10	**B is the correct answer** This is because the force is given by $F=kx$. So if k is doubled but x remains the same, F will be doubled.	**(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**

6	**The only correct answer is A Hard**	**1**
	***B** is not correct because the resistance to scratching of the surface of a material does not depend on the stiffness of the material* ***C** is not correct because the resistance to scratching of the surface of a material does not depend on the strength of the material* ***D** is not correct because the resistance to scratching of the surface of a material does not depend on the toughness of the material*	

7	**A is the correct answer as strain** $= \frac{\text{extension}}{\text{original length}} = \frac{0.2}{50}$ B is not the correct answer as the extension in mm was not converted to cm before being used in the equation for strain C is not the correct answer as the extension in mm was not converted to cm and the incorrect formula of original length/extension was used D is not the correct answer as the incorrect formula of original length/extension was used.	**(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**

6	**The only correct answer is A** $\left(\frac{2}{3}\Delta x\right)$ B is not correct because doubling the force does not give half the extension and three times the stiffness does not give three times the extension C is not correct because doubling the force does not give half the extension D is not correct because three times the stiffness does not give three times the extension	**1**

10	**A** 4σ	**1**
	Incorrect Answers: $\sigma \propto 1/A$ so if the thinner string has half the diameter, its cross-sectional area will be ¼ that of the thicker string. $1 \div ¼ = 4$ so σ is 4 times larger B – factor of ½ not squared when diameter squared in area equation C – inverse of distractor B, assumes $\sigma \propto$ diameter D – inverse of correct answer, assumes $\sigma \propto$ area	

9	**D weak under tension and strong under compression** 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	1

9	**C is the correct answer** A is not the correct answer as every column is wrong. B is not the correct answer as the P and Q columns are the wrong way round. D is not the correct answer as the Q and R columns are the wrong way round.	**(1)**

9	**9. The only correct answer is C** ***A*** *is incorrect because the percentage uncertainty should only be quoted to the same number of sf as the absolute uncertainty i.e. 1 sf* ***B*** *is incorrect because this is 2 times the correct percentage uncertainty and it has been quoted to 2 sf* ***D*** *is incorrect because this is 2 times the correct percentage uncertainty*	**(1)**

Question Number	Answer		Mark
16(a)	Compares ≈40 (MPa) (compression) with ≈10 (MPa) (tension)	(1)	
	Breaking/fracture/ultimate stress/force (much) greater under compression **Or** Breaking/fracture/ultimate stress is 40 MPa under compression, and 10 MPa under tension. **Or** Breaking/fracture/ultimate stress is 30 MPa greater under compression.	(1)	**(2)**
	(If no other mark scored, allow 1 mark for greater energy absorbed/stored under compression)		
16(b)	Breaking stress = 5.00 to 5.10 ($\times 10^8$ Pa)	(1)	
	Use of $\sigma = F/A$	(1)	
	$F = 8.0/8.1 \times 10^5$ N	(1)	**(3)**
	Example of calculation $A = \pi \times (2.25 \times 10^{-2}\ \text{m})^2 = 1.59 \times 10^{-3}\ \text{m}^2$ $F = 1.59 \times 10^{-3}\ \text{m}^2 \times 5.05 \times 10^8\ \text{Pa} = 8.03 \times 10^5$ N		
16(c)(i)	Concrete can withstand high(er) stress/force under compression **Or** Concrete is strong(er) under compression	(1)	
	The concrete remains under compression when tensile force applied. **Or** Applied/tensile force first has to overcome the compression **Or** When tensile force applied, concrete is still under compression	(1)	
	The steel/rods take (some of) the force/stress **Or** The force/stress causes deformation of the steel	(1)	
	Steel can withstand a large(r) tensile force/stress **Or** Steel is strong(er) under tension **Or** Ultimate tensile stress of steel is large(r)	(1)	**(4)**
16(c)(ii)	(When force removed) the rod will not return to its original length/shape **Or** The rod will be permanently/plastically deformed	(1)	
	the concrete will not compress (as much) **Or** The compression force will be less/zero	(1)	**(2)**
	Total for question 16		**11**

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

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 $\times 5 \times 10^{-4}$ J **Or** number of large cm squares $\times 1.25 \times 10^{-2}$ J **Or** area under graph approximated to a minimum of two shapes	(1)	
	Work done = 0.46 to 0.48 J	(1)	**3**
	Example of calculation: Work done = 929 squares $\times 5 \times 10^{-4}$ 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**

	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**
	Example calculation $A = \pi \times \left(\frac{0.56\times10^{-3}\text{ m}}{2}\right)^2 = 2.46 \times 10^{-7}\text{m}^2$ $\sigma = \frac{5.0\text{ N}}{2.46\times10^{-7}\text{m}^2} = 2.03 \times 10^{7}$ Pa $\varepsilon = \frac{2.03\times10^{7}\text{Pa}}{1.1\times10^{11}\text{Pa}} = 1.85 \times 10^{-4}$ $\Delta x = 1.85 \times 10^{-4} \times 2.5 = 4.61 \times 10^{-4}$ m		
	Total for question 16		**10**

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

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

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)**	Allow a tolerance of ±½ a small square	**4**
	Use of $\Delta F = k\Delta x$	**(1)**		
	$k = 2760\ \text{N m}^{-1}$	**(1)**	Allow a value of k between 2650 and 2850	
	Comparison with 2700 (N m^{-1}) and consistent conclusion	**(1)**	<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	

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

(Total for Question 17 = 9 marks)