Q1.

Question Number	Answer	Mark
(a)	• Use of Young modulus = gradient (of either initial linear region of graph) (1) (MP1 accept ratios of co-ordinates up to strains of (E_{28})0.0015 or (E_2) 0.0014) • See 3.2 to 3.3 × 10^{10} (Pa) **Or** 4.2 to 4.4 × 10^{10} (Pa) (1) • Comparison of the two values obtained i.e. use of E_{28}/E_2 **Or** $(E_{28} - E_2)/E_2$ (1) • E_{28}/E_2 = 1.30 to 1.40 **Or** $(E_{28} - E_2)/E_2$ = 0.30 to 0.40 (1) (MP4 is conditional on candidates using the linear sections for both graphs in MP1) <u>Example of calculation</u> $E_{28} = \frac{140 \times 10^{6}\text{ Pa}}{0.0032} = 4.38 \times 10^{10}\text{ Pa}$ $E_2 = \frac{104 \times 10^{6}\text{ Pa}}{0.0032} = 3.25 \times 10^{10}\text{ Pa}$ $E_{28}/E_2 = \frac{4.38 \times 10^{10}\text{ Pa}}{3.25 \times 10^{10}\text{ Pa}} = 1.35$	4
(b)	• Use of counting squares or approximation of the area to a series of shapes from the 28-day graph (1) • $\frac{0.35 \times 10^6 - \text{area under 28-day graph}}{0.35 \times 10^6}$ (1) • Percentage reduction = 12.0 % to 15.0 % (1) <u>Example of calculation</u> $\Delta E_{28} = (½ \times 80 \times 10^6\text{ Pa} \times 0.0019) + [½(80 + 128)\text{ Pa} \times 10^6 \times (0.0038 - 0.0019)] + (64 \times 0.0001 \times 4 \times 10^6\text{ Pa}) = 299\,200\text{ J m}^{-3}$ Percentage reduction = $\frac{350\,000\text{ J m}^{-3} - 299\,200\text{ J m}^{-3}}{350\,000\text{ J m}^{-3}} \times 100 = 14.5\ \%$	3
(c)	• The breaking stress/force is greater (1) • The concrete is less flexible **Or** the concrete is stiffer (Do not accept a greater Young modulus) (1) • There is a smaller plastic region **Or** the elastic region is greater **Or** there's little change in the toughness **Or** a change in the properties of the concrete after you've used it could cause problems (1)	3
	Total for question	**10**

Q2.

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

Q3.

Question Number	Answer		Mark
(a)	• Ratio of stress to strain (for a material). **Or** stress per unit strain. **Or** σ / ε with symbols defined. **Or** $\frac{F x}{A \Delta x}$ with symbols defined.	(1)	**(1)**
(b)(i)	• Mean diameter = 0.234 mm (rounds to) • Use of $A = \pi r^2$ • $A = 4.3 \times 10^{-8}$ m^2 **or** 0.043 mm^2 <u>Example of calculation</u> Mean diameter = ¼ (0.230 + 0.235 + 0.230 + 0.240) = 0.234 mm Area = $\pi \frac{(0.234 \times 10^{-3}\ m)^2}{4} = 4.30 \times 10^{-8}\ \text{m}^2$	(1) (1) (1)	**(3)**
(b)(ii)	• Use of $W = m g$ • Use of gradient = $m / \Delta x$ in Young Modulus formula i.e. E = gradient × g × x /A • $E = 1.6 \times 10^{11}$ Pa e.c.f. from (b)(i) <u>Example of calculation</u> Young modulus = $195 \times 9.81\ \text{N kg}^{-1} \times \frac{3.50\ \text{m}}{4.30 \times 10^{-8}\ \text{m}^2}$ $= 1.56 \times 10^{11}$ Pa	(1) (1) (1)	**(3)**
(b)(iii)	Shorter wire gives greater gradient. Young modulus the same.	(1) (1)	**(2)**

Q4.

Question Number	Answer		Mark
(a)(i)	Use of fall factor = $\frac{\text{height fallen before the rope begins to stretch}}{\text{total unstretched length of rope}}$	(1)	
	Use of $\varepsilon = \frac{\Delta x}{x}$ with x = 15.0 m	(1)	
	Use of $E_{grav} = mg\Delta h$	(1)	
	Use of $E_{grav} = E_{el}$ with their Δx	(1)	
	F_{max} = 14 000 (N)	(1)	5
	<u>Example of calculation</u> Height fallen = 15.0 m × 0.8 = 12 m Δx = 0.09 × 15.0 m = 1.35 m E_{grav} = 71 kg × 9.81 N kg^{-1}× 12 m = 8358 J (from fall) E_{grav} = 71 kg × 9.81 N kg^{-1}× 1.35 m = 940.3 J (from extension) 8358 J + 940.3 J = ½ × F_{max} × 1.35 m F_{max} = 13 775 N		
(a)(ii)	• This would not be a good idea, as the climber would reach a higher velocity (just before the rope stretches)	(1)	
	• (Hence) the climber's deceleration/force (as the rope stretches) would be greater	(1)	2

(b)	**Max 6**		
	• Use of area under the graph to determine the stored energy	(1)	
	• Energy = 800 J (new)	(1)	
	• Energy = 700 J (old)	(1)	
	• The old rope would absorb/store less energy	(1)	
	• Use of $F = k\Delta x$ to determine k (accept gradient of a tangent)	(1)	
	• Calculation of k for both ropes at same applied force	(1)	
	• The old rope is not as stiff as the new rope **Or** The old rope extends more	(1)	
	• The old rope would break at a smaller applied force/stress	(1)	6
	Total for question		**13**

Q5.

Question Number	Answer	Mark
	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)

Q6.

Question Number	Answer	Mark
	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)**

Q7.

Question Number	Answer		Mark
(a)(i)	• $E_{el} = ½\, k\, \Delta x^2$ **Or** Use of $E_{el} = ½\, F\Delta x$ **and** use of $F = k\, \Delta x$. • Elastic PE is transferred into kinetic energy **Or** $E_{el} = E_k$ • $½\, m\, v^2 = ½\, k\, \Delta x^2$ • States that m and k are constant so $v \propto \Delta x$. **Or** States that $= \sqrt{\frac{k}{m}}\Delta x$.	(1) (1) (1) (1)	**(4)**
(a)(ii)	• Gradient calculated. **Or** Use of a point on the line in a relevant equation. • Use of $½\, k\, \Delta x^2 = ½\, m\, v^2$ **or** gradient = $\sqrt{(k/m)}$ i.e. $k = m \times$ gradient^2 • k in range 22 – 26 N m^{-1} <u>Example of calculation</u> Gradient $\frac{4.8\text{ m s}^{-1} - 2.2\text{ m s}^{-1}}{0.30\text{ m}} = 8.67\ (\text{s}^{-1})$ k = mass × gradient^2 $k = 3.0 \times 10^{-1}\text{ kg} \times (8.67\text{ s}^{-1})^2$ $k = 22.6\text{ N m}^{-1}$	(1) (1) (1)	**(3)**
(b)	• Limit of proportionality exceeded. **Or** Extension no longer proportional to force. • Range of Hooke's Law exceeded. **Or** Hooke's Law no longer applies.	(1) (1)	**(2)**