Question			Expected Answers	Marks	Additional Guidance
1	(a)		Straight line through origin (judge by eye) Correct shape of curve in the plastic region	B1 B1	
	(b)		Copper	B1	
	(c)		Maximum stress material can withstand (before fracture)	B1	**Allow**: UTS = breaking stress **Allow**: UTS = breaking force /(cross-sectional) area
	(d)		extension (or compression) $\propto$ force (as long as elastic limit is not exceeded)	B1	**Allow**: 'load' instead of force **Not**: $x \propto F$, unless the labels are defined
	(e)	(i)	force = 75×0.085 F = 6.38 (N) ≈ 6.4 (N)	C1 A1	
		(ii)	acceleration = $\dfrac{6.38}{2.5\times10^{-3}}$ acceleration = 2550 (m s^{-2})	B1	**Note**: $a = \dfrac{kx - mg}{m}$ gives 2540 (m s^{-2}) Possible ecf
		(iii)	Correct selection of equation: mgh / $\frac{1}{2}kx^2$ / $\frac{1}{2}Fx$ $0.0025\times9.81\times h = \dfrac{1}{2}\times75\times0.085^2$ height = 11 (m)	C1 C1 A1	 **Note**: Bald answer of 11 (m) scores 3/3 marks
			Total	**11**	

Question			er	Marks	Guidance
2	(a)		The graph is a straight line through the <u>origin</u> / *F* <u>proportional</u> to *x* / force is <u>proportional</u> 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 $E = 1.6 \times 10^{11}$ (Pa) A1 **Allow** 2 marks for 1.6×10^n, $n \neq 11$ (POT error)
	(d)		(Straight line) with quarter gradient Correct reasoning, for example: • gradient = *EA*/*L* <u>and</u> *A* decreases by a factor of 4 • *A* decreases by a factor of 4 <u>and</u> the same force gives 4 times the extension	B1 B1	**Note**: No need to define the labels
	(e)		½ kx^2 = ½ mv^2 <u>Manipulation</u> 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**	

Question			Answers	Marks	Guidance
3	(a)		The extension $\propto$ (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**	

4	Expected Answers	Marks	Additional Guidance
a(i)	**Y** (is brittle)	B1	
a(ii)	(Both) obey Hooke's law	B1	**Allow** (For both) stress ∝ strain / elastic (behaviour) / 'not plastic (behaviour)' / force ∝ extension **Not**: 'straight line(s)'
a(iii)	Gradient (of the linear section) is equal to Young Modulus / gradient is largest **X** (has largest Young modulus)	B1 B1	**Allow**: 'slope' for 'gradient'
b	(force increases by a factor of) 30^2 force = 240×30^2 force = 2.16×10^5 (N)	C1 A1	 **Allow**: 1 mark for value of breaking stress of $1.2(2) \times 10^9$ (Pa)
	Total	**6**	

Question			Expected Answers	Marks	Additional Guidance
5	(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 $\propto$ <u>extension</u> / constant gradient (graph)	B1	**Not** 'force $\propto$ <u>length</u>'
	(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 = $\frac{1}{2}\times 3.0\times 0.06$ or $\frac{1}{2}\times 50\times 0.06^2$ 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**	