1 **(a)** Fig. 8.1 shows a graph of stress against strain for rubber.

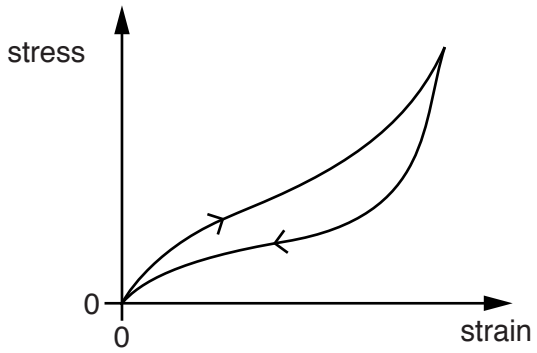

Fig. 8.1

Use Fig. 8.1 to describe the main physical properties of this material.

In your answer, you should use appropriate technical terms, spelled correctly.

.....

.....

.....

.....

.....

.....

..... **[3]**

(b) Fig. 8.2 shows a metal strip pulled from its ends until it breaks.

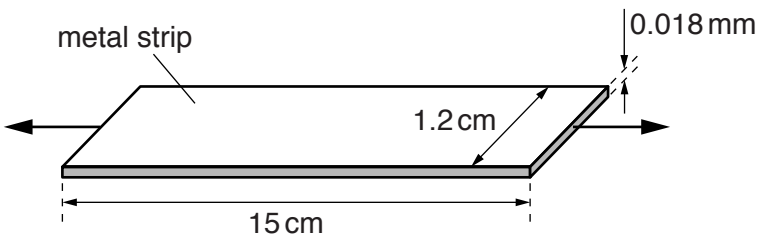

Fig. 8.2

The strip is 15 cm long, 1.2 cm wide and 0.018 mm thick. The breaking force for this strip is 16 N. The Young modulus of the metal is 7.1×10^{10} Pa.

(i) Calculate the extension of the metal strip when it breaks. State one assumption made in your calculation.

extension = ... m **[3]**

assumption: .....

..... **[1]**

(ii) Calculate the breaking force of a rod of radius 0.60 cm made from the same metal.

breaking force = ... N **[2]**

2 A light spring of unextended length 2.0 cm is hung from a fixed point. An object of weight 3.0 N is hung from the other end of the spring. Fig. 7.1 shows the length of the spring when the object is in equilibrium.

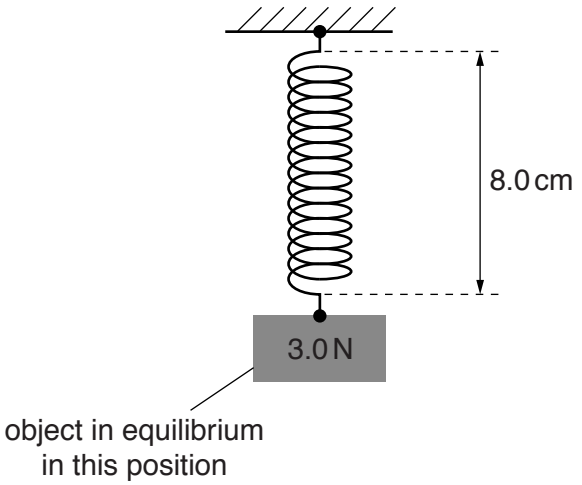

Fig. 7.1

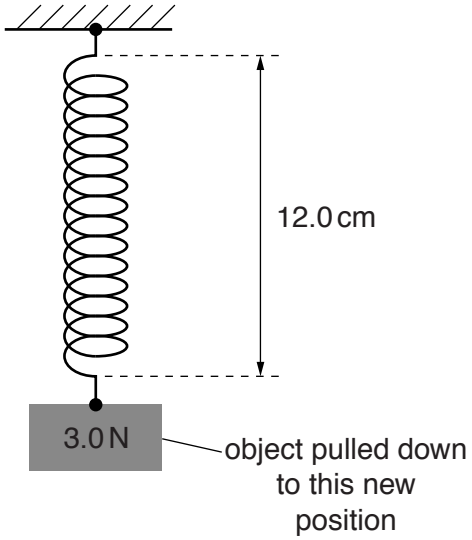

Fig. 7.2

(a) Show that the force constant of the spring is 50 N m^{-1}.

[1]

(b) The object is pulled vertically downwards. Fig. 7.2 shows the new length of the spring.

(i) Calculate the change in the elastic potential energy ΔE in the spring.

ΔE = ... J **[3]**

(ii) The object is released from its position shown in Fig. 7.2. Calculate the initial upward acceleration *a* of the object.

a = ... $m\,s^{-2}$ **[3]**

[Total: 7]

3 **(a)** Fig. 6.1 shows the stress against strain graphs of two materials **X** and **Y**.

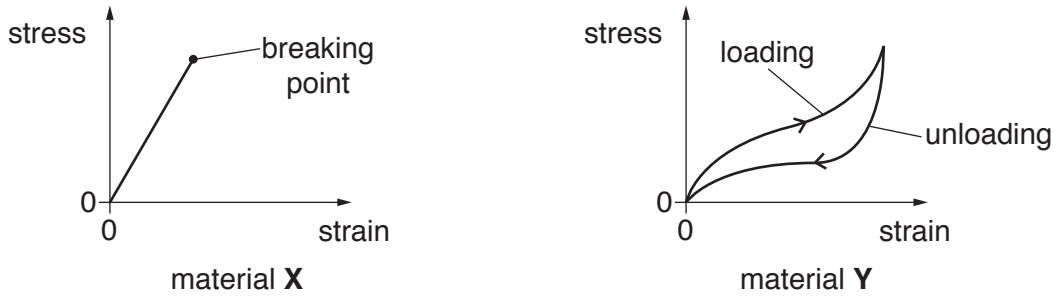

Fig. 6.1

Describe the properties of materials **X** and **Y**.

In your answer, you should use appropriate technical terms, spelled correctly.

material **X** .....

.....

.....

.....

.....

material **Y** .....

.....

.....

.....

..... **[5]**

(b) You are given a spring, a metre rule and a 100 g mass. Describe how you would determine the force constant k of the spring.

.....

.....

.....

.....

..... **[3]**

(c) A glider of mass 0.180 kg is placed on a horizontal frictionless air track. One end of the glider is attached to a compressible spring of force constant 50 N m^{-1}. The glider is pushed against a fixed support so that the spring compresses by 0.070 m, see Fig. 6.2. The glider is then released.

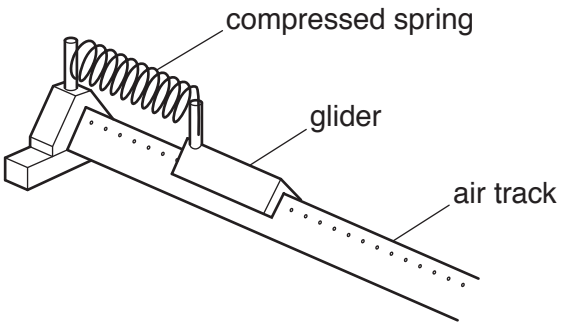

Fig. 6.2

(i) Calculate the horizontal acceleration of the glider **immediately** after release.

acceleration = ... m s^{-2} **[3]**

(ii) After release, the spring exerts a force on the glider for a time of 0.094 s. Calculate the average rate of work done by the spring on the glider.

average rate of work done = ... J s^{-1} **[2]**

[Total: 13]

4 **(a)** Atoms in a solid are held in position by electrical forces. These electrical forces can be represented by an imaginary 'interatomic spring' between neighbouring atoms, see Fig. 7.1.

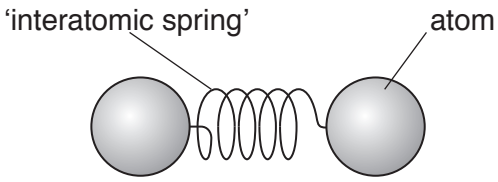

Fig. 7.1

The interatomic spring obeys *Hooke's law* and has a *force constant* just as a normal spring in the laboratory. Researchers in America have recently managed to determine the force experienced by an individual atom of cobalt when the atoms are squeezed together. The researchers found that a force of 210 pN changed the separation between a pair of atoms by a distance of 0.16 nm.

(i) State *Hooke's law*.

In your answer, you should use appropriate technical terms, spelled correctly.

.....

.....

..... **[1]**

(ii) Calculate the force constant of the interatomic spring for a pair of cobalt atoms.

force constant = ... $N\,m^{-1}$ **[3]**

(b) Fig. 7.2 shows a stress against strain graph for a metal wire up to its breaking point.

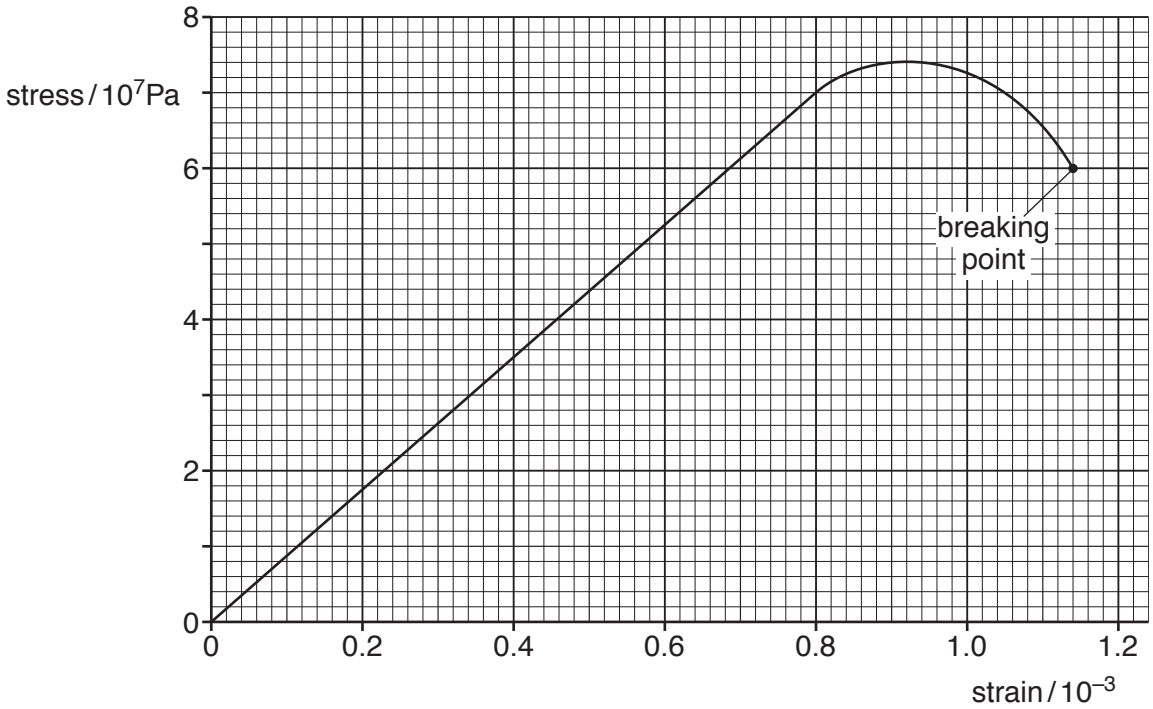

Fig. 7.2

(i) Use the graph to determine the Young modulus of the metal.

Young modulus = ... unit .....**[3]**

(ii) The wire breaks when a force of 19 N is applied. Use the graph to determine the cross-sectional area of the wire at the breaking point.

area = ... m^2 **[2]**

[Total: 9]

5 **(a)** Fig. 7.1 shows stress against strain graphs for two materials **X** and **Y** up to their breaking points.

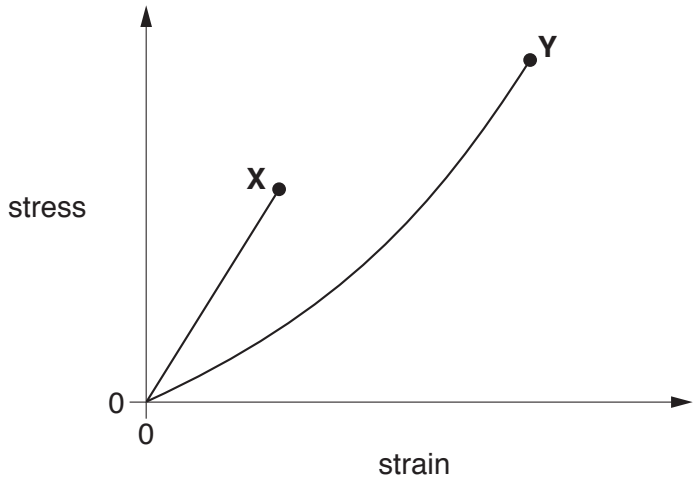

Fig. 7.1

Put a tick (✓) in the appropriate column if the statement applies to the material.

Statement	**X**	**Y**
This material is brittle.		
This material has greater breaking stress.		
This material obeys Hooke's Law.		

[1]

(b) Kevlar is one of the strongest man-made materials. It is used in reinforcing boat hulls, aircraft, tyres and bullet-proof vests. Sudden impacts cause this material to undergo plastic deformation.

(i) Explain what is meant by *plastic deformation*.

.....

.....

..... **[1]**

(ii) One particular type of Kevlar has breaking stress 3.00×10^9 Pa and Young modulus 1.30×10^{11} Pa. For a Kevlar thread of cross-sectional area 1.02×10^{-7} m^2 and length 0.500 m, calculate

1 the maximum breaking force

force = ... N

2 the extension of the thread when the stress is 1.20×10^9 Pa.

extension = ... m

[4]

[Total: 6]

Question			Answer	Marks	Guidance
1	a		The material is elastic / strain is zero when stress is removed / returns to its original shape when force is removed / there is no plastic deformation	B1	✎ The term **elastic / remove(d) / plastic** must be spelled correctly to gain this mark **Ignore** 'polymeric' **Not** 'it is ductile and elastic'
			It does not obey Hooke's law	B1	**Allow**: Stress is not proportional to strain / force is not proportional to extension
			The loading and unloading graphs are different (AW)	B1	**Allow**: It shows hysteresis / heat produced (when loaded and unloaded)
	b	i	(breaking) stress = $\frac{16}{0.012\times0.018\times10^{-3}}$ or 7.41×10^{7} (Pa)	C1	**Alternative:** $x=\frac{FL}{EA}$ (Any subject) C1
			strain = $\frac{7.41\times10^{7}}{7.1\times10^{10}}$ or 1.04×10^{-3}	C1	extension = $\frac{16\times0.15}{7.1\times10^{10}\times(0.012\times0.018\times10^{-3})}$ C1
			extension = $1.04\times10^{-3}\times0.15$		extension = 1.6×10^{-4} (m) A1
			extension = 1.6×10^{-4} (m)	A1	
			assumption: Hooke's law obeyed / elastic limit is not exceeded / not plastically deformed / (cross-sectional) area is the same / thickness is the same / width is the same / no 'necking' / material is brittle	B1	
		ii	(breaking) stress = same $\frac{F}{\pi\times(0.60\times10^{-2})^{2}}=7.41\times10^{7}$	C1	**Allow** other correct methods Possible ecf from **(b)(i)**
			force = 8.4×10^{3} (N)	A1	
			Total	**9**	

Question			Answers	Marks	Guidance
2	(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**	

Question			Answer	Marks	Guidance
3	(a)		Material **X** It is a ***brittle*** material No plastic deformation / It is elastic / It returns to same length when stress / force is removed Material **Y** It is a polymeric / polymer (material) It is elastic / It returns to same length when stress / force is removed **X** obeys Hooke's law / **Y** does not obey Hooke's law	 B1 B1 B1 B1 B1	**Use ticks on Scoris to show where the marks are awarded** ✎ ***Brittle*** must be spelled correctly to gain the mark. **Allow**: rubber / 'elastic band' **Allow**: energy 'lost' (when unloaded)
	(b)		Place the 100 g mass on the spring / hang the 100 g mass from the spring Determine the extension / compression of the spring (using a ruler) force constant = 0.98(1)/extension	B1 B1 B1	 **Allow**: k = (0.1 × 9.8)/extension **Allow**: k = 1.0 (N)/extension
	(c)	(i)	$F = kx$ $F = 50 \times 0.070$ / 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 = <u>average</u> 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) $E = \frac{1}{2} \times 50 \times 0.070^2 (= 0.1225)$ C1 power = 0.1225/ 0.094 power = 1.3 (J s^{-1}) A1
			Total	**13**	

Question			Expected Answers	Marks	Additional Guidance
4	a	i	Extension is proportional to force (applied as long as the elastic limit is not exceeded)	B1	**Must use tick or cross on Scoris to show if the mark is awarded** ✎ This B1 can only be scored when '***extension'*** is spelled correctly **Note:** If '*change in length'* or 'Δ *length'* used instead of '*extension'*, then ***length*** must be spelled correctly **Allow:** stress $\propto$ strain as BOD (stress or stain must be spelled correctly)
		ii	$p \rightarrow 10^{-12}$ $n \rightarrow 10^{-9}$ $k = \frac{F}{x}$ / $k = \frac{210 \times 10^{-12}}{0.16 \times 10^{-9}}$ force constant = 1.3 (N m^{-1}) or 1.31 (N m^{-1})	C1 C1 A1	 Possible ecf **Allow:** 1 mark for '210/0.16 =1312.5'
	b	i	E = gradient / E = stress/strain (linear section) $E = \frac{70 \times 10^{6}}{0.8 \times 10^{-3}}$ E = 8.8 × 10^{10} (Pa) or 8.75 × 10^{10} (Pa) unit: N m^{-2} or Pa	C1 A1 B1	 **Allow**: An answer in the range (8.3 to 9.1) × 10^{10} (Pa) **Allow**: 1 mark for an answer 8.75 × 10^{n}, n ≠ 10 **Note**: This is an independent mark
		ii	breaking stress = 6.0 × 10^{7} (Pa) $A = \frac{19}{6.0 \times 10^{7}}$ (Any subject) A = 3.2 × 10^{-7} (m^{2}) or 3.17 × 10^{-7} (m^{2})	 C1 A1	 **Allow:** 1 mark 3.17 × 10^{n} (m^{2}) , n ≠ -7 **Note:** No marks if breaking stress of <u>6.0</u> × 10^{n} is not used
			Total	**9**	

5	Expected Answers	Marks	Additional Guidance
a	<table><tr><th>X</th><th>Y</th></tr><tr><td>✓</td><td></td></tr><tr><td></td><td>✓</td></tr><tr><td>✓</td><td></td></tr></table>	B1	All 3 ticks correctly placed for 1 mark
b(i)	Material is permanently deformed / longer when stress / force is removed (wtte)	B1	**Note**: The answer must make reference to stress or forces removed
b(ii)1	(stress = force/area) force = $3.00 \times 10^{9} \times 1.02 \times 10^{-7}$ force = 306 (N) or 310 (N)	C1 A1	**Allow**: Any subject **Allow**: 2 marks for a bald 306 (N) or 310 (N)
b(ii)2	(E = stress/strain) strain = $\frac{1.20 \times 10^{9}}{1.30 \times 10^{11}}$ / strain = 9.23×10^{-3} extension = $9.23 \times 10^{-3} \times 0.500$ extension = $4.6(15) \times 10^{-3}$ (m)	C1 A1	 **Allow**: 4.6×10^{-3}, 4.61×10^{-3}, 4.62×10^{-3} **Allow**: 2 marks for a bald $4.6(15) \times 10^{-3}$ (m) **Allow**: 1 mark for using breaking stress of 3.0×10^{9} Pa; this gives an extension of 0.0115 (m) **Alternative answer:** $x = (1.20 \times 10^{9} \times 0.500)/1.30 \times 10^{11}$ C1 (Any subject) extension = $4.6(15) \times 10^{-3}$ (m) A1
	Total	**6**	