1. Fig. 6.2 shows a thin strip of aluminium which is secured by a clamp stand.

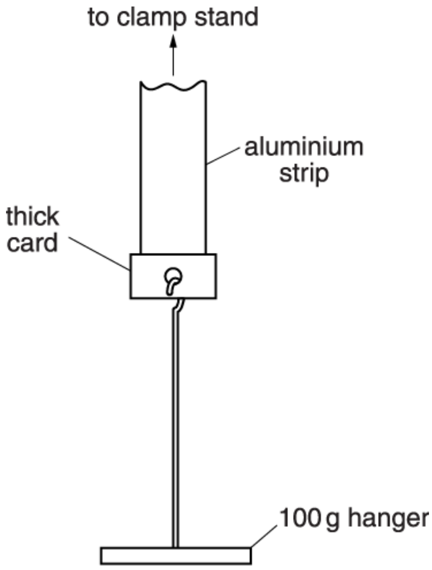

Fig. 6.2

The width of the strip has been measured to be 1.0 cm. A piece of thick card is taped to the lower end of the strip. A 100 g mass hanger is hooked through the card as shown in Fig. 6.2. A number of 100 g slotted masses and a micrometer are also available.

Describe how you would use the equipment to determine the **breaking stress** of aluminium.

-- **[3]**

2(a). The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

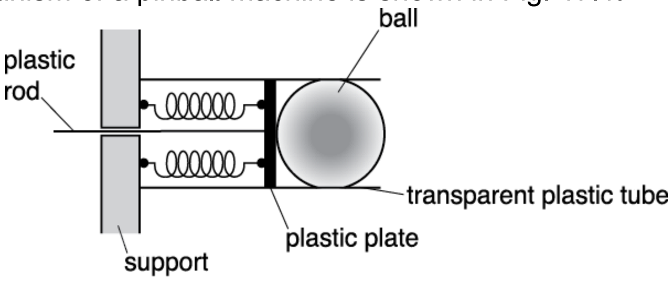

Fig. 17.1

A pair of identical compressible springs are fixed between a plastic plate and a support. The springs are in parallel. A plastic rod attached to the plate is pulled to the left to compress the springs. A ball, initially at rest, is fired when the plate is released.

A group of students are conducting an experiment to investigate the ball-release mechanism shown in Fig. 17.1. The students apply a force *F* and measure the compression *x* of the springs.
The table below shows the results.

***F* / N**	***x* / cm**
1.1 ± 0.2	2.0
2.0 ± 0.2	4.0
2.9 ± 0.2	6.0
4.0 ± 0.2	8.0
5.1 ± 0.2	10.0

Fig. 17.2 shows four data points from the table plotted on a *F* against *x* graph.

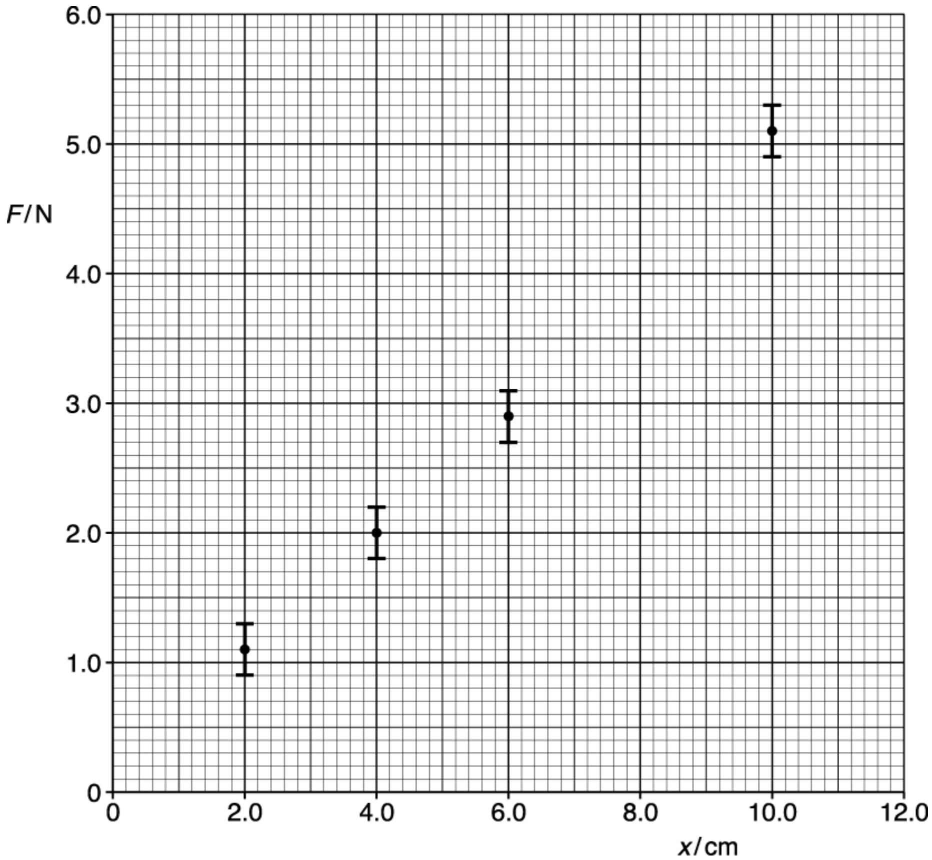

Fig. 17.2

i. Plot the missing data point and the error bar on Fig. 17.2.

[1]

ii. Describe how the data shown in the table may have been obtained in the laboratory.

--- **[2]**

iii. Draw the best fit and the worst fit straight lines on Fig. 17.2.

Use the graph to determine the force constant k for a **single** spring and the absolute uncertainty in this value.

k = ... ± .... N m^{-1}**[4]**

iv. State the feature of the graph that shows Hooke's law is obeyed by the springs.

--- **[1]**

v. The mass of the ball is 0.39 kg.

Use your answer from **(iii)** to calculate the launch speed v of the ball when the plastic plate shown in Fig. 17.1 is pulled back 12.0 cm.

v = ... m s^{-1}**[3]**

(b). A new arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

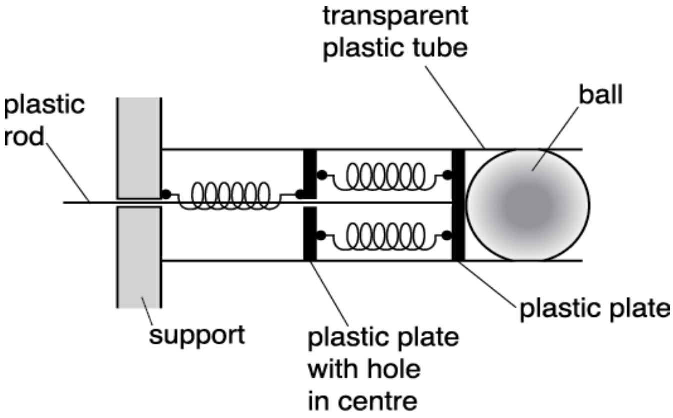

Fig. 17.3

The force constant of each spring is k.
The same ball of mass 0.39 kg is used. The plastic rod is pulled to the left by a distance of x.

Show that initial acceleration a of this ball is given by the equation

$$a = 1.7\,kx.$$

[2]

3. * A group of scientists have designed an alloy which is less dense than copper but may have similar mechanical properties. A researcher is given the task to determine the Young modulus of this alloy in the form of a wire.

Write a plan of how the researcher could do this in a laboratory to obtain accurate results. Include the equipment used and any safety precautions necessary.

[6]

4(a). The extension of a metal wire is x when the tension in the wire is F. The table in **Fig. 23.1** shows the results from an experiment, including the stress and the strain values.

F / N	x / 10^{-3} m	stress / 10^{7} Pa	strain / 10^{-3}
1.9	0.4	1.73	0.20
4.0	0.8	3.50	0.40
5.9	1.2	5.21	0.60
8.0		7.00	0.80
9.0	1.8	7.95	0.90

Fig. 23.1

Fig. 23.2 shows a graph of stress against strain for the metal.

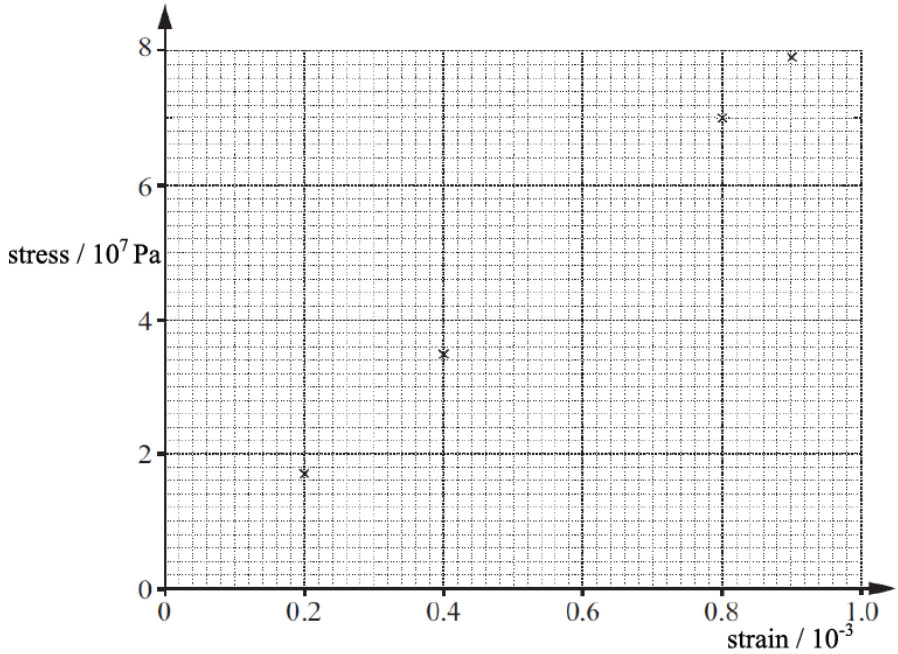

Fig. 23.2

i. On **Fig. 23.2,** plot the data point corresponding to the tension of 5.9 N and draw the line of best fit through all the data points.

[1]

ii. Use **Fig. 23.2** to determine the Young modulus of the metal.

Young modulus = ... Pa **[2]**

(b). The micrometer screw gauge used to determine the diameter of the wire had a zero error. The diameter recorded by a student was larger than it should have been.

Discuss how the actual value of the Young modulus would differ from the value calculated in **(b)(ii)**.

[3]

5. This question is about the behaviour of a mass on a spring.

The table below shows how the extension x of a spring varies as the mass m suspended vertically from it alters.

***m* / g**	***x* / cm**
100	2.5
200	5.1
300	7.5
400	9.9
500	12.5
600	15.0

i. Apply a test to the data to see if the extension of the spring is proportional to the applied force. Explain your method and state your conclusion.

[3]

ii. Calculate the spring constant k of this spring.
$g = 9.8 \text{ N kg}^{-1}$

k = ... N m^{-1} **[1]**

6(a). This question is about an experiment to determine the Young modulus of a copper wire.

The diameter D of the wire was measured using a micrometer screw gauge in several places along the length of the wire. The values obtained are shown in the dot-plot shown in Fig. 4.1. Each dot represents one reading.

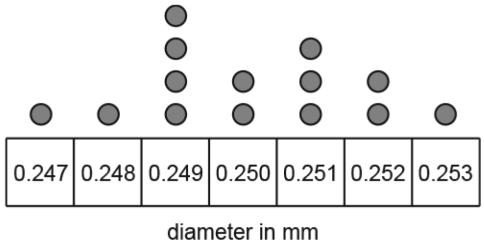

Fig. 4.1

i. Use the information in the dot–plot to find the mean D. Use the spread to determine the percentage uncertainty.

mean D = ... mm ± .... % **[3]**

ii. Calculate the cross sectional area A of the wire and include the uncertainty.

A = ... ± .... m^2 **[3]**

(b). A marker is placed to give an original length of the wire as 4.00 ± 0.02 m.

Fig. 4.2 shows the extension *x* of a metal wire at different applied loads *F*. *x* is measured to ± 0.5 mm and *F* is measured to ± 0.2 N.

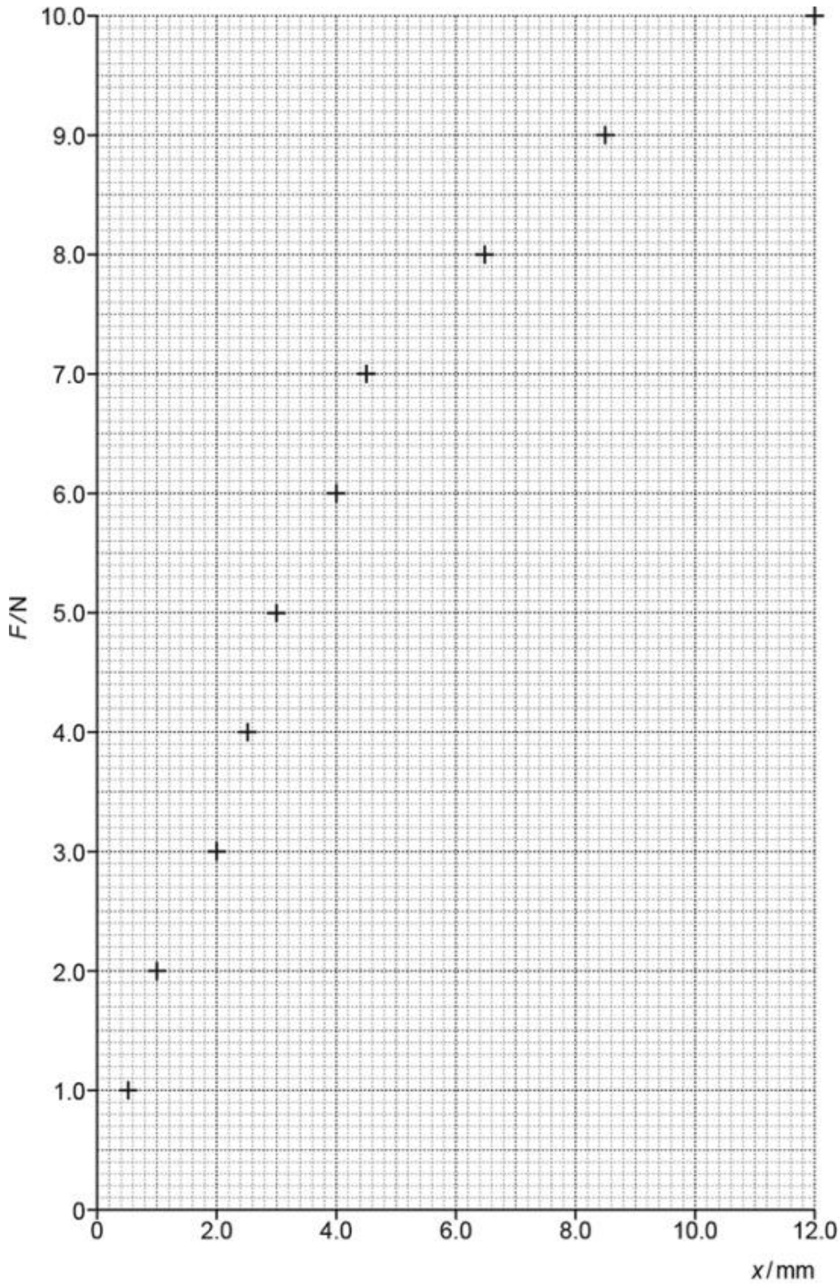

Fig. 4.2

i. On Fig. 4.2

1. complete vertical and horizontal error bars on each of the plots
2. label the regions of elastic and plastic deformation
3. draw a line of best fit through the straight section of the graph.

[4]

ii. Use the graph and the data given to calculate the value of the Young Modulus *E*. Include the appropriate unit.

E = ... unit .... **[5]**

(c). Use Fig. 4.2 and your answer to part **(b)(ii)** to estimate the percentage uncertainty in the calculated value of the Young Modulus and describe the main sources of error in the experiment.

Suggest and explain possible improvements to the experiment.

[6]

[Total marks: 53]

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			Measure the thickness of the strip (using the micrometer) and calculate its (cross-sectional) area	B1	**Not**: <u>surface</u> area
			Load the hanger until the strip breaks. Calculate the (maximum) weight of the masses using $W = mg$.	B1	**Allow**: 'force' for 'weight'
			breaking stress = (maximum) weight/(cross-sectional) area	B1	**Allow:** breaking stress = (maximum) force/(cross-sectional) area **Allow**: F/A if the words force and area have been used in the answer
			Total	**3**	
2	a	i	Missing data point and error bar plotted correctly.	B1	**Allow** ½ square tolerance.
		ii	Force measured by pulling back plate with a newton−meter.	B1	
			Extension measured with a ruler (placed close to the transparent plastic tube).	B1	
		iii	Best fit line drawn correctly and gradient determined correctly.	B1	**Ignore** POT for this mark; gradient = 50 ± 4 (N m^{-1})
			Worst fit line drawn correctly and its gradient determined correctly.	B1	**Note**: The line must have a greater/smaller gradient than the best fit line and must pass through all the error bars. **Ignore** POT for this mark.
			$2k = 50$ (N m^{-1}), therefore $k = 25$ (N m^{-1})	B1	Possible ECF.
			Absolute uncertainty determined correctly.	B1	Possible ECF within calculation.
		iv	$F \propto x$ / straight line passing through the origin.	B1	

		v	energy stored = ½ × 50 × 0.12^2 ½ × 50 × 0.12^2 = ½ × 0.39 × v^2 v = 1.4 (m s^{-1})	C1 C1 A1	Possible ECF from **(iii)** **Allow** 1 mark for v = 0.96 m s^{-1}; used k for single spring
	b		force constant of spring arrangement) = $\frac{2k}{3}$ $\frac{2k}{3}x = ma$ $a = \frac{2}{3 \times 0.39}kx$ a = 1.7 kx	M1 M1 A0	
			Total	**13**	
3			*** Level 3 (5–6 marks)** All points E1, 2, 3 and 4 for equipment All points M1, 2, 3 and 4 for measurements For calculations expect C1, C2, C3 and C4 Expect at least two points from reliability *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect E1 and E2; E3 or E4 for equipment Expect M2 and two from M1, M3, M4 for measurements For calculations expect at least C3 and C4 Expect at least one point from reliability *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)**	B1 × 6	The complete plan consists of four parts: **Equipment used safety (E)** 1. Wire fixed at one end with load added to wire. 2. Suitable scale with suitable marker on wire. 3. Micrometer screw-gauge **or** digital / vernier callipers for measuring diameter of wire. 4. Reference to safety concerning wire snapping. **Measurements (M)** 1. Original length from fixed end to marker on wire. 2. Diameter of wire. 3. Measure load. 4. New length of wire when load increased. **Calculation of Young modulus. (C)** 1. Find extension (for each load) or strain (for each load). 2. Determine cross-sectional area or stress.

			Expect at least E1 and E2 for equipment Expect at least two from measurements Expect C5 for the calculation No real ideas for obtaining reliable results *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		3. Plot graph of load-extension **or** graph of stress-strain. 4. Young modulus = gradient × original length / area **or** Young modulus = gradient. 5. Calculate Young modulus from single set of measurements of load, extension, area and length. **Reliability of results (R)** 1. Measure diameter in 3 or more places and take average. 2. Put on initial load to tension wire and take up 'slack' before measuring original length. 3. Take measurements of extension while unloading to check elastic limit has not been exceeded. 4. Use long wire (to give measurable extension). Scale or ruler parallel to wire.
			Total	**6**	
4	a	i	Data point plotted to within ± ½ small square and correct line of best fit though all the data points.	B1	
		ii	Gradient of line determined. E = gradient = $(8.8 \pm 0.1) \times 10^{10}$ (Pa).	M1 A1	 Allow 1 mark for $(8.8 \pm 0.1) \times 10^{n}$ Pa; where $n \neq 10$
	b		The actual cross-sectional area will be smaller. The actual stress values on the graph will be larger (because stress $\propto$ area^{-1}) The gradient of the graph will be larger; hence the Young modulus of the metal must be larger than the student's value.	B1 B1 B1	
			Total	**6**	
5		i	F is proportional to mass. A set (at least 5) of suitable calculations eg: m / x or F / x for each row of table; or Δx for each pair of rows (which have equal Δm = 100g);	**1** **1**	Could be shown as F=mg or calculations. NOT F=ma m / x will give 40.0, 39.2, 40.0, 40.4, 40.0, 40.0 Δx will give 2.6, 2.4, 2.4, 2.6, 2.5 F / x will give 0.392, 0.384, 0.392, 0.396, 0.392, 0.392

			Find one value for m / x (or F / x) and then use it to predict values for m for each value of x (or vice versa). $\Delta m/\Delta x$ is constant approximately / within experimental error / uncertainty	 1	Ignore POT as long as they are consistent. Calculated values should be to at least 2sf. If no (or insufficient) calculations then this mark can be awarded for describing a valid test to carry out.
		ii	$k = F / x = 0.6 \times 9.8 / 0.15 = 39$ N m^{-1}	1	Accept use of data from any row of the table. 38 N m^{-1} if second row is used.
			Total	**4**	
6	a	i	Mean value = [(0.247 + 0.248 + (4 × 0.249) + (2 × 0.250) + (3 × 0.251) + (2 × 0.252) + 0.253) ÷ 14 = 3.501 ÷ 14] = **<u>0.250</u>** mm ✓ Spread = ± $^1/_2$ range ✓ [= ± $^1/_2$ (0.253 − 0.247] = 0.003) % uncertainty = (0.003 ÷ 0.250) × 100 = **1(.2)**% ✓	3	Mean must be to <u>3sf</u>. ecf incorrect mean used to calculate %uncertainty, but not ecf incorrect spread.
		ii	Area = Π d^2 ÷ 4 = **$4.9(1)\times10^{-8}$m²** ✓ **EITHER** % error in area measurement (= 2 × % error in d) = 2.4%✓ Absolute uncertainty = [$4.9(1)\times10^{-8}$ × 0.024 =] **$1(.2)\times10^{-9}$ m²** ✓ **OR** Maximum = 5.03×10^{-8} m² and/or minimum = 4.79×10^{-8} m² ✓ Absolute error in area = [$^1/_2$ (max − min) OR max − actual OR actual − min] = ± **$0.1(2)\times10^{-8}$ m²** ✓	3	Use of r = 0.250 mm gives A = 1.96×10^{-7} m². ALLOW % uncertainty is twice % uncertainty in diameter calculated in (a)(i). ALLOW ecf for uncertainty on incorrect calculation of A. [±4.8×10^{-9} for A = 1.96×10^{-7} m²]
	b	i	x–error bars at ± 0.5 ✓	4	At least 6 correct to $^1/_2$small square in total line length.

			y–error bars at ± 0.2 ✓ Elastic region labelled at the straight section of the graph (F ≤ 7 N by eye) **AND** Plastic region labelled at the curved section of the graph (F ≥ 7 N by eye) ✓ <u>Straight</u> LoBF drawn with a fair spread of **their** points above and below the line by eye, extending as least as far as 6 N. ✓		At least 6 correct to $^{1}/_{2}$small square in total line length Both correct for a mark. Can be labelled anywhere on the graph. LoBF should not use top 3 plots. Ignore any line drawn at F > 7 N Line drawn should not cross the x axis and there should be similar number of points either side of line.
		ii	Calculate gradient using two points on **their line** which are at least half the length of **their line** apart. ✓ Use of Young Modulus = *Fl/Ax* or stress/strain [= gradient × (*l/A*)]✓ Calculate value of Young Modulus using value of A from **(a)(ii)** and *l* = 4.00 m and <u>gradient</u>. ✓ Correct units (Pa or N m^{-2}). ✓ Answer has correct POT for their units. ✓	**5**	Look for ΔF ≥ 5.0 if full height line drawn. If a single data point is used to find gradient check drawn line goes through both origin and data point and F is greater than half height of line. Gradient should be in range 1.3×10^3 to 1.7×10^3. Ignore POT in gradient calc. ALLOW ecf from incorrect lbf. If E calculated from data point values or stress over strain; max 3 marks (not first or third marking point). Expect $1\times10^{11} \geq E \geq 1.4\times10^{11}$ Pa. ALLOW ecf of incorrect A in part (a)(ii). [If A = 1.96×10^{-7} m^2 then E will be a quarter the value above − approx 3×10^{10} Pa.] **<u>Examiner's Comments</u>** In order to gain full marks in the question candidates need to use the gradient of the line rather than a single data point. Most candidates gave the correct unit and used the correct relationship to find Young Modulus. A few candidates mis-read the data from the graph or used two points on the line which were too close together.
	c		**Level 3 (5–6 marks)** ✓✓	**6**	

			• Combines their %uncertainties correctly to find overall %uncertainty in *E*. • Identifies (with reason) that extension provides the greatest source of uncertainty • Justifies improvement for any two sources of uncertainty. *There is a well–developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks) ✓✓** Minimum 2 of: • Calculation of reasonable %uncertainty in variable(s) (not area) or *E*. • Comparison of two or more %uncertainties or complete set of uncertainties listed (*A*, *l*, *F* and *x* **OR** *A*, *l* and gradient). • Identifies reasons for at least two sources of uncertainty. • Suggest improvements to mitigate at least two sources of uncertainty. *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks) ✓✓** Minimum 2 of: • Identifies reason for source of uncertainty; • Suggests improvement for at least one source of uncertainty • Attempts to calculate % uncertainty for at least one variable other than area.		

			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. **0 marks** No response or no response worthy of credit.		
			Total	**21**	
			Total marks	**53**	