

Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is C $\left(\frac{(300 + 50 + 50) \times 6 \times 10^{-3}}{2}\right)$ A is not correct because this would be the change in elastic energy if the initial force applied was 0 N B is not correct because the final force on the spring is (300 + 50) N so this does not take account that the initial force on the spring was 50 N D is not correct because this would be the total elastic energy of the spring	1

Q2.

Question Number	Answer	Mark
	The correct answer is B A is not the correct answer because gpe should be added not subtracted on the right hand side C is not the correct answer because the total elastic energy is not $F\Delta x$ and gpe should be added not subtracted on the right hand side D is not the correct answer because the total elastic energy is not $F\Delta x$	1

Q3.

Question Number	Answer	Mark
(a)	It's the force / stress beyond which the cable does not return to its original length when the force / stress is removed (1)	1
(b)(i)	Use of $\varepsilon = \Delta x/x$ (1) $\varepsilon = 0.021$ (1) <u>Example of calculation</u> $\varepsilon = 0.126 \text{ m} \div 6 \text{ m} = 0.021$	2
(b)(ii)	Use of $\sigma = F/A$ (1) $\sigma = 1.4 \times 10^9 \text{ Pa}$ (1) <u>Example of calculation</u> $\sigma = 1.34 \times 10^6 \text{ N} \div 9.6 \times 10^{-3} \text{ m}^2 = 1.40 \times 10^9 \text{ Pa}$	2
Total for question		5

Q4.

Question Number	Answer	Mark																																						
(a)*	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. The following table shows how the marks should be awarded for indicative content and lines of reasoning. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> <table><tr><td></td><td>Marks</td></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></table>	IC points	IC mark	Max linkage mark available	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0		Marks	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	
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	Indicative content: 1. There is a (backward) force/friction on floor from wheels/car 2. Newton's Third Law implies forward/opposite force from floor 3. Compression/deformation of spring reduces (as car moves forward) 4. (Resultant) force is proportional to compression/deformation of spring Or Reference to Hooke's law. 5. Acceleration is proportional to resultant force Or Reference to $F = ma$ 6. Acceleration reduces (as distance travelled increases) Or Acceleration is zero once spring has returned to original state Accept "resultant force" for "acceleration" in IC6	6
	Total for question	6

Q5.

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

Q6.

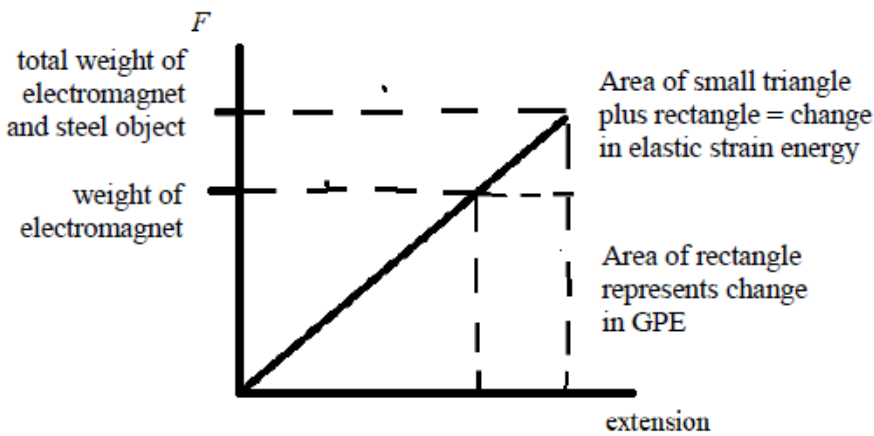
Question Number	Answer	Mark
(a)	Maximum value of weight/force for which weight/force is proportional to extension Or Point beyond which Hooke's Law no longer applies Or Point beyond which graph line ceases to be straight Or Point beyond which weight/force is no longer proportional to extension (1)	1
(b)(i)	Use of large triangle to determine gradient (1) Gradient = $18\,500 \text{ (N m}^{-1}\text{)}$ (sf range 18 - 19, no ue) (1) <u>Example of calculation</u> gradient = $37 \text{ N} \div (2 \times 10^{-3} \text{ m}) = 18\,500 \text{ (N m}^{-1}\text{)}$	2
(b)(ii)	Rearranges $E = \text{stress} / \text{strain}$ to get $E = \text{gradient} \times \frac{x}{A}$ Or Rearranges $E = \text{stress} / \text{strain}$ to get gradient = $\frac{A}{x} E$ (1) Use of $A = \pi r^2$ (1) Young modulus = $2 \times 10^{11} \text{ Pa}$ (1) (allow ecf from (b)(i)) <u>Example of calculation</u> $A = \pi \times (2.8 \times 10^{-4})^2 = 2.46 \times 10^{-7} \text{ m}^2$ $E = 1.85 \times 10^4 \text{ N m}^{-1} \times 2.6 \text{ m} \div 2.46 \times 10^{-7} \text{ m}^2 = 1.95 \times 10^{11} \text{ Pa}$	3

(c)	Use of $\sigma = \frac{F}{A}$ (1) Determines maximum safe load Or Determines maximum stress Or Determines minimum cross section (1) Valid conclusion by comparison with student's calculation (1)	3
	<u>Example of calculation</u> $\sigma_{\max} = \frac{W_{\max}}{A}$ $4.80 \times 10^8 \text{ Pa} = \frac{W_{\max}}{2.46 \times 10^{-7} \text{ m}^2}$ $W_{\max} = 4.80 \times 10^8 \text{ Pa} \times 2.46 \times 10^{-7} \text{ m}^2 = 118 \text{ N} > 100 \text{ N}$ so yes	
	Total for question	9

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> $\Delta E_{28} = (\frac{1}{2} \times 80 \times 10^6 \text{ Pa} \times 0.0019) + [\frac{1}{2}(80 + 128) \text{ Pa} \times 10^6 \times (0.0038 - 0.0019)] + (64 \times 0.0001 \times 4 \times 10^6 \text{ Pa}) = 299\,200 \text{ J m}^{-3}$ $\text{Percentage reduction} = \frac{350\,000 \text{ J m}^{-3} - 299\,200 \text{ J m}^{-3}}{350\,000 \text{ J m}^{-3}} \times 100 = 14.5\%$	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

Question Number	Answer	Mark
(a)	They act on the same object	(1)
	They are not the same type of force	(1)
(b)(i)	Use of $\epsilon = \frac{\Delta x}{x}$	(1)
	Use of $F = k\Delta x$ and $\sigma = \frac{F}{A}$	(1)
	Use of $E = \frac{\sigma}{\epsilon}$ [allow a method using $E = \frac{kx}{A}$ for 3 marks]	(1)
	$E = 2.1 \times 10^{11} \text{ Pa}$	(1)
	<u>Example calculation</u> $\Delta x = 3 \times 10^{-4} \times 3.8 \text{ m} = 1.14 \times 10^{-3} \text{ m}$ $F = 2.8 \times 10^7 \text{ N m}^{-1} \times 1.14 \times 10^{-3} \text{ m} = 3.19 \times 10^4 \text{ N}$ $\sigma = \frac{3.19 \times 10^4 \text{ N}}{5.1 \times 10^{-4} \text{ m}^2} = 6.26 \times 10^7 \text{ Pa}$ $E = \frac{6.26 \times 10^7 \text{ Pa}}{3.0 \times 10^{-4}} = 2.09 \times 10^{11} \text{ Pa}$	4

(b)(ii)	Area under graph = elastic strain energy (can be indicated on graph)	(1)	5
	Weight of electromagnet is still exerted on cable after object falls (can be indicated on graph)	(1)	
	So change in elastic strain energy = area under graph between total weight (of electromagnet and steel object) and weight of electromagnet (can be shown on graph or given as an algebraic equivalent using $E_{el} = \frac{1}{2} F \Delta x$)	(1)	
	And change in gravitational potential energy of electromagnet is weight of electromagnet $\times$ change in extension (can be indicated on graph)	(1)	
	So the change in elastic strain energy stored $>$ change in gravitational potential energy of the electromagnet	(1)	
	<u>Example of graph</u> 		
Total for question			11

Q9.

Question Number	Answer	Mark
(a)	The greater the length of the rope, the greater the extension for a given force (1) Stiffness $k = F / \Delta x$ so stiffness decreases (if extension increases). (1)	2
(b)(i)	Use of $E = \frac{\sigma}{\epsilon}$ and $\sigma = \frac{F}{A}$ and $\epsilon = \frac{\Delta x}{x}$ (1) Use of $F = k\Delta x$ (1) $k = 1.35 \times 10^5 \text{ (N m}^{-1}\text{)}$ (1) <u>Example of calculation</u> $2.70 \times 10^9 \text{ N m}^{-2} = F \times 6.00 \text{ m} \div (3.00 \times 10^{-4} \text{ m}^2 \times \Delta L)$ $F = (2.70 \times 10^9 \text{ N m}^{-2} \times 3.00 \times 10^{-4} \text{ m}^2 \div 6.00 \text{ m}) \times \Delta L = k \Delta x$ $k = \frac{F}{\Delta L} = \frac{2.70 \times 10^9 \text{ N m}^{-2} \times 3.00 \times 10^{-4} \text{ m}^2}{6.00 \text{ m}}$ $= 1.35 \times 10^5 \text{ N m}^{-1}$	3
(b)(ii)	Correct use of factor of 2 to calculate F or Δx (1) Use of $\Delta F = k\Delta x$ (1) $1.85 \times 10^{-2} \text{ (m)}$ (allow ecf from (i)) (1) <u>Example of calculation</u> $F = 5\,000 \text{ N} / 2 = 2\,500 \text{ N}$ $\Delta x = \frac{F}{k} = \frac{2\,500 \text{ N}}{1.35 \times 10^5 \text{ N m}^{-1}} = 1.85 \times 10^{-2} \text{ m}$	3
(b)(iii)	Use of $\Delta E_{el} = \frac{1}{2} F\Delta x$ (1) $\Delta E_{el} = 23.1 \text{ J}$ (allow ecf from (ii)) (1) <u>Example of calculation</u> $\Delta E_{el} = 0.5 \times 2\,500 \text{ N} \times 1.85 \times 10^{-2} \text{ m} = 23.13 \text{ J}$	2
(c)	Use of $W = F\Delta s$ (to find the work done in lifting the load) (1) Compares $7\,500 \text{ J}$ with their calculated value in b(iii) and draws suitable conclusion (1) <u>Example of calculation</u> Work done by pulley system $= 5 \times 10^3 \text{ N} \times 1.5 \text{ m} = 7\,500 \text{ J}$ $23(1) \text{ (J)} \ll 7\,500 \text{ (J)} \therefore$ not significant	2
Total for question		12

Q10.

Question Number	Answer	Additional Guidance	Mark
(a)	There is some energy stored in the spring when the bread is in the toaster (1) Or Some work is done by gravity Total work done (to stretch the spring) is work done by gravity plus work done by force of the person (1) So the (total elastic strain) energy stored is greater than the work done (by the person) (1)	(dependent on MP1 or MP2)	3
(b)(i)	Determines the force on each spring (1) Use of $\Delta F = k\Delta x$ (1) $k = 6.2 \text{ (N m}^{-1}\text{)}$ (to at least 2 significant figures) (1)	<u>Example of calculation</u> Force on each spring = $\frac{0.52 \text{ N}}{4} = 0.13 \text{ N}$ $k = \frac{0.13 \text{ N}}{0.021 \text{ m}} = 6.19 \text{ N m}^{-1}$	3

(b)(ii)	Use of $\Delta F = k\Delta x$ (1)	<u>Example of calculation</u>	6
	Use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ (1)	$x = \frac{\left(\frac{1.2 \text{ N} + 0.52 \text{ N}}{4} \right)}{6.19 \text{ N m}^{-1}} = 0.0695 \text{ m}$	
	Use of $\Delta E_{grav} = mg\Delta h$ with $mg = 0.52 \text{ N}$ (1)	$E_{elastic} = 0.5 \times (1.2 \text{ N} + 0.52 \text{ N}) \times 0.0695 \text{ m} = 0.0598 \text{ J}$	
	Applies conservation of energy (1)	$\Delta E_{grav} = 0.52 \text{ N} \times 0.0695 \text{ m} = 0.0361 \text{ J}$	
	Use of $E_k = \frac{1}{2} mv^2$ and use of $W = mg$ (1)	$\Delta E_k = 0.0598 \text{ J} - 0.0361 \text{ J} = 0.0237 \text{ J}$	
	$v = 0.95 \text{ m s}^{-1}$ (ecf from (b)(i)) (show that value gives $v = 0.96 \text{ m s}^{-1}$) (1)	$m = \frac{0.52 \text{ N}}{9.81 \text{ N kg}^{-1}} = 0.0530 \text{ kg}$ $v = \sqrt{\frac{2 \times 0.0237 \text{ J}}{0.0530 \text{ kg}}} = 0.946 \text{ m s}^{-1}$	
Total for question			12

Q11.

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

(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

Q12.

Question Number	Answer	Mark
(a)	Stress (or strain) value at/beyond which a material/object undergoes a sudden or large plastic deformation (1)	1
(b)(i)	The force/tension from/in the cable (on the actor) is greater than the weight of the actor (1) (So) there is a resultant/net/unbalanced force (upwards) (1)	2

(b)(ii)	Use of $W = m g$ (1) Use of $\Sigma F = m a$ (1) Tension = 917 (N) (1) <u>Example calculation</u> $W = 77 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 755 \text{ N}$ $T - 755 \text{ N} = 77 \text{ kg} \times 2.1 \text{ m s}^{-2}$ $T = 162 \text{ N} + 755 \text{ N} = 917 \text{ N}$	3
(b)(iii)	Use of $A = \pi r^2$ (1) Use of $\sigma = F \div A$ (ecf from (b)(ii)) (1) Allowed stress (15% yield stress of steel) = $3.8 \times 10^7 \text{ Pa}$ and $\sigma = 2.0 \times 10^7 \text{ Pa}$ Or (15%)⁻¹ of cable stress = $1.3 \times 10^8 \text{ Pa}$ Or Max safe tension = $1.7 \times 10^3 \text{ N}$ Or Min safe diameter = $5.6 \times 10^{-3} \text{ m}$ Or Percentage of yield stress = 8% Or Max safe acceleration = 12.3 m s^{-2} (1) Valid conclusion by comparison of relevant student values (1) <u>Example calculation</u> $A = \frac{\pi d^2}{4} = \frac{\pi \times (7.6 \times 10^{-3} \text{ m})^2}{4} = 4.54 \times 10^{-5} \text{ m}^2$ $\sigma = \frac{917 \text{ N}}{4.54 \times 10^{-5} \text{ m}^2} = 2.02 \times 10^7 \text{ Pa}$ (show that value gives $2.03 \times 10^7 \text{ Pa}$) $0.15 \times 2.5 \times 10^8 \text{ Pa} = 3.75 \times 10^7 \text{ Pa}$ $2.03 \times 10^7 \text{ Pa} < 3.75 \times 10^7 \text{ Pa}$ so it is safe.	4

(c)	New cable has a greater cross sectional area, (but same breaking stress) so a greater force is required (1) Because new cable has smaller Young modulus, there is a greater strain for the same stress (1) So (at breaking stress) there will be a greater extension (because cables are the same length) [dependent on MP2] Or Smaller Young modulus implies greater extension (at breaking stress, because cables are the same length) [independent mark] (1) (And as) force and extension both increase, work done to break the new cable is greater than that for the original cable [independent mark] (1)	4
	Total for question	14