Question	Answer	Marks
1 (a)	Measure the initial length of the spring using a 30 cm ruler or a metre rule. Attach the spring from a stand and hang a known mass *m* from its lower end. Measure its new length and determine the extension using: new length – initial length. The force constant is equal to *mg*/extension, where *g* = acceleration of free fall.	1 1 1 1
1 (b) (i)	Graph of *E* against *x* showing a curve of increasing gradient. Some indication on the graph that $E \propto x^2$.	1 1
1 (b) (ii)	The extension increases by a factor of 1.5. The elastic potential (stored) energy *E* must therefore increase by a factor of 1.5^2. stored energy = $1.5^2 \times 0.10 = 0.225$ J	1 1 1
2 (i)	$F = kx$ $F = 50 \times 0.070 = 3.5$ N $a = \frac{3.5}{0.180}$ acceleration = 19 m s^{-2}	1 1 1
2 (ii)	average work done = <u>average</u> force × displacement = 1.75 × 0.070 (= 0.1225) average rate of work done = $\frac{0.1225}{0.094}$ average rate of work done = 1.3 J s^{-1}	1 1
3 (a)	area = $\pi r^2 = \pi \times (0.45 \times 10^{-3})^2 = 6.36 \times 10^{-7}$ m^2 % uncertainty in the area = $2 \times \frac{0.01}{0.90} \times 100 = 2.22$ ... % absolute uncertainty = 0.022... × $6.36 \times 10^{-7} = 1.41 \times 10^{-8}$ m^2	1 1 1
3 (b)	$E = \frac{\text{stress}}{\text{strain}} = \frac{FL}{Ax}$ $F = mg = 8.00 \times 9.81$ $E = \frac{(8.00 \times 9.81) \times 2.500}{6.36 \times 10^{-7} \times 4.0 \times 10^{-3}}$ $E = 7.71 \times 10^{10}$ Pa	1 1 1 1
3 (c) (i)	Brittle metal: A straight line graph passing through the origin showing no plastic deformation. Ductile metal: A straight line graph passing through the origin followed by plastic deformation beyond its elastic limit.	1 1
3 (c) (ii)	The ductile metal shows **elastic** behaviour for stresses below its elastic limit. Beyond the elastic limit, the metal shows **plastic** deformation.	1 1
4 (a)	tensile stress = $\frac{\text{force}}{\text{cross-sectional area}}$ tensile strain = $\frac{\text{extension}}{\text{original length}}$	1 1
4 (b) (i)	$E = \frac{\text{stress}}{\text{strain}} = \frac{FL}{Ax}$ $x = \frac{FL}{AE} = \frac{12.0 \times 1.80}{1.92 \times 10^{-7} \times 200 \times 10^{9}}$ $x = 5.63 \times 10^{-4}$ m	1 1 1
4 (b) (ii)	$x = \frac{FL}{AE} \propto \frac{1}{A}$ The cross-sectional area will quadruple when the diameter is doubled. The extension is smaller; extension is $\frac{5.63 \times 10^{-4}}{4} = 1.41 \times 10^{-4}$ m.	1 1 1
5 (a) (i)	The gradient is equal to the force constant of the spring.	1
5 (a) (ii)	The area under the graph is equal to the energy stored in the spring – the elastic potential energy.	1

Question	Answer	Marks
5 (b) (i)	$E = \frac{1}{2}kx^2 = \frac{1}{2} \times 160 \times 0.072^2$ $E = 0.4147$ J	1 1
5 (b) (ii)	KE of object = 0.60 × 0.4147 = 0.249 J $\frac{1}{2} \times 0.080 \times v^2 = 0.249$ $v = 2.5$ m s^{-1}	1 1 1
6 (a)	Elastic means that the spring will return to its original length when the forces are removed.	1
6 (b) (i)	extension = force/force constant **and** the force on each spring is 16 N. total extension = $\left(\frac{16}{20} + \frac{16}{60}\right) = 1.07$ m Assumption: Both springs obey Hooke's law and remain elastic.	1 1 1
6 (b) (ii)	force constant = $\frac{16}{1.07}$ force constant = 15 N m^{-1}	1 1
7 (a)	The extension of a spring (or wire) is directly proportional to the applied force (as long as the elastic limit is not exceeded).	1
7 (b)	force constant = $\frac{\text{force}}{\text{extension}}$	1
7 (c)	Hang the spring from a stand and suspend an object from its bottom end. Use a ruler to determine the extension of the spring (by subtracting the original length from the final length). Determine the mass of the object using a digital balance. Calculate the force constant by dividing the weight of the object (mass × 9.81) by the extension.	1 1 1 1
7 (d) (i)	The graph shows a straight line. The graph passes through the origin (hence force $\propto$ extension).	1 1
7 (d) (ii)	force constant = $\frac{F}{x} = \frac{12}{0.080}$ force constant k = 150 N m^{-1}	1 1
7 (d) (iii)	The area under the graph is equal to the energy stored. $E = \frac{1}{2}Fx = \frac{1}{2} \times 12 \times 0.080$ $E = 0.48$ J	1 1 1
8 (a)	tensile stress = $\frac{\text{force}}{\text{area}}$ tensile strain = $\frac{\text{extension}}{\text{original length}}$	1
8 (b)	force has units kg m s^{-2} area has units m^2 units of stress: $\frac{\text{kg m s}^{-2}}{\text{m}^2} \rightarrow$ kg m^{-1} s^{-2}	1 1 1
8 (c) (i)	The wire returns to its original length therefore it shows elastic behaviour. The extension is proportional to force, hence it obeys Hooke's law.	1 1
8 (c) (ii)	Micrometer (screw gauge) or vernier (calliper/scale).	1
8 (c) (iii)	$E = \frac{\text{stress}}{\text{strain}} = \frac{FL}{xA}$ $E = \frac{50.0 \times 1.640}{2.52 \times 10^{-3} \times 3.2 \times 10^{-7}}$ $E = 1.02 \times 10^{11}$ Pa	1 1 1
8 (c) (iv)	Plot a graph of F against x. The gradient is equal to $\frac{EA}{L}$; hence Young modulus = gradient × $\frac{L}{A}$. (Allow: Plot a stress against strain graph, with gradient = Young modulus)	1 1 1
9 (a)	Young modulus = $\frac{\text{stress}}{\text{strain}}$	1

Question	Answer	Marks
9 (b) (i)	density = $\frac{\text{mass}}{\text{volume}}$ area × length = $\frac{\text{mass}}{\text{density}}$ area = $\frac{2.0 \times 10^{-3}}{7800 \times 0.5}$ or area = $\frac{2.56 \times 10^{-7}}{0.5}$ = 5.13×10^{-7} m^2	1 1
9 (b) (ii)	$E = \frac{F \times l}{A \times e}$ stress = $\frac{F}{A}$ = 1.6×10^8 and strain = $\frac{e}{L}$ = 8×10^{-4} $F = \frac{E \times A \times e}{L}$ $F = \frac{2 \times 10^{11} \times 5.1 \times 10^{-7} \times 4.0 \times 10^{-4}}{0.5}$ F = 81.6 N	 1 1 1
9 (b) (iii)	Diameter for D is half G hence area is $\frac{1}{4}$ of G Extension is 4× greater Tension required is the same = 82 N	 1
9 (b) (iv)	The extension is proportional to the force or Hooke's law	1
10 (a)	force = 50 N and extension = 0.25 mm at the elastic limit.	1
10 (b)	The area under the graph is equal to the energy stored. $E = \frac{1}{2} F x = \frac{1}{2} \times 50 \times (0.25 \times 10^{-3})^2$ $E = 1.56 \times 10^{-6}$ J	1 1 1
10 (c)	$F = \frac{EA}{L} x$, therefore gradient = $\frac{EA}{L}$ A = gradient × $\frac{L}{E}$ $A = \frac{\left(\frac{50}{0.25 \times 10^{-3}}\right) \times 1.82}{1.2 \times 10^{11}}$ $A = 3.03 \times 10^{-6}$ m^2	1 1 1 1
11 (a)	gain in GPE = elastic potential energy $mgh = \frac{1}{2} k x^2$ Therefore $h \propto x^2$ because m, g and k are constants.	1 1 1
11 (b) (i)	h = 0.60 m when $x^2 = 1.5 \times 10^{-4}$ m^2 and $\frac{h}{x^2}$ = constant Therefore $h = \frac{0.60 \times 0.02^2}{1.5 \times 10^{-4}}$ h = 1.6 m Assumption: No frictional losses or the spring remains elastic.	1 1 1 1
11 (b) (ii)	gradient = $\frac{k}{2mg}$ gradient = $\frac{0.60}{1.5 \times 10^{-4}} = 4.0 \times 10^3$ m^{-1} Therefore $k = 2 \times 0.008 \times 9.81 \times 4.0 \times 10^3$ = 628 N m^{-1}	1 1 1