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

= 6.8×10^{-4} .... A1 [4]

(ii) stress = force/area C1

= $(6.0 \times 9.8)/(7.9 \times 10^{-7})$ C1

= 7.44×10^{7} Pa .... A1 [3]

(iii) Young modulus = stress/strain C1

= $(7.44 \times 10^{7})/(6.8 \times 10^{-4})$

= 1.1×10^{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

= $60/(7.9 \times 10^{-7})$

= 7.6×10^{7} Pa A1 [2]

(ii) Young modulus = stress/strain C1

limiting strain = 0.03/24 (= 1.25×10^{-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

= 9.0×10^{-3} J A1 [2]

(c) If hard, ball does not deform (much) B1

and either (all) kinetic energy converted to strain energy B1

If soft, E_k becomes strain energy of ball and window B1

(no mention of strain energy, max 2 marks)

or 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	M1	
	(do not allow 'force proportional to extension')		
	so elastic change	A0	**[1]**
	(b) work done = area under graph line OR average force × distance	B1	
	$= \frac{1}{2}Fx$ $\quad\frac{1}{2}(F_2 + F_1)(x_2 - x_1)$	A1	
	$F = kx$, so work done = $= \frac{1}{2}kx^2$ $\quad\frac{1}{2}k(x_2 + x_1)(x_2 - x_1)$	A1	
	work done $= \frac{1}{2}k(x_2^2 - x_1^2)$	A0	**[3]**
	(c) gain in energy of trolley $= \frac{1}{2}k(0.060^2 - 0.045^2) + \frac{1}{2}k(0.030^2 - 0.045^2)$	C1	
	= 0.36 J	C1	
	kinetic energy $= \frac{1}{2} \times 0.85 \times v^2 = 0.36$	C1	
	$v = 0.92\ \text{m s}^{-1}$	A1	**[4]**

Q4.

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

Q5.

4	**(a) (i) 1.** stress = force / (cross-sectional) area	B1	[1]
	2. strain = extension / <u>original</u> length	B1	[1]
	3. Young modulus = stress / strain	B1	[1]
	(ratios must be clear in each answer)		
	(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	M1	
	ΔV is very small *or* $\Delta V/V$ is very small, (so 'incompressible')	A1	[2]
	(c) $\Delta p = h\rho g$		
	$1.01 \times 10^5 = h \times 1.08 \times 10^3 \times 9.81$	C1	
	$h = 9.53$ m	C1	
	$\Delta h / h = 0.47 / 10$ *or* $0.47 / 9.53$		
	error = 4.7% *or* 4.9% *or* 5%	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 = ½ × 180 × 4.0 × 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 / <u>original</u> 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 4*e*	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 × 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 × 1250 × $(36 \times 10^{-3})^2$ or 0.5 × 45 × 36 × 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 × 9.8) / 15 × 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	
	= ½ × [(0.4 × 9.8) / 15 × 10^{-2}] × $(15 \times 10^{-2})^2$	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 <u>metre</u> ruler / tape measure the <u>diameter</u> with micrometer (screw gauge) *allow digital vernier calipers*	B1 B1	[2]
		(iii)	energy = ½ Fe or area under graph or ½ kx^2 = ½ × 0.25 × 10^{-3} × 3 = 3.8 × 10^{-4} J	C1 A1	[2]
	(c)		straight line through origin below original line line through (0.25, 1.5)	M1 A1	[2]

Q14.

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

Q15.

4	(a)	(i)	stress = force / cross-sectional area	B1	[1]
		(ii)	strain = extension / <u>original</u> length	B1	[1]
	(b)	(i)	E = stress / strain E = 0.17 × 10^{12} stress = 0.17 × 10^{12} × 0.095 / 100 = 1.6(2) × 10^{8} Pa	C1 C1 C1 A1	[4]
		(ii)	force = (stress × area) = 1.615 × 10^{8} × 0.18 × 10^{-6} = 29(.1) N	C1 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
$1.47 \times 10^{7} = 7.1 \times 10^{10} \times (\Delta l / 1.8)$
Δl = 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 $= \frac{3.8}{2.1}$ 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	
	$= \frac{1}{2} \times F \times x$	B1	
	(Hooke's law) extension proportional to (applied) force	B1	
	hence $F = kx$	B1	
	so $E = \frac{1}{2}kx^2$	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
$= 0.024$ 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
$0.012 = \frac{1}{2}k \times d^2$ $\quad kd^2 = \frac{1}{2}k \times (2.6 \times 10^{-2})^2$ C1
$d = 0.018$ m $\quad d = 0.018$ m
$= 1.8$ cm $\quad = 1.8$ 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 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 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 / original 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
$F = 220 \times 10^6 \times 1.54 \times 10^{-6} = 340\ (338.8)\,\text{N}$ — A1 [2]

(ii) $E = (F \times l) / (A \times e)$ — C1
$e = (90 \times 10^6) \times 1.75 / (1.2 \times 10^{11}) = 1.31 \times 10^{-3}\,\text{m}$ — 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
$x = 0.16\,\text{m}$ — 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
$a = 3.7\ (3.66)\,\text{m s}^{-2}$ gives $3.6\,\text{m s}^{-2}$ — 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]