1}{0.0493} = 20.3$ N m^{-1}		

*(c)	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)**		
	MP1 and 2 are for atom separation decreasing When pushed together the repulsive force is the greater force	(1)	
	(because) the repulsive graph is steeper (at smaller separations) **Or** repulsive force increases more rapidly	(1)	
	MP3 is for atom separation increasing. When pulled apart the repulsive force is the smaller force **Or** repulsive force is zero but attractive force is still present	(1)	3
	Total for question		11

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $F = k\,\Delta x$ **(1)** • $k = 14.4$ N m^{-1} **(1)** • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • Use of $f = 1/T$ **(1)** • $f = 2.4$ Hz **(1)**	Example of calculation: $k = mg/\Delta x = 66\times 10^{-3}$ kg $\times$ 9.81m s^{-2})/4.5×10^{-2} m = 14.4 N m^{-1} $T = 2\pi(0.066/14.4.0)^{1/2} = 0.425$ s $f = 1/T = 1/0.425 = 2.35$ Hz	**5**

Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of (breaking) stress = F/A • Use of $A = \pi r^2$ • Diameter = 1.06 mm and choose 1.22 mm because it is the thinnest wire with stress lower than the breaking stress	(1) (1) (1)	Example of calculation For max stress, 3.10×10^8 N m^{-2} = 28 kg × 9.81 N kg^{-1}/A $A = 8.86 \times 10^{-7}$ m^2 8.86×10^{-7} m^2 = πr^2 $r = 5.3 \times 10^{-4}$ m diameter = 1.06 mm	3
(ii)	• Use of stress = F/A and $A = \pi r^2$ (ecf for radius from (b)(i)) • Use of Young modulus = stress / strain and strain = $\Delta x/x$ • Extension =1.3 cm	(1) (1) (1)	Allow ecf for radius of wire chosen in part (b)(i), but not for the calculated radius or area Example of calculation stress = 28 kg × 9.81 N kg^{-1}/ π (1.22 × 10^{-3} m / 2) ^{2} strain = 2.34×10^8 Pa / 200 GPa = 0.00117 extension = 0.00117 × 11.2 m = 0.0132 m	3

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
	• states wavelength = 1.2 cm • use of E = stress / strain • use of $A = \pi d^2/4$ • use of stress = F/A • use of $v = \sqrt{(T/\mu)}$ • use of $v = f\lambda$ with any two of the stated / measured / calculated values of v, f or λ to calculate the other • comparison of this calculated value of v, f or λ with the value obtained another way	(1) (1) (1) (1) (1) (1) (1)	Example of calculation: $\lambda = 4.8 \times 0.25$ cm = 1.2 cm $A = \pi d^2 / 4$ $= \pi(3.6 \times 10^{-6}$ m$)^2 / 4$ $= 1.012 \times 10^{-11}$ m^2 stress = strain × E = $9.7 \times 10^{-9} \times 1.2 \times 10^9$ N m^{-2} = 11.64 N m^{-2} $T = F$ = stress × A = 11.64 N m^{-2} × 1.012×10^{-11} m^2 = 1.18×10^{-10} N $v = \sqrt{(\ \div\ )} = \sqrt{8.92 \times 10^{-3}}$ = 0.094 m s^{-1} Using $v = f\lambda$, v = 7.9 Hz × 0.012 m = 0.0912 m s^{-1} Agree to within 3%, so suggests consistent	**7**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of stress = F/A **(1)** • Use of Young modulus = stress / strain **(1)** • Use of strain = $\Delta x/x$ **(1)** • Extension = 0.053 m **(1)**	Example of calculation stress = 93.4 N / 6.6 $\times 10^{-7}$ m^2 = 1.42 $\times 10^{8}$ N m^{-2} strain = 1.42 $\times 10^{8}$ N m^{-2} / 1.8 $\times 10^{9}$ N m^{-2} = 0.0786 extension = 0.0786 × 0.68 m = 0.053 m	**4**
(ii)	• Increase tension so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ **Or** decrease μ so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ **(1)** • Since $v = f\lambda$ and wavelength unchanged, this increases frequency **(1)**		**2**

Q4.

(a)(i)	Use of density = $\frac{\text{mass}}{\text{volume}}$ **Or** see upthrust = ρVg	(1)	
	Use of upthrust = mass of water displaced x g	(1)	
	Upthrust = 0.026 N	(1)	
	Idea that the effect of the upthrust is more significant for the nylon than for the copper (e.g. a quantitative comparison made between the 2 net forces **Or** a sensible comment linking the upthrust to the 2 weights)	(1)	
	Or		
	Use of density = $\frac{\text{mass}}{\text{volume}}$	(1)	
	Use of weight = mass × g	(1)	
	Density $_{\text{copper}}$ = 8625 kg m^{-3} **Or** density $_{\text{nylon}}$ = 1098 kg m^{-3}	(1)	
	Comparison of the densities of both copper and nylon to that of sea water 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	(1)	**4**
	<u>Example of calculations</u> Mass of water displaced by either line = 1030 kg m^{-3} × 1.30 × 10^{-7} m^2 × 20.0 m = 2.68 × 10^{-3} kg Upthrust = 2.68 × 10^{-3} kg × 9.81 N kg^{-1} = 0.0263 N Net downwards force on Copper = 0.220 N – 0.0263N = 0.194 N Net downwards force on nylon = 0.0280 N – 0.0263 N = 0.00170 N		

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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 $E = \frac{Fx}{A\triangle x}$ Use of Young modulus = $\frac{\text{stress}}{\text{strain}}$ **Or** use of $E = \frac{Fx}{A\triangle x}$ (1) Extension = 0.0775 m (1) Example of calculation Stress = $\frac{65.0\text{ N}}{1.30 \times 10^{-7}\text{ m}^2} = 5.00 \times 10^8$ Pa **Or** strain = $\frac{\text{extension}}{20.0\text{ m}}$ 129×10^9 Pa = 5.00×10^8 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**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• use of strain = extension / length (1) • change in length = 4.8×10^{-18} (m) **Or** max strain for 0.001× proton size = 2.2×10^{-22} (1) • comparison of their change in length to 8.8×10^{-19}(m) **Or** comparison of their max strain to 1.2×10^{-21} (1)	Example of calculation Change in length = $1.2 \times 10^{-21} \times 4000$ m = 4.8×10^{-18} m Fraction of proton diameter = 4.8×10^{-18} m ÷ 8.8×10^{-16} m = 0.0055	**3**

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• half wavelength path difference means waves in antiphase	(1)	Do not accept 'out of phase' for MP1	
	• so destructive interference takes place	(1)		
	• this results in zero amplitude, (so no signal detected)	(1)		
	• a change in length will result in a change in path difference, so signal detected **Or** a change in length will result in a change in phase difference, so signal detected	(1)	Accept reference to being 'not out of phase' for MP4	**4**

Question Number	Acceptable answers		Additional guidance	Mark
(iii)	• if initially the path difference is zero there will be a maximum signal	(1)	MP2 alternative: a change from minimum amplitude would represent a much larger percentage (therefore more sensitive)	
	• a change from max amplitude would represent a much smaller percentage (therefore less sensitive)	(1)	MP2 Accept 'it is easier to detect the change from no light to light' MP2 Accept suitable reference to uncertainty	**2**

Q6.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Use of $E = \frac{stress}{strain}$ **and** $stress = \frac{F}{A}$	(1)	Example of calculation Stress $= 1.8 \times 10^{11} \times 0.005 = 9.0 \times 10^{8}$ N m^{-2} $A = \frac{5.0 \times 10^{6}\text{kg} \times 9.81\text{N kg}^{-1}}{9.0 \times 10^{8}\text{ N m}^{-2}}$ $= 5.45 \times 10^{-2}$ m^2	**2**
	• 5.5×10^{-2} m^2	(1)		

Question Number	Acceptable Answers		Additional guidance	Mark
	• load needs to be accelerated upwards	(1)		**3**
	• so greater force/stress/tension in cables	(1)		
	• a greater area decreases the stress	(1)		

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
(a)(i)	• σ = 54-56 (MPa) • Use of $\sigma = \frac{F}{A}$ with their value of σ • F = 64.5 N – 67.5 N	(1) (1) (1)	do not penalise powers of 10 Example of calculation $F = 56\times10^{6}\,\text{Nm}^{-2} \times 1.2\times10^{-6}\,\text{m}^{2}$ F = 67 N	3

Question Number	Acceptable answers		Additional guidance	Mark
(a)(ii)	• Use of $\varepsilon = \frac{\Delta x}{x}$ • Extension = 1.0 cm	(1) (1)	Example of calculation 0.04 = Δx / 25 cm Δx = 0.04 × 25 cm = 1.0 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 **Or** Shrilk is stiffer • Shrilk breaks at a higher stress (compared to polythene) **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) (1) (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

Q8.

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 **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 × diameter of 1 carbon atom (1) • Use of cross-sectional area = depth × (0.5×10^{-3} m) (1) • Use of $\rho = \frac{RA}{l}$ (1) • $\rho = 3.6 \times 10^{-5}\ \Omega$ m **Or** 36 μΩ m	Example of calculation Depth of graphite = $100 \times 1.4 \times 10^{-10}$ m = 1.4×10^{-8} m CSA = 1.4×10^{-8} m × 0.50×10^{-3} m = 7.0×10^{-12} m^2 $\rho = \frac{1.029 \times 10^{6}\Omega \times 7.0 \times 10^{-12}\text{m}^2}{0.200\text{ m}} =$ $3.6 \times 10^{-5}\ \Omega$ 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

Q9.

Question Number	Answers	Additional Guidance	Mark
	B	$\frac{Fl_0}{(l - l_0)A}$	**(1)**

Q10.

Question Number	Answer		Mark
(a)	Use of $\Delta x = (1.12 \times \text{diameter} - \text{diameter})$ e.g. $\Delta x = 1.27 \times 10^{-11}$ m Use of $F = k\Delta x$ $F = 1.4 \times 10^{-8}$ N Example of calculation $\Delta x = 0.12 \times 1.06 \times 10^{-10}$ m $= 1.27 \times 10^{-11}$ m $F = 1130$ N m$^{-1} \times 1.27 \times 10^{-11}$ N $F = 1.44 \times 10^{-8}$ N	(1) (1) (1)	3
(b)(i)	**Max 3** For positive force/extension the spring is in tension/stretched/extended (accept after/right of origin) For negative force/extension the spring is in compression/squashed (accept before/left of origin) From −0.7 (± 0.1) N to 1.5(± 0.1) N the spring obeys Hooke's law At 1.5 (± 0.1) N the spring has reached its elastic limit (allow limit of proportionality, yield point) **Or** at −0.9 (± 0.1) N the spring is fully compressed (allow coils touching) (answers may be given in terms of extension 1.5 N →7.6 (± 0.4) cm, −0.9 N → −4.0 (± 0.4) cm and − 0.7 N → − 3.6 (± 0.4) cm)	(1) (1) (1) (1)	3
(b)(ii)	Use of gradient **Or** pairs of points from the graph within the linear region $k = 20$ N m^{-1} Or 0.20 N cm^{-1} (allow 19 to 21 N m^{-1}) Example of calculation gradient $= \frac{7.4 \times 10^{-4}\text{ m}}{1.5\text{ N}} = 0.0493$ m N^{-1} $k = \frac{1}{\text{gradient}} = \frac{1}{0.0493} = 20.3$ N m^{-1}	(1) (1)	2

*(c)	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** **MP1 and 2 are for atom separation decreasing** When pushed together the repulsive force is the greater force (because) the repulsive graph is steeper (at smaller separations) **Or** repulsive force increases more rapidly **MP3 is for atom separation increasing.** When pulled apart the repulsive force is the smaller force **Or** repulsive force is zero but attractive force is still present	(1) (1) (1)	3
	Total for question		11

Q11.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	A description that makes reference to **two** of the following: • No need for further calculation **Or** gives a value for resistance without calculation **(1)** • No need for an additional power supply **(1)** • Uncertainties caused by two devices is (possibly) greater than that caused by one device **(1)**	Do not accept more precise **or** no parallax **or** quicker	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• (As applied force increases) the length (l) (of wire) increases/stretches **Or** the wire is longer **(1)** • the resistance increases with reference to $R = \frac{\rho l}{A}$ **(1)**	Reference to formula may be in terms of proportionality or direct quote of equation Do not accept change in resistivity	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• Use of $GF = \frac{\Delta R}{\epsilon R}$ **(1)** • Substitution of $\epsilon = \frac{\Delta w}{w}$ into GF equation **(1)** • $\Delta w = 2.5 \times 10^{-5}$ m **(1)**	(x may seen in place of w) Example of calculation: $GF = \frac{\Delta R}{\epsilon R}$ $2 = \frac{0.001}{\Delta w / (5 \times 10^{-2})}$ $\Delta w = 2.5 \times 10^{-5}$ m Accept 2.5×10^{-3} cm / 2.5×10^{-2} mm	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An explanation that makes reference to the following: • As small changes (in w) are multiplied many times **Or** can use a longer wire (on a small gauge) **Or** to achieve a greater change in the length **(1)** • (So) greater sensitivity **Or** larger changes in R (for a given change in width) **(1)**		**2**

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• reference point so that reliable timings can be made (1) • end of metre rule will be travelling fastest at its equilibrium position (so uncertainty is determining when rule is at this position is least) (1)		**(2)**
(a)(ii)	• calculate average time period for each ruler [T_1 = 0.962 s, T_2 = 1.072 s] (1) • use of $T^2 \propto \frac{ML^3}{E}$ (1) • $\frac{E_2}{E_1} = 0.80$ (1)	Example of calculation: $T_1 = \frac{19.3\text{s} + 19.1\text{s} + 19.3\text{s}}{60} = 0.962\text{s}$ $T_2 = \frac{21.3\text{s} + 21.5\text{s} + 21.5\text{s}}{60} = 1.07\text{s}$ $T^2 \propto \frac{ML^3}{E} \therefore \frac{E_1}{E_2} = \frac{T_2^2}{T_1^2}$ $\frac{E_2}{E_1} = \frac{T_1^2}{T_2^2} = \left(\frac{0.962\text{s}}{1.07\text{s}}\right)^2 = 0.804$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	T^2 on y-axis and L^3 on x-axis (or vice versa)		**(1)**
(b)(ii)	An explanation that makes reference to the following: • $T^2 = \frac{KML^3}{E}$, so gradient will be $\frac{KM}{E}$ (if T^2 plotted against L^3) (1) • $\therefore E = \frac{KM}{\text{gradient}}$, if K is known E can be determined (1)	If axes reversed in (b)(i), gradient = E/KM for full credit	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An explanation that makes reference to the following: • time a larger number of oscillations (1) • as the greater the total time the smaller the % uncertainty (1)		**(2)**

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to: • Stress caused by component of F **(1)** • Parallel to surface **(1)** • = F sin α **(1)** • As α increases, sin α increases **(1)**		**4**

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• (For linear section of graph) area under graph = $\frac{1}{2}$ stress × strain **(1)** • Use of stress = F/A and strain = $\Delta x/x$ to show that area = $\frac{1}{2} \times \frac{F}{A} \times \frac{\Delta x}{x} = \frac{F_{av}.\Delta x}{V} = \frac{E}{V}$ **(1)**	Candidates who only use the graph to show that the area has units J m^{-3} can score a maximum 1 mark Accept F_{av} for $\frac{1}{2}F$	**2**
(ii)	• Area under graph up to 0.075 calculated **(1)** • Energy per unit volume = 7.1×10^5 J m^{-3} **(1)** • This is much less than the value given in (a), and so belt does not absorb all the KE. **(1)** **OR** • Graph used to determine stress when strain is 0.075 and $\sigma = \frac{F}{A}$ used to calculate force **(1)** • $\epsilon = \frac{\Delta x}{x}$ used to calculate extension and $W = \frac{1}{2}F\Delta x$ used to calculate energy **(1)** • Statement that this energy is much less than the value in (a), and so belt does not absorb all the kinetic energy **(1)**	Example of calculation: When strain is 0.075 Area = $\frac{1}{2} \times 19 \times 10^6 \text{Pa} \times 0.075 = 7.13 \times 10^5$ J m^{-3}	**3**

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Calculate force = mg (1) • calculate the cross-sectional area $A = \pi\frac{d^2}{4}$ (1) • x- and y- variables to produce a suitable straight-line graph (1) • correct use of the gradient from their graph to determine E (1)	Accept $A = \pi r^2$ **and** $r = \frac{d}{2}$	**4**

Q16.

Question Number	Answer	Mark
	The only correct answer is B because $x = Fl/EA$ where $F = mg$ so $x = mgl/EA = \frac{24 \times 9.81 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$	**1**

Q17.

Question Number	Answer	Mark
	A $\frac{36000 \times 0.5}{4.5 \times 10^{-4} \times 2.0 \times 10^{-4}}$	**1**
	Incorrect Answers: B – incorrect arrangement of equation C– incorrect arrangement of equation D – incorrect arrangement of equation	

Q18.

Question Number	Answer	Mark
	C $\frac{F/A}{\Delta x/x}$ (stress/strain)	1
	Incorrect Answers: A incorrect arrangement B incorrect arrangement D incorrect arrangement for strain	

Q19.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\sigma = \frac{F}{A}$ and $A = \frac{\pi d^2}{4}$ (1) • Use of $E = \frac{\text{stress}}{\text{strain}}$ with strain = 0.2 % (1) • $E = 1.4 \times 10^9$ Pa (1)	Example of Calculation Stress = $\frac{14\text{ N}}{\pi \times \left(\frac{2.5 \times 10^{-3}\text{ m}}{2}\right)^2} = 2.85 \times 10^6\text{ N m}^{-2}$ $E = \frac{2.85 \times 10^6\text{ N m}^{-2}}{0.2/100} = 1.4 \times 10^9\text{ N m}^{-2}$	3

Q20.

Question Number	Answer		Mark
(a)(i)	See (or use of) $E = \dfrac{F \times x}{A \times \Delta x}$ in any arrangement (accept l for x) (accept seeing or use of $E = \frac{F/A}{\Delta x/x}$) $\dfrac{\Delta x_C}{\Delta x_S} = \dfrac{E_S A_S}{E_C A_C}$ **Or** Calculate $E_C A_C$ (104) and $E_S A_S$ (234) or their reciprocals (962 and 427) (ignoring powers of ten at this stage) $\dfrac{\Delta x_C}{\Delta x_S} = 2.2 / 2.3$ Or ratio is 2.2/2.3:1 <u>Example of calculation</u> $\dfrac{\Delta x_C}{\Delta x_S} = \dfrac{E_S A_S}{E_C A_C}$ $\dfrac{\Delta x_C}{\Delta x_S} = \dfrac{1.3 \times 10^{-6}\ \text{m}^2 \times 1.8 \times 10^{11}\ \text{Pa}}{0.8 \times 10^{-6}\ \text{m}^2 \times 1.3 \times 10^{11}\ \text{Pa}}$ $\dfrac{\Delta x_C}{\Delta x_S} = 2.25$	**(1)** **(1)** **(1)**	**3**
(a) (ii)	Use of $\Delta x_C + \Delta x_S = 0.01$ **Or** use of ratio 2.25:1 with 0.01 m Extension = 6.9×10^{-3} m to at least 2 SF (ecf from part (a)(i)) (show that value gives extension = 6.7×10^{-3} m) <u>Example of calculation</u> $2.25x + x = 0.01$ $\frac{0.01 \times 2.25}{3.25} = 6.92 \times 10^{-3}$ m	**(1)** **(1)**	**2**
	Total for question		**5**

Mark Scheme

Q1.

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**

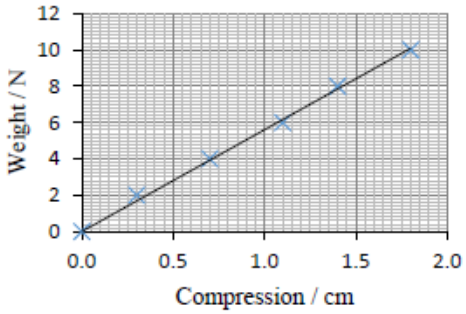
Q2.

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 $= \frac{5\text{ N}}{0.25\text{ m}} = 20$ N m^{-1}	**3**

Q3.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Comment that a straight line graph through the origin (up to 5 N) is consistent with Hookes law / $F \propto x$	(1)		
	• Comment that indicates that the max extended length 400 mm is not covered by the student's results	(1)		
	• Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ **and** $F = k\Delta x$ with $\Delta x = 0.4$ m **Or** Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ using extrapolated readings from graph	(1)	Example of calculation $k = 21 \pm 1.05 = 19.95 - 22.05$ N m^{-1} $F = k\Delta x = 20$ N m^{-1} × 0.4 m = 8.0 N	
	• Candidate's calculated energy value compared with 1.6 J and valid conclusion given	(1)	$\Delta E_{el}(\text{max}) = \frac{1}{2} \times 8.0$ N × 0.4 m = 1.6 J	
	Either • Use of %U to determine the range in k (manufacturer's)	(1)		**6**
	• Comparison of values for k with conclusion consistent with candidates calculated value	(1)		
	Or • Calculates % difference between candidate's calculated value for k and 21 N m^{-1}	(1)		
	• Comparison of calculated % difference with 5% and conclusion made	(1)		

Q4.

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) 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

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 N / 0.0176 m = 568 (N m^{-1}) (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 $\Delta E_{el} = ½ F\Delta x$ (1) • Use of $E_k = ½ mv^2$ (1) • v = 6.7 m s^{-1} to 6.8 m s^{-1} (1)	<u>Example of calculation</u> $\Delta F = k\Delta x$ = 610 N m^{-1} × 0.054 m = 32.94 N $\Delta E_{el} = ½ F\Delta x$ = ½ × 32.94 N × 0.054 m = 0.90 J $E_k = ½ mv^2$ so 0.90 J = ½ × (0.0041 + 0.0354) kg × v^2 v = 6.75 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**

Q5.

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	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 |	**6**

Q6.

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

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because the gradient of this graph is change in length ÷ change in force and the change in length is the same as the change in extension, so the gradient is equal to stiffness A is not correct because a graph of extension against force will have a gradient of $1/k$ C is not correct because a graph of stress against strain will have a gradient equal to the Young modulus for the sample D is not correct because a graph of strain versus length is equivalent to a graph of extension versus (length)^2, so it does not have a gradient equal to k		1

Q8.

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.	

Q9.

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

Q10.

(a)(i)	Use of density = $\frac{\text{mass}}{\text{volume}}$ **Or** see upthrust = ρVg	(1)	
	Use of upthrust = mass of water displaced x g	(1)	
	Upthrust = 0.026 N	(1)	
	Idea that the effect of the upthrust is more significant for the nylon than for the copper (e.g. a quantitative comparison made between the 2 net forces **Or** a sensible comment linking the upthrust to the 2 weights)	(1)	
	Or		
	Use of density = $\frac{\text{mass}}{\text{volume}}$	(1)	
	Use of weight = mass × g	(1)	
	Density $_{\text{copper}}$ = 8625 kg m^{-3} **Or** density $_{\text{nylon}}$ = 1098 kg m^{-3}	(1)	
	Comparison of the densities of both copper and nylon to that of sea water 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	(1)	4
	Example of calculations Mass of water displaced by either line = 1030 kg m^{-3} × 1.30 × 10^{-7} m^2 × 20.0 m = 2.68 × 10^{-3} kg Upthrust = 2.68 × 10^{-3} kg × 9.81 N kg^{-1} = 0.0263 N Net downwards force on Copper = 0.220 N – 0.0263N = 0.194 N Net downwards force on nylon = 0.0280 N – 0.0263 N = 0.00170 N		

(a)(ii)	Use of either stress $= \frac{\text{load}}{\text{cross sectional area}}$ **Or** strain $= \frac{\text{extension}}{\text{original length}}$ (1) **Or** see $E = \frac{Fx}{A\triangle x}$ Use of Young modulus $= \frac{\text{stress}}{\text{strain}}$ **Or** use of $E = \frac{Fx}{A\triangle x}$ (1) Extension = 0.0775 m (1) Example of calculation Stress $= \frac{65.0\text{ N}}{1.30 \times 10^{-7}\text{ m}^2} = 5.00 \times 10^8$ Pa **Or** strain $= \frac{\text{extension}}{20.0\text{ m}}$ 129×10^9 Pa $= 5.00 \times 10^8$ Pa $\div \frac{\text{extension}}{20.0\text{ m}}$ 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**

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	B		**1**

Q12.

Question Number		Mark
(a)	(The line) AB (extended)does not pass through the origin /initially **Or** the graph is curved as it passes through the origin **Or** the graph (before A) is not a straight line through the origin. (1) The device does not obey Hooke's law (conditional mark) (1)	**2**
(b) (i)	Reference to finding area (1) **Detail** count squares **OR** approximate the shape of the graph to a triangle **Or** reference to using a trapezium(could be described as rectangles and triangles) (1)	**2**
(b) (ii)	Identifies that force is the problem. (1) Explains why force used is an overestimate e.g. maximum force has been used (each time) **Or** average force was not used (each time) **Or** the force is changing (continuously) **Or** should have used the trapezium rule **Or** area of rectangle has been used (1)	**2**
(c)	Use of 25% of 540 kJ i.e. find the energy to be used (1) Use of $\frac{\text{total available energy (either 540 000 J or 135 000 J)}}{\text{energy per stretch or energy per unit time}}$ (1) Time = 612 min (1) Example of calculation 540 000 J x 25% = 135 000 J 135 000 J / 14.7 J = 9184 stretches 9184 / 15 stretches per minute = 612 minutes (36 720 s **Or** 10.2 h)	**3**
(d)	smaller extension **Or** will not stretch as much (1) less work with reference to either same force applied **Or** to work done being force x extension (1) (Do not accept displacement or distance in place of extension for MP1or MP2)	**2**
	Total for question	**11**

Q13.

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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**

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
(a)(i)	• σ = 54-56 (MPa) (1) • Use of $\sigma = \frac{F}{A}$ with their value of σ (1) • F = 64.5 N – 67.5 N (1)	do not penalise powers of 10 Example of calculation $F = 56\times10^{6}\,\text{Nm}^{-2} \times 1.2\times10^{-6}\,\text{m}^{2}$ F = 67 N	3

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	• Use of $\varepsilon = \frac{\Delta x}{x}$ (1) • Extension = 1.0 cm (1)	Example of calculation 0.04 = Δx / 25 cm Δx = 0.04 × 25 cm = 1.0 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 **Or** Shrilk is stiffer (1) • Shrilk breaks at a higher stress (compared to polythene) **Or** Shrilk can withstand a greater stress/force/load/weight **Or** Shrilk is stronger (1) • 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

Q15.

Question Number	Answers	Additional Guidance	Mark
	A		**(1)**

Q16.

Question Number	Answer	Mark
	A	1

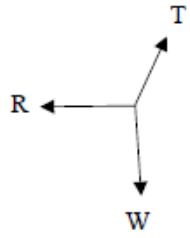
Q17.

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 Stress = Force / Area Answer (62900 N) Use of weight = *mg* Divide by 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 MPa × 3.76×10^{-4} m^2 = 62900 N is approx equal to 883 N x 70 = 61 810 N **Or** 883N x 70 /3.76×10^{-4} m^2 = 167 (MPa) ≈ 170 (MPa)) (ratio= 68.3 comes from misreading graph and scores 3 marks) <u>Example of calculation</u> Force = stress × area Force = 170 MPa × 3.76×10^{-4} m^2 = 62900 N Weight = *mg* = 90 kg × 9.81 m s^{-2} = 883 N Force / weight = 62900 N / 883 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**

Q18.

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

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Arrow upwards and to the right at approximately 20° to the vertical labelled Tension/T (1) • Arrow to left and horizontal labelled Reaction/R (1) • Arrow vertically down labelled Weight/W/mg/540 N (1)	Accept Push (from rock) /Contact  Max 2 if any additional arrows drawn	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)(i)	• Resolve tension vertically: $T\cos 20$ **Or** $T\sin 70$ (1) • Equate mg and their vertical component of T (1) • Tension = 570 (N) (1)	Example of calculation $55 \times 9.81 = T \cos 20$ $T = 574$ N	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)(ii)	• Use of $\Delta E = ½ F \Delta x$ (1) • Energy stored = 7.1 – 7.2 J (1)	(ecf from (b)(i)) show that value gives 7.5 J Example of calculation $\Delta E = \frac{1}{2} \times 570 \text{ N} \times 2.5 \times 10^{-2} \text{ m}$ $\Delta E = 7.1$ J	2

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Question Number	Acceptable answers	Additional guidance	Mark
(b)(iii)	• Rope has extended linearly **Or** Hooke's law applies **Or** extension ∝ force **Or** has not exceeded limit of proportionality (1)	Do not accept elastic limit	1

Q20.

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}	Example of calculation $k = \frac{\Delta F}{\Delta x} = \frac{60\ \text{N}}{0.06\ \text{m}} = 1000\ \text{N m}^{-1}$	2

Mark Scheme

Q1.

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** (1) breaking stress of 30-year-old lens is greater	Accept answers for the 23-year-old	**1**
ii	• Reference to the graph consistent with their answer to **(i)** (1)		**1**

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of (breaking) stress = F/A • Use of $A = \pi r^2$ • Diameter = 1.06 mm and choose 1.22 mm because it is the thinnest wire with stress lower than the breaking stress	**(1)** **(1)** **(1)**	Example of calculation For max stress, 3.10×10^8 N m^{-2} = 28 kg × 9.81 N kg^{-1}/A $A = 8.86 \times 10^{-7}$ m^2 8.86×10^{-7} m^2 = πr^2 $r = 5.3 \times 10^{-4}$ m diameter = 1.06 mm	**3**
(ii)	• Use of stress = F/A and $A = \pi r^2$ (ecf for radius from (b)(i)) • Use of Young modulus = stress / strain and strain = $\Delta x/x$ • Extension =1.3 cm	**(1)** **(1)** **(1)**	Allow ecf for radius of wire chosen in part (b)(i), but not for the calculated radius or area Example of calculation stress = 28 kg × 9.81 N kg^{-1}/ π (1.22 × 10^{-3} m / 2) ^{2} strain = 2.34×10^8 Pa / 200 GPa = 0.00117 extension = 0.00117 × 11.2 m = 0.0132 m	**3**

Q3.

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 **Or** less strain under the same stress (1) • 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

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• X is brittle at greater stresses/forces (1) • Y will deform plastically at greater stresses/forces (1) (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	Accept converse for MP3 and MP4 MP4: accept less stiff for flexible.	4

Q5.

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

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(a)(i)	• σ = 54-56 (MPa)	(1)	do not penalise powers of 10	3
	• Use of $\sigma = \frac{F}{A}$ with their value of σ	(1)	Example of calculation	
	• F = 64.5 N – 67.5 N	(1)	$F = 56\times10^{6}\,\text{Nm}^{-2} \times 1.2\times10^{-6}\,\text{m}^{2}$ F = 67 N	

Question Number	Acceptable answers		Additional guidance	Mark
(a)(ii)	• Use of $\varepsilon = \frac{\Delta x}{x}$	(1)	Example of calculation	2
	• Extension = 1.0 cm	(1)	0.04 = Δx / 25 cm Δx = 0.04 × 25 cm = 1.0 cm Allow 1 cm, 0.01 m, 10 mm	

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

Q7.

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 **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 × diameter of 1 carbon atom (1) • Use of cross-sectional area = depth × (0.5×10^{-3} m) (1) • Use of $\rho = \frac{RA}{l}$ (1) • $\rho = 3.6 \times 10^{-5}\ \Omega$ m **Or** 36 μΩ m	Example of calculation Depth of graphite = $100 \times 1.4 \times 10^{-10}$ m = 1.4×10^{-8} m CSA = 1.4×10^{-8} m × 0.50×10^{-3} m = 7.0×10^{-12} m^2 $\rho = \frac{1.029 \times 10^{6}\Omega \times 7.0 \times 10^{-12}\text{m}^2}{0.200\text{ m}} =$ $3.6 \times 10^{-5}\ \Omega$ 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

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q9.

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

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	B		1

Mark Scheme

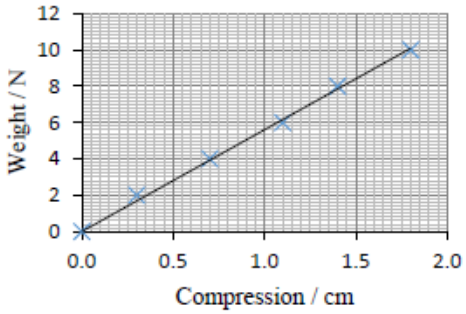
Q1.

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**

Q2.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Comment that a straight line graph through the origin (up to 5 N) is consistent with Hookes law / $F \propto x$	(1)		
	• Comment that indicates that the max extended length 400 mm is not covered by the student's results	(1)		
	• Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ **and** $F = k\Delta x$ with $\Delta x = 0.4$ m **Or** Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ using extrapolated readings from graph	(1)	Example of calculation $k = 21 \pm 1.05 = 19.95 - 22.05$ N m^{-1} $F = k\Delta x = 20$ N m^{-1} × 0.4 m = 8.0 N	
	• Candidate's calculated energy value compared with 1.6 J and valid conclusion given	(1)	$\Delta E_{el}(\text{max}) = \frac{1}{2} \times 8.0$ N × 0.4 m = 1.6 J	
	Either • Use of %U to determine the range in k (manufacturer's)	(1)		**6**
	• Comparison of values for k with conclusion consistent with candidates calculated value	(1)		
	Or • Calculates % difference between candidate's calculated value for k and 21 N m^{-1}	(1)		
	• Comparison of calculated % difference with 5% and conclusion made	(1)		

Q3.

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) 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

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 N / 0.0176 m = 568 (N m^{-1}) (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 $\Delta E_{el} = ½ F\Delta x$ (1) • Use of $E_k = ½ mv^2$ (1) • v = 6.7 m s^{-1} to 6.8 m s^{-1} (1)	<u>Example of calculation</u> $\Delta F = k\Delta x$ = 610 N m^{-1} × 0.054 m = 32.94 N $\Delta E_{el} = ½ F\Delta x$ = ½ × 32.94 N × 0.054 m = 0.90 J $E_k = ½ mv^2$ so 0.90 J = ½ × (0.0041 + 0.0354) kg × v^2 v = 6.75 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**

Q4.

Question Number	Answer	Mark
	B	**1**

Q5.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>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)</td>
<td>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>
</td>
<td>6</td>
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</table>

Q6.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>• Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ (1)
• $0.026\,\text{J}$ (1)</td>
<td><u>Example of calculation</u>

$\Delta E_{el} = \frac{1}{2} \times 130\,\text{N} \times 4.0 \times 10^{-4}\,\text{m} = 0.026\,\text{J}$</td>
<td>2</td>
</tr>
</table>

Q7.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is C because for the original spring $F = kx$ so $x = F/k$, so $E = ½ Fx = ½ F^2/k$. For $2F$ and $2k$ the epe is $E \times 2^2 / 2 = 2E$ A is not correct because it is $E/2$ B is not correct because it is E A is not correct because it is $8E$	1

Q8.

Question Number	Answer	Mark
	The only correct answer is C because each spring is extended by the same amount so each stores the same energy so the total is doubled	1

Q9.

Question Number	Answer	Mark
	B	1

Q10.

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)	Example of Calculation $\Delta E_{el} = \frac{1}{2} \times 14\ \text{N} \times (0.002 \times 2.0\ \text{m})$ $= 0.028\ \text{J}$	2

Q11.

Question Number	Answer	Mark
(a)(i)	The increase in extension is constant for a fixed increase in mass **Or** mass is proportional to extension **Or** extension is proportional to mass **Or** graph is a rising/increasing straight line (1) The wire obeys Hooke's law (1)	2
(a)(ii)	Use of area under the graph **Or** use of ½ $F\Delta x$ (with m or F) (1) Identify that the limit of proportionality is at 2.6 ± 0.1 kg (1) Elastic potential energy = 0.5 J (1) (accept 0.40 J to 0.50 J) Example of calculation Area under the graph = ½ × 3.5×10^{-2} m × 2.6 kg = 0.046 kg m Area × g = 0.046 kg m × 9.81 N kg^{-1} Elastic potential energy = 0.45 J	3
(a)(iii)	The wire will experience a large (increase in) extension/strain for a small (increase in applied) force/stress/mass (1) The wire will not return to its original length/shape (once the force is removed) **Or** the wire will be permanently deformed **Or** the wire will exhibit plastic deformation/behaviour (1)	2

(b)(i)	Thinner wire **Or** smaller CSA/ diameter/radius **Or** longer wire **Or** wire with a lower stiffness/k/spring constant **Or** wire that is more ductile **Or** wire with a lower Young modulus (1) (comments must be comparative)	1
(b)(ii)	**Max 2** Use a pointer on the wire/masses (1) Sensible suggestion to reduce parallax e.g. read at eye level **Or** place the rule as near as possible to the mass/wire (1) Use a set square to ensure rule is vertical (1) Wait for the extension to finish (1) Add masses gently (1)	2
	Total for question	10

Q12.

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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	

Q13.

Question Number		Mark
(a)	(The line) AB (extended)does not pass through the origin /initially **Or** the graph is curved as it passes through the origin **Or** the graph (before A) is not a straight line through the origin. (1) The device does not obey Hooke's law (conditional mark) (1)	**2**
(b) (i)	Reference to finding area (1) **Detail** count squares **OR** approximate the shape of the graph to a triangle **Or** reference to using a trapezium(could be described as rectangles and triangles) (1)	**2**
(b) (ii)	Identifies that force is the problem. (1) Explains why force used is an overestimate e.g. maximum force has been used (each time) **Or** average force was not used (each time) **Or** the force is changing (continuously) **Or** should have used the trapezium rule **Or** area of rectangle has been used (1)	**2**
(c)	Use of 25% of 540 kJ i.e. find the energy to be used (1) Use of $\frac{\text{total available energy (either 540 000 J or 135 000 J)}}{\text{energy per stretch or energy per unit time}}$ (1) Time = 612 min (1) Example of calculation 540 000 J x 25% = 135 000 J 135 000 J / 14.7 J = 9184 stretches 9184 / 15 stretches per minute = 612 minutes (36 720 s **Or** 10.2 h)	**3**
(d)	smaller extension **Or** will not stretch as much (1) less work with reference to either same force applied **Or** to work done being force x extension (1) (Do not accept displacement or distance in place of extension for MP1or MP2)	**2**
	Total for question	**11**

Q14.

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Question Number	Answer		Mark
(a)(i)	Finds extension = 3.4 (cm) **Or** line on graph at 3.4 cm Force = 3.2 (N) (accept range between 3.10 and 3.25 N)	(1) (1)	2
(a)(ii)	An attempt to find an area under the graph **Or** use of ½ FΔx A calculation of the correct area using counting squares or trapezium for a extension of 3.0 - 3.4 cm (ecf their extension from (a)(i)) (counting 1 cm squares is approximately 51 - 52 squares) Example of calculation Using counting cm squares: energy = (51 squares × 1.25×10^{-3} J) = 0.064 (J)	(1) (1)	2
(a)(iii)	Use of gpe = mgh **Or** equations that would allow h to be calculated Height = 1.7 (m) (ecf) (0.06 J → 1.61 m, 0.054 J → 1.45 m) (Candidates may use the longer route of 0.063 J = ½ mv^2 to find v = 5.78 m s^{-1} and then use $mgh = 1/2mv^2$ to give h = 1.7 m) Example of calculation 0.063 J = 0.0038 kg x 9.81 N kg^{-1} x h h = 1.7(m)	(1) (1)	2
(b)(i)	25.8 cm an anomaly (accept outlier in place of anomaly) excluded from the mean **Or** mean of the remaining three numbers is 30.0 cm **Or** (30.0 + 30.3 + 29.7)/3 = 30.0 (cm)	(1) (1)	2
(b)(ii)	The block moves Some energy is transferred to the block **Or** acceleration (of marble) is less **Or** launch velocity is less **Allow one mark only for one of the following if no mention of block moving** Energy transferred due to friction **Or** energy transferred due to air resistance **Or** friction was acting between moving parts **Or** air resistance was acting on the marble **Or** energy transferred to internal energy in the band **Or** energy transferred to thermal energy of the surroundings **Or** energy dissipated as heat	(1) (1) (1)	2
(b)(iii)	Any **one** from Use additional rubber band(s) Double up rubber band Use a longer channel Use a lighter block/type of wood Replace elastic band with a stiffer, shorter or wider one Any sensible practical idea to reduce friction e.g. use a lubricant/oil **Or** a material with lower friction e.g. plastic	(1)	1

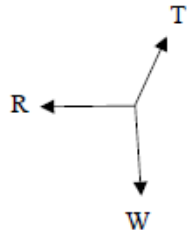
Q15.

Question Number	Answer	Additional guidance	Mark
	C	(elastic strain energy in the wire.)	**(1)**

Q16.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B**: for each spring, ½ force, so ½ extension, so ½ *Fx* gives ¼ *E*, so total is ½ *E* A is not correct because it is the energy for one spring with this extension C is not correct because it only applies the factor of ½ once D is not correct because it is the energy for two springs, each with the original extension	1

Q17.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Arrow upwards and to the right at approximately 20° to the vertical labelled Tension/T	(1)	Accept Push (from rock) /Contact  Max 2 if any additional arrows drawn	3
	• Arrow to left and horizontal labelled Reaction/R	(1)		
	• Arrow vertically down labelled Weight/W/mg/540 N	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)(i)	• Resolve tension vertically: *T*cos20 **Or** *T*sin70	(1)	Example of calculation $55 \times 9.81 = T \cos 20$ $T = 574$ N	3
	• Equate *mg* and their vertical component of *T*	(1)		
	• Tension = 570 (N)	(1)		

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Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	• Use of $\Delta E = ½ F \Delta x$ • Energy stored = 7.1 – 7.2 J	(1) (1)	(ecf from (b)(i)) show that value gives 7.5 J Example of calculation $\Delta E = \frac{1}{2} \times 570\ \text{N} \times 2.5 \times 10^{-2}\ \text{m}$ $\Delta E = 7.1\ \text{J}$	2

Question Number	Acceptable answers		Additional guidance	Mark
(b)(iii)	• Rope has extended linearly **Or** Hooke's law applies **Or** extension ∝ force **Or** has not exceeded limit of proportionality	(1)	Do not accept elastic limit	1

Q18.

Question Number	Answer	Mark
	D	1

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An explanation that makes reference to: • balance measures to 1 g **(1)** • more rubber bands should have been placed on the balance to obtain a reading of at least 10 g **(1)** • so that a more precise reading is obtained **(1)**		**3**
(b)	• use of area under graph to represent work done **(1)** • uses area accurately between line and distance axis to determine work done **(1)** • 0.97 J (range from printed graph) **(1)**	Do not award first mark for use of E=1/2Fx	**3**
(c)	• use of ke = ½ mv^2 **(1)** • v = 70 m s^{-1} **(1)**	Example of calculation: 0.97 J = ½ mv^2 = ½ 0.0004 kg × v^2 v = 70 m s^{-1}	**2**
(d)	An explanation that makes reference to: • video the band over a short distance so it determines the initial speed **(1) OR** because its speed will rapidly reduce because of air resistance **(1)** • include a scale or object of known length in the area filmed **(1)** • analyse the video to determine the time taken to travel the known distance **AND** calculate the speed using the measured time in speed = distance/time **(1)** • (light gates would not be suitable because) the band is not sufficient in size to interrupt the light gate beam **(1)**		**4**

Q20.

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