10	**The only correct answer is D**	1

Extension of L	Extension of M	Extension of N
x	x	$2x$

	A *is not correct because The extension of L, M and N will not be the same* ***B*** *is not correct because M will have the same extension as L which is x and N will have double the extension to L and M* ***C*** *is not correct because The extension of N is double that of L and M and not half*	
	Total for multiple choice questions	**10**

8	**8. The only correct answer is B** ***A*** *is not correct because a larger diameter wire would produce a smaller stress, a smaller strain and hence a smaller extension.* ***C*** *is not correct because a larger diameter wire would produce a smaller stress, a smaller strain and hence a smaller extension. For the same strain, a shorter wire would also produce a smaller extension.* ***D*** *is not correct because, for the same strain, a shorter wire would produce a smaller extension.*	**(1)**

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

4	**The only correct answer is D (the spring does not return to its original length)** A is not correct because beyond the elastic limit force is not proportional to extension B is not correct because plastic deformation starts occurring after the spring reaches the elastic limit C is not correct because plastic deformation occurs beyond the elastic limit	1

7	**The only correct answer is A (the wire is elastically deformed)** B is not correct because only elastic deformation occurs below the elastic limit. C is not correct because plastic deformation beyond the elastic limit increases the extension D is not correct because the wire can be extended beyond the elastic limit before it snaps	1

1	**The only correct answer is B (the gradient of the graph)** A is not correct because the Young modulus is not the area under the graph C is not correct because stress × strain is not equivalent to the Young modulus D is not correct because the Young modulus should be stress / strain	1

2	**The only correct answer is D** (50 N m^{-1}) A is not correct because $k = \frac{\Delta F}{\Delta x} = \frac{1.5\ \text{N}}{0.030\ \text{m}} = 50\ \ \text{N m}^{-1}$ B is not correct because $k = \frac{\Delta F}{\Delta x} = \frac{1.5\ \text{N}}{0.030\ \text{m}} = 50\ \ \text{N m}^{-1}$ C is not correct because $k = \frac{\Delta F}{\Delta x} = \frac{1.5\ \text{N}}{0.030\ \text{m}} = 50\ \ \text{N m}^{-1}$	**1**

3	**A is the correct answer** B is not correct because the answer should not be square rooted C is not correct because the answer is inverted and should not be square rooted D is not correct because the answer is inverted	**1**

9	**C is the correct answer** A is not correct because P has a smaller breaking stress than Q B is not correct because P has a smaller breaking strain than Q D is not correct because graph P has an initial gradient greater than graph Q	**1**

9	**D weak under tension and strong under compression**	**1**
	Incorrect Answers: A – Concrete is not strong under tension B – Concrete is neither strong under tension nor weak under compression C – Concrete is strong under compression	

Question Number	Acceptable Answer		Additional Guidance	Mark
15(a)	the stiffness of the material / metal / copper **Or** (Young modulus =) $\frac{\text{Stress}}{\text{Strain}}$ in the linear region **Or** (Young modulus =) $\frac{Fx}{A\Delta x}$ in the linear region with all terms defined	**(1)**		**1**
15(b)(i)	Calculates mean diameter Calculates cross sectional area $A = 4.3 \times 10^{-8}\ \text{m}^2$ ($= 4.3 \times 10^{-2}\ \text{mm}^2$)	**(1)** **(1)** **(1)**	Example calculation Mean diameter $= \frac{0.230\ \text{mm} + 0.235\ \text{mm} + 0.230\ \text{mm} + 0.240\ \text{mm}}{4}$ Mean diameter $= 0.234 \times 10^{-3}$ m $A = \pi \frac{(0.234\ \times 10^{-3}\ m)^2}{4} = 4.30 \times 10^{-8}\ \text{m}^2$	**3**
15(b)(ii)	Use of $W = mg$ Use of $\sigma = \frac{F}{A}$ **and** Use of $\varepsilon = \frac{\Delta x}{x}$ **and** use of $E = \frac{\sigma}{\varepsilon}$ **Or** Calculates gradient $\times \frac{\text{length}}{\text{area}}$ Young modulus = 1.6×10^{11} Pa (ecf from (b)(i))	**(1)** **(1)** **(1)**	Example calculation $\frac{F}{\Delta x} = 195\ \text{kg m}^{-1} \times 9.81\ \text{N kg}^{-1} = 1913\ \text{N m}^{-1}$ $E = 1913\ \text{N m}^{-1} \times \frac{3.50\ \text{m}}{4.30 \times 10^{-8}\ \text{m}^2}$ $= 1.557 \times 10^{11}$ Pa	**3**
15(b)(iii)	The gradient will be greater (for the shorter wire) The Young modulus is the same	**(1)** **(1)**		**2**

(Total for Question 15 = 9 marks)

Question Number	Answer		Mark
14(a)	Use of area under the graph **Or** approximation to a triangle using $E_{el} = ½ F\Delta x$	(1)	
	Number of small squares × 5 × 10^{-4} J **Or** number of large cm squares × 1.25 × 10^{-2} J **Or** area under graph approximated to a minimum of two shapes	(1)	
	Work done = 0.46 to 0.48 J	(1)	**3**
	<u>Example of calculation:</u> Work done = 929 squares × 5 × 10^{-4} J = 0.465 J		
14(b)	Curve drawn below given curve starting at the end of the given graph	(1)	
	Graph ending at beginning of the given graph	(1)	**2**
	Total for question 14		**5**

Question Number	Answer		Additional Guidance	Mark
15(a)	Use of $W = mg$	**(1)**	<u>Example calculation</u>	
	Use of $F = k\Delta x$ to determine k	**(1)**	$0.200\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 1.962\ \text{N}$	
	Use of $F = k\Delta x$ to determine weight of ball	**(1)**	$k = \frac{1.962\ \text{N}}{0.375\ \text{m} - 0.250\ \text{m}} = 15.70\ \text{N m}^{-1}$	
	$W = 0.71$ N	**(1)**	$F = 15.70\ \text{N m}^{-1} \times (0.295\ \text{m} - 0.250\ \text{m}) = 0.707\ \text{N}$	**4**
15(b)	Elastic strain energy is equal to the area under graph **Or** k is constant (because the gradient is constant)	**(1)**		
	Area under graph = $\frac{1}{2}F\Delta x$ **and** $\Delta x = \frac{F}{k}$ **Or** $E_{el} = \frac{1}{2}F\Delta x$ **and** $\Delta x = \frac{F}{k}$	**(1)**		
	(So) elastic strain energy = $\frac{F^2}{2k}$	**(1)**		**3**
	Total for question 15			**7**

	Indicative content IC1 Measure the original length (from clamp to marker) IC2 Measure distance moved by marker from original position to determine extension. **Or** Measure new length and subtract original length to determine extension IC3 Calculate weight of masses using $W = mg$ **Or** Use a newtonmeter to measure weight of masses IC4 Use diameter to calculate cross-sectional area IC5 Calculate stress using $\frac{\text{force}}{\text{area}}$ **and** calculate strain using $\frac{\text{extension}}{\text{original length}}$ (allow symbol equations if terms defined) **Or** plot a graph of stress against strain **Or** plot a graph of force against extension IC6 Calculate Young Modulus using $\frac{\text{stress}}{\text{strain}}$ (allow symbol equations if terms defined) **Or** Correctly relate gradient of (straight section of) graph to Young Modulus.		

16(b)	Calculates cross-sectional area	**(1)**	
	Use of $\sigma = \frac{F}{A}$	**(1)**	
	Use of $E = \frac{\sigma}{\varepsilon}$ **and** use of $\varepsilon = \frac{\Delta x}{x}$	**(1)**	
	$\Delta x = 4.6 \times 10^{-4}$ m	**(1)**	**4**
	<u>Example calculation</u> $A = \pi \times \left(\frac{0.56 \times 10^{-3}\text{ m}}{2}\right)^2 = 2.46 \times 10^{-7}\text{m}^2$ $\sigma = \frac{5.0\text{ N}}{2.46 \times 10^{-7}\text{m}^2} = 2.03 \times 10^7$ Pa $\varepsilon = \frac{2.03 \times 10^7\text{Pa}}{1.1 \times 10^{11}\text{Pa}} = 1.85 \times 10^{-4}$ $\Delta x = 1.85 \times 10^{-4} \times 2.5 = 4.61 \times 10^{-4}$ m		
	Total for question 16		**10**

Question Number	Acceptable Answer	Additional Guidance	Mark
15(a)	Compression changes from 60 nm to 97.5 nm **(1)** Use of $E_{el} = \frac{1}{2}F\Delta x$ with corresponding values of F and compression **or** Determines area under graph between 85 N and 140 N **(1)** Increase in elastic strain energy = 4.3×10^{-6} J **(1)**	Allow compression changes from a value between 55 nm and 62 nm to a value between 95 nm and 100nm Allow an answer consistent with their allowed readings from the graph. <u>Example calculation</u> $E_{el} = \frac{1}{2} 140\text{ N} \times 97.5 \times 10^{-9}\text{ m} = 6.83 \times 10^{-6}\text{ J}$ $E_{el} = \frac{1}{2} 85\text{ N} \times 60 \times 10^{-9}\text{ m} = 2.55 \times 10^{-6}\text{ J}$ $\Delta E_{el} = 6.83 \times 10^{-6}\text{ J} - 2.55 \times 10^{-6}\text{ J} = 4.28 \times 10^{-6}\text{ J}$	3

Question Number	Acceptable Answer	Additional Guidance	Mark
15(a)	Compression changes from 60 nm to 97.5 nm **(1)** Use of $E_{el} = \frac{1}{2}F\Delta x$ with corresponding values of F and compression **or** Determines area under graph between 85 N and 140 N **(1)** Increase in elastic strain energy = 4.3×10^{-6} J **(1)**	Allow compression changes from a value between 55 nm and 62 nm to a value between 95 nm and 100nm Allow an answer consistent with their allowed readings from the graph. <u>Example calculation</u> $E_{el} = \frac{1}{2} 140\text{ N} \times 97.5 \times 10^{-9}\text{ m} = 6.83 \times 10^{-6}\text{ J}$ $E_{el} = \frac{1}{2} 85\text{ N} \times 60 \times 10^{-9}\text{ m} = 2.55 \times 10^{-6}\text{ J}$ $\Delta E_{el} = 6.83 \times 10^{-6}\text{ J} - 2.55 \times 10^{-6}\text{ J} = 4.28 \times 10^{-6}\text{ J}$	3
15(b)	(The brick) returns to its original size / shape / length when the force / stress is removed **(1)**		1

(Total for Question 15 = 4 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
17(a)	Corresponding force and extension read from graph **(1)** Use of $\Delta F = k\Delta x$ **(1)** $k = 2760\text{ N m}^{-1}$ **(1)** Comparison with 2700 (N m^{-1}) and consistent conclusion **(1)**	Allow a tolerance of ±½ a small square Allow a value of k between 2650 and 2850 <u>Example calculation</u> $k = \frac{80\text{ N}}{29 \times 10^{-3}\text{ m}} = 2760\text{ N m}^{-1}$ $2760\text{ N m}^{-1} \approx 2700\text{ N m}^{-1}$ so this is string Y	4

Question Number	Acceptable Answer		Additional Guidance	Mark
17(a)	Corresponding force and extension read from graph Use of $\Delta F = k\Delta x$ $k = 2760\ \mathrm{N\ m^{-1}}$ Comparison with 2700 ($\mathrm{N\ m^{-1}}$) and consistent conclusion	(1) (1) (1) (1)	Allow a tolerance of ±½ a small square Allow a value of k between 2650 and 2850 Example calculation $k = \frac{80\ \mathrm{N}}{29 \times 10^{-3}\ \mathrm{m}} = 2760\ \mathrm{N\ m^{-1}}$ $2760\ \mathrm{N\ m^{-1}} \approx 2700\ \mathrm{N\ m^{-1}}$ so this is string Y	4
17(b)	Calculates cross-sectional area of string Use of $\sigma = \frac{F}{A}$ Use of $\varepsilon = \frac{\Delta x}{x}$ Use of $E = \frac{\sigma}{\varepsilon}$ $E = 6.0$ GPa	(1) (1) (1) (1) (1)	Example calculation $A = \pi \times (0.85 \times 10^{-3}\ \mathrm{m})^2 = 2.27 \times 10^{-6}\ \mathrm{m^2}$ $\sigma = \frac{36\ \mathrm{N}}{2.27 \times 10^{-6}\ \mathrm{m^2}} = 15.9 \times 10^6\ \mathrm{Pa}$ $\varepsilon = \frac{0.002\ \mathrm{m}}{0.750\ \mathrm{m}} = 0.00267$ $E = \frac{15.9 \times 10^6\ \mathrm{Pa}}{0.00267} = 5.96 \times 10^9\ \mathrm{Pa}$	5

(Total for Question 17 = 9 marks)