1)

(a)		The extension ∝ (applied) force (on spring) (as long as the elastic limit is not exceeded)	B1	
(b)	(i)	Gradient / slope (of line / graph) / force divided by extension **The term *gradient /slope / divided* to be included and spelled correctly to gain the B1 mark**	B1	**Must use tick or cross on Scoris to show if the mark is awarded**
	(ii)	Area (under the graph / line)	B1	**Allow**: ½ × force × extension **Allow**: ½ × force constant × extension^2 if **(b)(i)** is correct
(c)		The extension (for the combination) is doubled Force (for each spring) is the same / constant (force constant = force/extension, hence it is halved)	B1 B1	**Allow**: 1 mark for '*F* is the same, *x* is doubled' **Allow**: 2 marks for 'the springs need half the force to give the same (total) extension'
(d)	(i)	Young modulus = stress/strain As long as the elastic limit is not exceeded / in the linear region of stress against strain graph / Hooke's law is obeyed	M1 A1	
	(ii) 1	stress = $\frac{4.2}{0.20\times10^{-6}}$ stress = 2.1×10^7 (Pa)	C1 A1	**Allow**: 1 mark for 2.1×10^n, $n \neq 7$
	(ii) 2	Young modulus = $\frac{2.1\times10^7}{0.015}$ Young modulus = 1.4×10^9 (Pa)	C1 A1	Possible ecf from **(ii)1**
	(ii) 3	energy = $\frac{1}{2}Fx$ $x = 0.70 \times 0.015$ / $x = 0.0105$ (m) energy = $\frac{1}{2}\times4.2\times(0.70\times0.015)$ energy = 2.2×10^{-2} (J)	C1 C1 A1	
		Total	**14**	

2)

(a)		The graph shows length and not extension of the spring / spring has original length (of 2.0 cm) (AW)	B1	**Allow**: 'length cannot be zero'
(b)		Straight line (graph) / linear graph / force ∝ extension / constant gradient (graph)	B1	**Not** 'force ∝ length'
(c)		force constant = $\frac{2.0}{0.04}$ force constant = 50 (N m^{-1})	C1 A1	**Note**: The mark is for any correct substitution **Allow**: 1 mark for 0.5 (N m^{-1}) – 10^n error **Allow** 1 mark for $5/12 \times 10^{-2}$ = 41.7 or $4/10 \times 10^{-2}$ = 40 or $3/8 \times 10^{-2}$ = 37.5 or $2/6 \times 10^{-2}$ = 33.3 or $1/4 \times 10^{-2}$ = 25
(d)		work done = $\frac{1}{2}Fx$ or $\frac{1}{2}kx^2$ or 'area under graph' work done = $\frac{1}{2}\times3.0\times0.06$ or $\frac{1}{2}\times50\times0.06^2$ work done = 0.09 (J)	C1 A1	 Possible ecf **Note**: 1 sf answer is allowed
(e)		Find the gradient / slope (of the tangent / graph) Maximum speed at 1.0s / 3.0s / 5.0s / steepest 'part' of graph / displacement = 0	B1 B1	 **Allow**:2 marks for 'steepest / maximum gradient'
		Total	**8**	

3)

(a)		The graph is a straight line through the origin / *F* proportional to *x* / force is proportional to extension	B1	**Use ticks on Scoris to show where the marks are awarded** ***origin / proportional*** must be spelled correctly to gain the mark **Not**: $F \propto x$
(b)		force constant	B1	**Allow**: spring constant
(c)		stress = $\frac{100}{\pi \times (2.8\times10^{-4})^2}$ (= 4.06 × 10^8 Pa) strain = $\frac{4.0\times10^{-3}}{1.60}$ (= 2.5 × 10^{-3}) $E = \frac{4.06\times10^{8}}{2.5\times10^{-3}}$ Young modulus = 1.6 × 10^{11} (Pa)	C1 C1 A1	**Allow** use of any other point on the graph. **Alternative method:** $E = \frac{FL}{Ax}$ C1 (Any subject) $E = \frac{100\times1.60}{\pi\times(2.8\times10^{-4})^2\times4.0\times10^{-3}}$ C1 *E* = 1.6 × 10^{11} (Pa) A1 **Allow** 2 marks for 1.6 × 10^n, n ≠ 11 (POT error)
(d)		(Straight line) with quarter gradient Correct reasoning, for example: • gradient = *EA*/*L* and *A* decreases by a factor of 4 • *A* decreases by a factor of 4 and the same force gives 4 times the extension	B1 B1	**Note**: No need to define the labels
(e)		½ kx^2 = ½ mv^2 Manipulation leading to $v \propto x$, for example: • taking square root of both sides (gives $v \propto x$) • $v^2 \propto x^2$ (hence $v \propto x$) • $v = (\sqrt{k/m})x$ (and therefore $v \propto x$)	M1 A1	**Note**: No need to define the labels
		Total	**9**	

4)

(i)	$F = kx$ $F = 50\times0.070$ / *F* = 3.5 (N) *a* = 3.5/0.180 acceleration = 19 (m s^{-2})	C1 C1 A1	Answer to 3 sf is 19.4 (m s^{-2})
(ii)	average work done = average force × displacement = 1.75 × 0.070 (= 0.1225) av rate of work done = 0.1225/0.094 av rate of work done = 1.3 (J s^{-1})	C1 A1	**Aternative** (allow full credit for other correct methods) $E = \frac{1}{2}\times50\times0.070^2 (= 0.1225)$ C1 power = 0.1225/ 0.094 power = 1.3 (J s^{-1}) A1

5)

(i)	force = 75 × 0.085 *F* = 6.38 (N) ≈ 6.4 (N)	C1 A1	
(ii)	acceleration = $\frac{6.38}{2.5\times10^{-3}}$ acceleration = 2550 (m s^{-2})	B1	**Note**: $a = \frac{kx - mg}{m}$ gives 2540 (m s^{-2}) Possible ecf
(iii)	Correct selection of equation: mgh / $\frac{1}{2}kx^2$ / $\frac{1}{2}Fx$ $0.0025\times9.81\times h = \frac{1}{2}\times75\times0.085^2$ height = 11 (m)	C1 C1 A1	**Note**: Bald answer of 11 (m) scores 3/3 marks

6)

(a)		force/extension or force per (unit) extension	B1	**Allow**: force/compression **Not**: $F = kx$ and the labels are defined, because k is not the subject
(b)	**(i)**	Arrow showing the force exerted by **A** is to the left on Fig.3.1	B1	**Allow** an unlabelled arrow
	(ii)	**1** (F_A =) 14 × 0.30 (= 4.2 N) or (F_B =) 14 × 0.50 (= 7.0 N) or (net force =) 2.8 (N) a = 2.8/0.80 acceleration = 3.5 (m s^{-2})	C1 C1 A1	**Allow**: (net force =) 14 × [0.50 – 0.30] = 2.8 (N) **Allow**: acceleration of either 5.25 (m s^{-2}) or 8.75 (m s^{-2}) **Allow** this C1 mark for a = 8.75 – 5.25 **Note**: $a = \frac{7.0+4.2}{0.80} = 14$ (m s^{-2}) scores 1 mark **Note**: $a = \frac{14 \times 0.80}{0.80} = 14$ (m s^{-2}) scores zero
		2 E = ½ Fx or E = ½ kx^2 or 1.75 (J) or 0.63 (J) ratio = $\left(\frac{0.50}{0.30}\right)^2 = 2.8$	C1 A1	**Note**: Using $E = Fx$ scores zero because of wrong physics **Note**: Answer to 3 sf is 2.78 **Allow** fractions (Ignore any units given for the ratio)
	(iii)	The resultant force (on the trolley) is smaller (AW)	B1	
	(iv)	The acceleration decreases Correct reasoning, eg: For the same (net force) F, a = F/m (therefore a is smaller) For the same (net force) F, $a \propto 1/m$ (therefore a is smaller)	M1 A1	**Allow**: $F = ma$. As m increases then a must decrease because F is constant
		Total	**10**	

7)

(a)		force constant = $\frac{3.0}{0.06}$ (Any subject) force constant = 50 (N m^{-1})	M1 A0	**Not** 3.0/6.0 = 50 (N m^{-1}) **Note**: There is no mark for the answer because it is given on the paper; the mark is for the working.
(b)	(i)	(E_i =) ½ × 50 × 0.06^2 or ½ × 3.0 × 0.06 or 0.09 (J) (E_f =) ½ × 50 × 0.10^2 or ½ × 5.0 × 0.10 or 0.25 (J) ΔE = 0.25 – 0.09 ΔE = 0.16 (J)	C1 C1 A1	 **Special case** '½ × 50 × (0.10 - 0.06)^2 = 0.04 (J)' mark or '½ × 50 × (0.12 - 0.08)^2 = 0.04 (J)' scores 1
	(ii)	tension in spring = 50 × 0.10 or tension in spring = 5.0 (N) net force = 5.0 – 3.0 and mass of object = 3.0/9.81 a = 2.0/(0.3058..) a = 6.5 (m s^{-2})	C1 C1 A1	 **Special case:** 5.0/(3.0/9.81) = 16.35 (m s^{-2}) scores 1 mark because of the first C1 mark **Note**: a = 16.35 – 9.81 = 6.5(4 m s^{-2}) scores full marks
		Total	**7**	

8)

(a)(i)	force/extension or force/change in length	B1	**Allow**: force per unit extension or force per unit compression
(a)(ii)	Tension/force in each spring is halved so the extension (of each spring) is also halved. (Therefore the force constant is twice that of one spring.)	B1	**Allow**: the extension of each spring is halved, the force is the same (for the system, hence the force constant doubles)
(b)	Measure the thickness of the strip (using the micrometer) and calculate its (cross-sectional) area Load the hanger until the strip breaks. Calculate the (maximum) weight of the masses using $W = mg$. breaking stress = (maximum) weight/(cross-sectional) area	B1 B1 B1	**Not**: surface area **Allow**: 'force' for 'weight' **Allow:** breaking stress = (maximum) force/(cross-sectional) area **Allow**: F/A if the words force and area have been used in the answer
(c)(i)	Any **one** from: Elastic (behaviour) / obeys Hooke's law / stress is proportional to strain	B1	
(c)(ii)	It will be longer / permanent strain / suffer plastic deformation (AW)	B1	
(c)(iii)	The statement is incorrect because the Young modulus can only be determined from the linear region of the graph.	B1	**Allow**: Young modulus only applies to elastic behaviour **Allow:** stress is not proportional to strain as the line is curved **Not:** stress is not proportional to strain
	Total	**8**	