Q1.

3	(a)	(i)	ductile	B1	
		(ii)1	L shown at end of straight line	B1	
		(ii)2	reciprocal of gradient of straight line region	B1	[3]
	(b)	(i)1	circumference = 3π cm or arc $= r\theta$	C1	
			extension = $(6.5/360) \times 3\pi$ = 1.5 sin (or tan) 6.5	M1	
			= 0.17 cm	A0	
		(i)2	strain = extension/length	C1	
			= 0.17/250		
			$= 6.8 \times 10^{-4}$	A1	[4]
		(ii)	stress = force/area	C1	
			$= (6.0 \times 9.8)/(7.9 \times 10^{-7})$	C1	
			$= 7.44 \times 10^{7}$ Pa	A1	[3]
		(iii)	Young modulus = stress/strain	C1	
			$= (7.44 \times 10^{7})/(6.8 \times 10^{-4})$		
			$= 1.1 \times 10^{11}$ Pa	A1	[2]
		(iv)	remove extra load and see if pointer returns to original position or wire returns to original length	B1	[1]

Q2.

4	(a)		brittle	B1	**[1]**
	(b)	(i)	stress = force/area	C1	
			$= 60/(7.9 \times 10^{-7})$		
			$= 7.6 \times 10^{7}$ Pa	A1	**[2]**
		(ii)	Young modulus = stress/strain	C1	
			limiting strain = 0.03/24 ($= 1.25 \times 10^{-3}$)	C1	
			Young modulus $= (7.6 \times 10^{7})/(1.25 \times 10^{-3}) = 6.1 \times 10^{10}$ Pa	A1	**[3]**
		(iii)	energy $= \frac{1}{2} \times 60 \times 3.0 \times 10^{-4}$	C1	
			$= 9.0 \times 10^{-3}$ J	A1	**[2]**
	(c)		If hard, ball does not deform (much)	B1	
			and <u>either</u> (all) kinetic energy converted to strain energy	B1	
			If soft, E_k becomes strain energy of ball and window	B1	
			(no mention of <u>strain</u> energy, max 2 marks)		
			<u>or</u> impulse for hard ball takes place over shorter time (B1)		
			larger force/greater stress (B1)		**[3]**

Q3.

5	**(a)**	no hysteresis loop/no permanent deformation *(do not allow 'force proportional to extension')* so elastic change	M1 A0	**[1]**
	(b)	work done = area under graph line OR average force × distance $= \frac{1}{2}Fx$ $\frac{1}{2}(F_2 + F_1)(x_2 - x_1)$ $F = kx$, so work done = $= \frac{1}{2}kx^2$ $\frac{1}{2}k(x_2 + x_1)(x_2 - x_1)$ work done $= \frac{1}{2}k(x_2^2 - x_1^2)$	B1 A1 A1 A0	**[3]**
	(c)	gain in energy of trolley $= \frac{1}{2}k(0.060^2 - 0.045^2) + \frac{1}{2}k(0.030^2 - 0.045^2)$ $= 0.36$ J kinetic energy $= \frac{1}{2} \times 0.85 \times v^2 = 0.36$ $v = 0.92$ m s^{-1}	C1 C1 C1 A1	**[4]**

Q4.

2	**(a)**	**(i)**	k is the reciprocal of the gradient of the graph k = {32 / (4 × 10^{-2}) = } 800 N m^{-1}	C1 A1	[2]
		(ii)	*either* energy = average force × extension *or* $\frac{1}{2}kx^2$ *or* area under graph line energy = ½ × 800 × (3.5 × 10^{-2})^2 *or* ½ × 28 × 3.5 × 10^{-2} energy = 0.49 J	 C1 M1 A0	[2]
	(b)	**(i)**	momentum before cutting thread = momentum after 0 = 2400 × V – 800 × v v / V = 3.0	C1 M1 A0	[2]
		(ii)	energy stored in spring = kinetic energy of trolleys 0.49 = ½ × 2.4 × ($\frac{1}{3}v$)^2 + ½ × 0.8 × v^2 v = 0.96 m s^{-1} *(if only one trolley considered, or masses combined, allow max 1 mark)*	C1 C1 A1	 [3]

Q5.

4	**(a)**	**(i)**	**1.** stress = force / (cross-sectional) area **2.** strain = extension / <u>original</u> length **3.** Young modulus = stress / strain *(ratios must be clear in each answer)*	B1 B1 B1	[1] [1] [1]
		(ii)	*either* fluids cannot be deformed in one direction / cannot be stretched *or* fluids can only have volume change *or* no fixed shape	 B1	 [1]
	(b)		*either* unless Δp is very large *or* 2.2 × 10^9 is a large number ΔV is very small *or* $\Delta V/V$ is very small, (so 'incompressible')	M1 A1	 [2]
	(c)		$\Delta p = h\rho g$ 1.01 × 10^5 = h × 1.08 × 10^3 × 9.81 h = 9.53 m $\Delta h / h$ = 0.47 / 10 *or* 0.47 / 9.53 error = 4.7% *or* 4.9% *or* 5%	 C1 C1 A1	 [3]

Q6.

4 **(a)** **(i)** change of shape / size / length / dimension C1
when (deforming) force is removed, returns to original shape / size A1 [2]

(ii) $L = ke$ .... B1 [1]

(b) $2e$ B1
$\frac{1}{2}k$ …(*allow e.c.f. from extension*) B1

$\frac{1}{2}e$ and $2k$ B1

$\frac{3}{2}e$ …(*allow e.c.f. from extension in part 2*) B1
$\frac{2}{3}k$ …(*allow e.c.f. from extension*) .... B1 [5]

Q7.

3 **(a)** *either* energy (stored)/work done represented by area under graph
or energy = average force × extension B1
energy = $\frac{1}{2} \times 180 \times 4.0 \times 10^{-2}$ C1
= 3.6 J .... A1 [3]

(b) **(i)** *either* momentum before release is zero M1
so sum of momenta (of trolleys) after release is zero A1
or force = rate of change of momentum (M1)
force on trolleys equal and opposite (A1)
or impulse = change in momentum (M1)
impulse on each equal and opposite (A1) [2]

(ii) **1** $M_1V_1 = M_2V_2$ .... B1 [1]

2 $E = \frac{1}{2} M_1V_1^2 + \frac{1}{2} M_2V_2^2$ .... B1 [1]

(iii) **1** $E_K = \frac{1}{2}mv^2$ and $p = mv$ combined to give M1
$E_K = p^2 / 2m$ .... A0 [1]

2 m smaller, E_K is larger because p is the same/constant M1
so trolley B .... A0 [1]

Q8.

5 **(a)** **(i)** Young modulus = stress/strain C1
data chosen using point in linear region of graph M1
Young modulus = $(2.1 \times 10^8)/(1.9 \times 10^{-3})$
= 1.1×10^{11} Pa .... A1 [3]

(ii) This mark was removed from the assessment, owing to a power-of-ten inconsistency in the printed question paper.

(b) area between lines represents energy/area under curve represents energy .. M1
when rubber is stretched and then released/two areas are different A1
this energy seen as thermal energy/heating/difference represents energy released as heat .... A1 [3]

Q9.

4	(a)	(i)	*stress* is force / area	B1	[1]
		(ii)	*strain* is extension / original length	B1	[1]
	(b)	(i)	$E = [F / A] \div [e / l]$	C1	
			$e = (25 \times 1.7) / (5.74 \times 10^{-8} \times 1.6 \times 10^{11})$	C1	
			$e = 4.6 \times 10^{-3}$ m	A1	[3]
		(ii)	A becomes $A/2$ or stress is doubled	B1	
			$e \propto l / A$ or substitution into full formula	B1	
			total extension increase is $4e$	A1	[3]

Q10.

4	(a)	clamped horizontal wire over pulley or vertical wire attached to ceiling with mass attached	B1	
		details: reference mark on wire with fixed scale alongside	B1	[2]
	(b)	measure original length of wire to reference mark with metre ruler / tape	(B1)	
		measure diameter with micrometer / digital calipers	(B1)	
		measure initial and final reading (for extension) with metre ruler or other suitable scale	(B1)	
		measure / record mass or weight used for the extension	(B1)	
		good physics method: measure diameter in several places / remove load and check wire returns to original length / take several readings with different loads	(B1)	
		MAX of 4 points	B4	[4]
	(c)	determine extension from final and initial readings	(B1)	
		plot a graph of force against extension	(B1)	
		determine gradient of graph for F / e	(B1)	
		calculate area from $\pi d^2 / 4$	(B1)	
		calculate E from $E = F l / e A$ or gradient $\times l / A$	(B1)	
		MAX of 4 points	B4	[4]

Q11.

4	**(a)**	force is proportional to extension	B1	[1]
	(b) (i)	gradient of graph determined (e.g. $50 / 40 \times 10^{-3}$) = 1250 $N m^{-1}$	A1	[1]
	(ii)	$W = \frac{1}{2} k x^2$ or $W = \frac{1}{2}$ final force × extension	M1	
		$= 0.5 \times 1250 \times (36 \times 10^{-3})^2$ or $0.5 \times 45 \times 36 \times 10^{-3}$	M1	
		= 0.81 J	A0	[2]
	(c) (i)	$0.81 = \frac{1}{2} mv^2$	C1	
		v = 8.0 (8.0498) $m s^{-1}$	A1	[2]
	(ii)	4 × KE / 4 × WD or 3.24 J	C1	
		hence twice the compression = 72 mm	A1	[2]
	(iii)	Max height is when all KE or WD or elastic PE is converted to GPE	C1	
		ratio = 1/4 or 0.25	A1	[2]

Q12.

3	**(a)**	Resultant force (and resultant torque) is zero	B1	
		Weight (down) = force from/due to spring (up)	B1	[2]
	(b) (i)	0.2, 0.6, 1.0 s (*one of these*)	A1	[1]
	(ii)	0, 0.8 s (*one of these*)	A1	[1]
	(iii)	0.2, 0.6, 1.0 s (*one of these*)	A1	[1]
	(c) (i)	Hooke's law: extension is proportional to the force (*not mass*)	B1	
		Linear/straight line graph hence obeys Hooke's law	B1	[2]
	(ii)	Use of the gradient (*not just* $F = kx$)	C1	
		K $= (0.4 \times 9.8) / 15 \times 10^{-2}$	M1	
		= 26(.1) $N m^{-1}$	A0	[2]
	(iii)	*either* energy = area to left of line *or* energy = $\frac{1}{2} ke^2$	C1	
		$= \frac{1}{2} \times [(0.4 \times 9.8) / 15 \times 10^{-2}] \times (15 \times 10^{-2})^2$	C1	
		= 0.294 J (*allow 2 s.f.*)	A1	[3]

Q13.

5	(a)	E = stress / strain	B1	[1]
	(b) (i)	1. diameter / cross sectional area / radius 2. original length	B1	[1]
	(ii)	measure original length with a metre ruler / tape	B1	
		measure the diameter with micrometer (screw gauge) *allow digital vernier calipers*	B1	[2]
	(iii)	energy = ½ Fe or area under graph or ½ kx^2	C1	
		$= ½ \times 0.25 \times 10^{-3} \times 3 = 3.8 \times 10^{-4}$ J	A1	[2]
	(c)	straight line through origin below original line	M1	
		line through (0.25, 1.5)	A1	[2]

Q14.

1	(a)	the wire returns to its original length	(*not 'shape'*)	M1	
		when the load is removed		A1	[2]

Q15.

4	(a) (i)	stress = force / cross-sectional area	B1	[1]
	(ii)	strain = extension / original length	B1	[1]
	(b) (i)	E = stress / strain	C1	
		$E = 0.17 \times 10^{12}$	C1	
		stress $= 0.17 \times 10^{12} \times 0.095 / 100$	C1	
		$= 1.6(2) \times 10^8$ Pa	A1	[4]
	(ii)	force = (stress × area) $= 1.615 \times 10^8 \times 0.18 \times 10^{-6}$	C1	
		= 29(.1) N	A1	[2]

Q16.

9 (a) (i) stress = F / A C1
= $25 / (1.7 \times 10^{-6})$
= 1.47×10^7 Pa ......(do not allow 1 sig fig) A1

(ii) stress = $E \times$ strain C1
$1.47 \times 10^7 = 7.1 \times 10^{10} \times (\Delta l / 1.8)$
$\Delta l = 0.37$ mm .... A1 [4]

(b) $R = \rho l / A$ OR $R \propto L$ C1
so, $\Delta R / R = \Delta l / l$ C1
$\Delta R = (3.7 \times 10^{-4} / 1.8) \times 0.03 = 6.2 \times 10^{-6}\ \Omega$ .... A1 [3]

May calculate $\rho = 2.833\ldots \times 10^{-8}\ \Omega$ m
giving new R as $3.0006167 \times 10^{-2}\ \Omega$
hence ΔR - full credit possible

However, if rounds off ρ as $2.83 \times 10^{-8}\ \Omega$ m,
then $R_{new} < R_{old}$!
Allow 1 mark only for $R \propto L$

Q17.

5 (a) (i)	F/A	**B1**	
(ii)	ΔL/L	**B1**	
(iii)	FL/A.ΔL	**B1**	**[3]**
(b) (i)	ΔL = 0.012 x 0.62 x 350	**M2**	
	= 2.6 mm	**A0**	**[2]**
(ii)	$2.0 \times 10^{11} = (F \times 0.62)/(7.9 \times 10^{-7} \times 2.6 \times 10^{-3})$	**C1**	
	F = 660 N	**A1**	**[2]**

(iii) *either* stress when cold = 660/(7.9 x 10^{-7}) = 840 MPa

or tension at uts = 198 N **M1**

either this is greater than the ultimate tensile stress

or tension at uts is less then tension in **(ii)** **A1**

the wire will snap **A1 [3]**

(Allow possibility for the two 'A' marks to be scored as long as some quantitative answer – even if incorrect – has been given for the 'M' mark)

Q18.

6	**(a)**	**(i)**	$R = \rho L / A$	B1	
		(ii)	strain = $\Delta L / L$	B1	
			either $\Delta R = \rho \Delta L / A$ *or* $R \propto L$ with ρ and A constant	B1	
			dividing, $\Delta R / R = \Delta L / L$	A0	[3]
	(b)		Young modulus = stress / strain	C1	
			strain = 72.0 / (1.20 × 10^{-7} × 2.10 × 10^{11})	C1	
			= 2.86 × 10^{-3} *(allow 1/350*	A1	
			ΔR = 2.86 × 10^{-3} × 4.17 = 1.19 × 10^{-2} Ω	A1	
			answer given to 3 sig. fig	B1	[5]

Q19.

4	**(a)**	brittle	B1	[1]
	(b)	Young modulus = stress / strain	C1	
		= (9.5 × 10^{8}) / 0.013		
		= 7.3 × 10^{10} Pa (*allow* ± *0.1* × 10^{10} *Pa*)	A1	[2]
	(c)	stress = force / area	C1	
		(minimum) area = (1.9 × 10^{3}) / (9.5 × 10^{8})		
		= 2.0 × 10^{-6} m^2	C1	
		(max) area of cross-section = (3.2 – 2.0) × 10^{-6}		
		= 1.2 × 10^{-6} m^2	A1	[3]
	(d)	when bent, 'top' and 'bottom' edges have different extensions	M1	
		with thick rod, difference is greater (than with a thin rod)	A1	
		so breaks with less bending	A0	[2]

Q20.

4 **(a)** **(i)** returns to original shape / size / length etc. B1
when load / distorting forces / weight / strain is removed .... B1 [2]

(ii) **1** $R = \rho L / A$ .... B1 [1]
2 $E = WL / Ae$ .... B1 [1]

(b) $E = WR / e\rho$ C1
$= (34 \times 0.44) / (7.7 \times 10^{-4} \times 9.2 \times 10^{-8})$ C1
$= 2.1 \times 10^{11}$ Pa .... A1 [3]

[Total: 7]

Q21.

4 **(a)** ability to do work B1
as a result of a change of shape of an object/stretched etc .... B1 [2]

(b) work = average force ×distance moved (in direction of the force) B1
either work = $\frac{1}{2} \times F \times x$
or work is area under F/x graph which is $\frac{1}{2}Fx$ B1
$F = kx$ B1
so work / energy = $\frac{1}{2}kx^2$ .... A0 [3]

(c) **(i)** spring constant $= \dfrac{3.8}{2.1}$ M1
$= 1.8$ N cm^{-1} .... A0 [1]

(ii) **1** $\Delta E_P = mg\Delta h$ *or* $W\Delta h$ C1
$= 3.8 \times 1.5 \times 10^{-2}$
$= 0.057$ J .... A1 [2]
2 $\Delta E_S = \frac{1}{2} \times 1.8 \times 10^2 (0.036^2 - 0.021^2)$ M1
$= 0.077$ J .... A0 [1]
3 work done = 0.077 – 0.057
= 0.020 J .... A1 [1]
(allow e.c.f. if $\Delta E_S > \Delta E_P$)

[Total: 10]

Q22.

4	(a) (i)	F / A	B1	[1]
	(ii)	$\Delta L / L$	B1	[1]
	(iii)	allow $FL / A\Delta L$	B1	[1]
	(iv)	allow $\rho L / A$ or $\rho(L + \Delta L) / A$	B1	[1]
	(b) (i)	$\Delta L = FL / EA$		
		$= (30 \times 2.6) / (7.0 \times 10^{10} \times 3.8 \times 10^{-7})$	M1	
		$= 2.93 \times 10^{-3}$ m = 2.93 mm	A0	[1]
	(ii)	$\Delta R = \rho\Delta L / A$	C1	
		$= (2.6 \times 10^{-8} \times 2.93 \times 10^{-3}) / (3.8 \times 10^{-7})$		
		$= 2.0 \times 10^{-4}\ \Omega$	A1	[2]
	(c)	change in resistance is (very) small	M1	
		so method is not appropriate	A1	[2]

Q23.

4	(a)	energy = average force × extension	B1	
		= ½ × $F \times x$	B1	
		(Hooke's law) extension proportional to (applied) force	B1	
		hence $F = kx$	B1	
		so $E = ½kx^2$	A0	[4]
	(b) (i)	correct area shaded	B1	[1]
	(ii)	1.0 cm^2 represents 1.0 mJ or correct units used in calculation	C1	
		$E_S = 6.4 \pm 0.2$ mJ	A2	[3]
		(for answer > ±0.2 mJ but ≤ ±0.4 mJ, then allow 2/3 marks)		
	(iii)	arrangement of atoms / molecules is changed	B1	[1]

Q24.

5 **(a)** **(i)** Fig. 5.2 B1 [1]

(ii) Fig. 5.3 B1 [1]

(b) kinetic energy increases from zero then decreases to zero B1 [1]

(c) **(i)** $\Delta E_P = mg\Delta h$ / mgh C1

$= 94 \times 10^{-3} \times 9.8 \times 2.6 \times 10^{-2}$ using g = 10 then –1

$= 0.024\,\text{J}$ A1 [2]

(ii) *either* $0.024 = \frac{1}{2} k \times (2.6 \times 10^{-2})^2$ *or* $\frac{1}{2} kd^2 = \frac{1}{2}k \times (2.6 \times 10^{-2})^2 - \frac{1}{2}kd^2$ C1

$0.012 = \frac{1}{2}k \times d^2$ — $kd^2 = \frac{1}{2}k \times (2.6 \times 10^{-2})^2$ C1

$d = 0.018\,\text{m}$ — $d = 0.018\,\text{m}$

$= 1.8\,\text{cm}$ — $= 1.8\,\text{cm}$ A1 [3]

Q25.

6 **(a)** extension is proportional to force (for small extensions) B1 [1]

(b) **(i)** point beyond which (the spring) does not return to its original length when the load is removed B1 [1]

(ii) gradient of graph = $80\,\text{N m}^{-1}$ A1 [1]

(iii) work done is area under graph / ½ Fx / ½ kx^2 C1

= 0.5 × 6.4 × 0.08 = 0.256 (allow 0.26) J A1 [2]

(c) **(i)** extension = 0.08 + 0.04 = 0.12 m A1 [1]

(ii) spring constant = 6.4 / 0.12 = $53.3\,\text{N m}^{-1}$ A1 [1]

Q26.

3 **(a)** **(i)** stress = force / (cross-sectional) area B1 [1]

(ii) strain = extension / original length **or** change in length / original length B1 [1]

(b) point beyond which material does not return to the original length / shape / size when the load / force is removed B1 [1]

(c)	UTS is the maximum force / <u>original</u> cross-sectional area	M1	
	wire is able to support / before it breaks	A1	[2]
	allow one: maximum stress the wire is able to support / before it breaks		
(d) (i)	straight line from (0,0)	M1	
	correct shape in plastic region	A1	[2]
(ii)	only a straight line from (0,0)	B1	[1]
(e) (i)	ductile: initially force proportional to extension then a large extension for small change in force	B1	
	brittle: force proportional to extension until it breaks	B1	[2]
(ii) 1.	does not return to its original length / permanent extension (as entered plastic region)	B1	
2.	returns to original length / no extension **(as no plastic region / still in elastic region)**	B1	[2]

Q27.

5 (a)	when the load is removed then the wire / body object does not return to its original shape / length	B1	[1]
(b) (i)	stress = force / area	C1	
	$F = 220 \times 10^{6} \times 1.54 \times 10^{-6} = 340\ (338.8)$ N	A1	[2]
(ii)	$E = (F \times l) / (A \times e)$	C1	
	$e = (90 \times 10^{6}) \times 1.75 / (1.2 \times 10^{11}) = 1.31 \times 10^{-3}$ m	A1	[2]
(c)	the stress is no longer proportional to the extension	B1	[1]

Q28.

6 (a)	extension is proportional to force / load		B1	[1]
(b)	$F = mg$		C1	
	$x = (mg / k) = 0.41 \times 9.81 / 25 = (4.02 / 25)$		M1	
	$x = 0.16$ m		A0	[2]
(c) (i)	weight and (reaction) force from spring (which is equal to tension in spring)		B1	[1]
(ii)	F – weight	or $0.06 \times 25 = ma$	C1	
	$F = 0.2209 \times 25 = 5.52$ (N)	or $0.22 \times 25 = 5.5$		
	$a = (5.52 - 0.41 \times 9.81) / 0.41$	or $1.5 / 0.41$ and $(5.5 - 4.02)$	C1	
	$a = 3.7\ (3.66)$ m s^{-2}	gives 3.6 m s^{-2}	A1	[3]
(d)	elastic potential energy / strain energy to kinetic energy and gravitational potential energy		B1	
	stretching / extension reduces and velocity increases / height increases		B1	[2]