

PHYSICS



EXAM QUESTION PACK

MODULE 2 FUNDAMENTAL DATA ANALYSIS

SCORE

/126

PERCENTAGE

%

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- 1 A teacher uses strobe photography to demonstrate the motion of a tennis ball thrown under gravity. She opens the camera shutter in a darkened room and throws the tennis ball in front of the lens as the strobe flashes at 20 ± 2 Hz. Fig. 1 shows the result, superimposed on a metric grid.

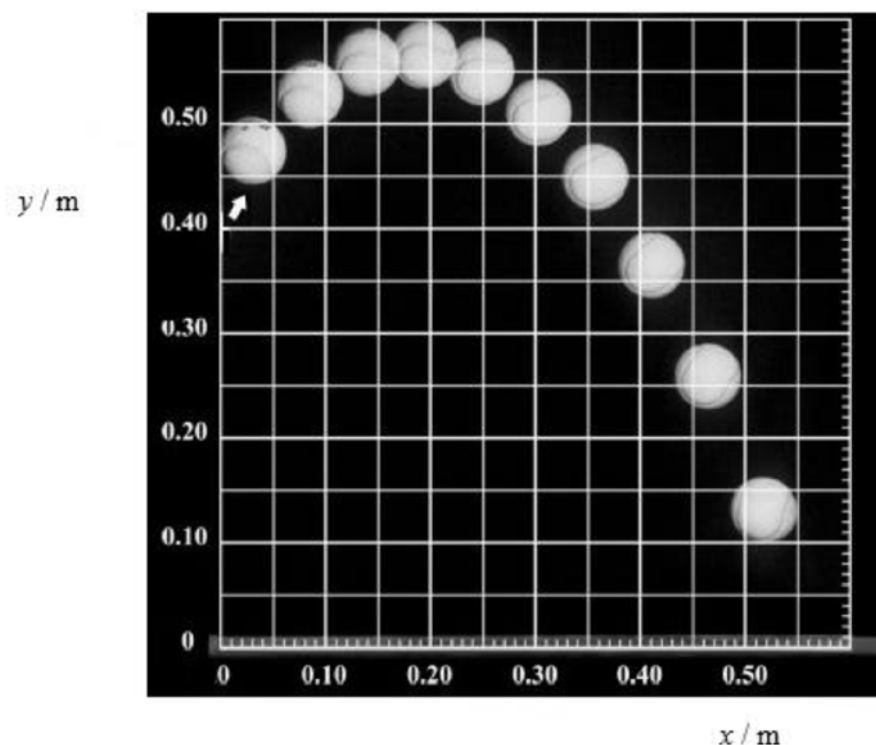


Fig. 1

A student takes measurements of the y position from Fig. 1, starting from the image centred on $x = 0.20$ m. He measures the y positions from the bottom of the ball and performs calculations; some are recorded in the table below. He concludes that g , the acceleration of gravity, is $9.2 \pm 0.4 \text{ ms}^{-2}$.

$t / \text{s} \pm 10\%$	$y / \text{m} \pm 0.005 \text{ m}$	$\Delta y / \text{m}$	$\Delta y / \Delta t / \text{ms}^{-1}$	$\Delta v / \text{ms}^{-1}$	$\Delta v / \Delta t / \text{ms}^{-2}$
0	0.54				
0.05	0.52	0.02	0.40		
0.10	0.48	0.04	0.80	0.40	
0.15	0.42	0.06	1.20	0.40	
0.20	0.33	0.09	1.80		
0.25	0.22	0.11	2.20		
0.30	0.10	0.12	2.40		

(i) Record further values in the spaces provided to complete the data in the table.

[2]

(ii) Complete your own analysis of the data by calculating the mean value for g with an estimate of its uncertainty.

$g = \text{-----} \pm \text{-----} \text{ ms}^{-2}$ [2]

(iii) You are planning to improve the accuracy of this experiment to estimate g . Suggest and explain which of the measured quantities is most worth improving to achieve this.

[2]

- 2 A converging lens is used to form a real image of an object on a screen. The object consists of a black line marked on a sheet of thin white paper illuminated from behind with red light as shown in Fig. 1.1.

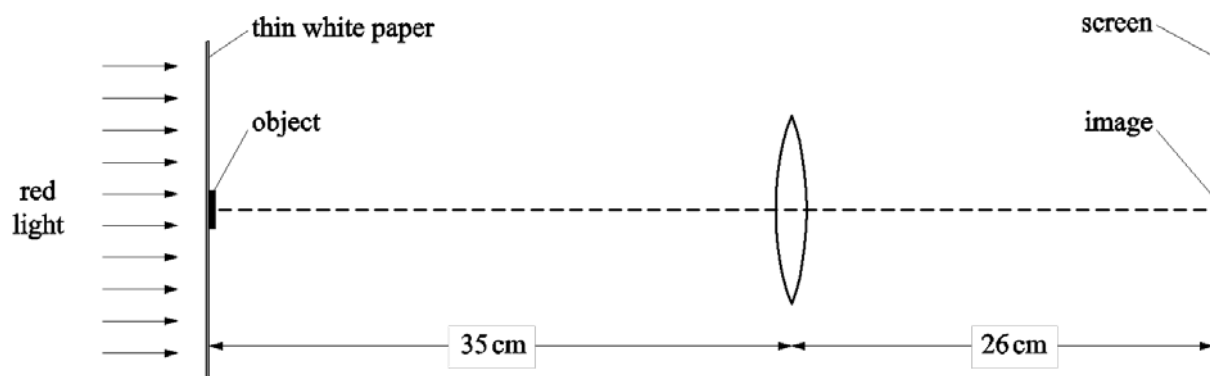


Fig. 1.1

The object is 2.5 cm in height. Using data from the diagram:

- (i) calculate the image height

height = ... cm [2]

- (ii) calculate the power P of the lens.

$P =$ D [2]

- (iii) The ruler used to measure the object and image distances allows measurement to the nearest mm. However, the sharpest position of the image can be judged only to ± 5 mm.

Calculate the uncertainty ΔP in the power of the lens, explaining any assumptions made.

$\Delta P =$ D [3]

3(a) This question is about measuring the air pressure inside a vacuum cleaner hose.

A vacuum cleaner reduces the pressure in its inlet hose to below atmospheric pressure. This reduction in pressure is about 20 kPa.

To test this, a student sets up the experiment shown in Fig. 12.1.

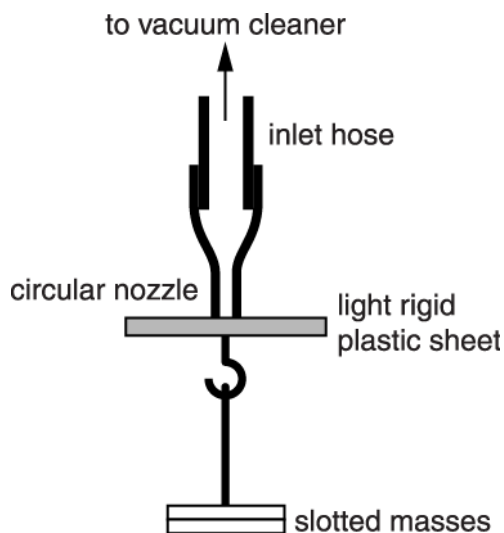


Fig. 12.1

When the vacuum cleaner is turned on, a number of slotted 100 g masses can be hung from the plastic sheet.

- (i) Explain, in terms of the behaviour of the air particles on each side of the sheet, how this difference in pressure holds the sheet in place.



Your answer should clearly link the forces on the sheet to the motion of the air particles on each side of it.

[3]

- (ii) The student finds that only two 100 g masses can be hung from the plastic sheet before it is pulled from the nozzle.

Calculate the pressure of the air in the hose.

nozzle diameter = 12 mm

atmospheric pressure = 100 kPa

$g = 9.8 \text{ N kg}^{-1}$

pressure = _____ Pa [3]

- (b) The student proposes to improve the precision of the measurement by removing the nozzle on the end of the inlet hose, as shown in Fig. 12.2.

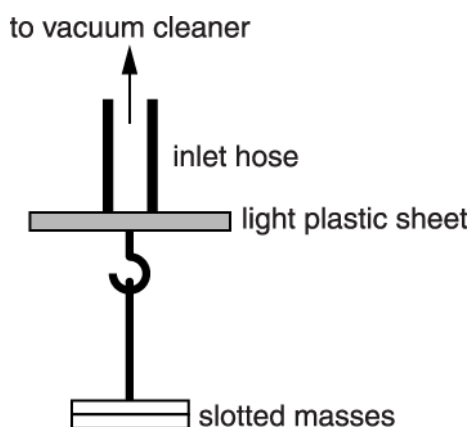


Fig. 12.2

This increases the diameter of the hose touching the sheet to 30 mm. This reduces the uncertainty in the measurement of the maximum mass supported by the light plastic sheet. Calculate what effect this has on the precision of the measurement of the pressure in the vacuum hose.

[3]

- 4 Which experimental procedure reduces systematic error of the quantity being measured?

- A timing a large number of oscillations to find the period of a pendulum
- B measuring the diameter of a wire several times to find an average
- C adjusting a voltmeter to remove its zero error before measuring a p.d.
- D repeating readings of the activity of a radioactive rock before taking an average

Your answer

[1]

5 Which quantity is followed by a reasonable estimate of its magnitude?

- A wavelength of green light 500 nm
- B frequency of a radio wave 900 GHz
- C mass of a bee 800 μg
- D volume of water for a bath 3000 mm^3

Your answer

[1]

6 The table shows some measurements of air density at different temperatures at constant pressure.

Temperature / K	Density / kg m^{-3}
273	1.29
283	1.25
293	1.20
303	1.16

Kinetic theory suggests that the density ρ of an ideal gas with particles of mass m and pressure p is related to its kelvin temperature T by the equation

$$\rho = \frac{pm}{kT}$$

where k is the Boltzmann constant.

Do the measurements support this equation? Justify your answer with calculations.

[2]

- 7(a) This question is about possible flaws in an attempt to estimate a value for the gravitational constant G using Earth-based observations.

The table contains the results of data required.

radius of Earth at equator	$6.4 \times 10^6 \text{ m}$
mean density of surface rocks on Earth	$2.7 \times 10^3 \text{ kg m}^{-3}$
period of Moon's orbit around the Earth	$2.4 \times 10^6 \text{ s}$
time for a laser pulse fired at the Moon to return	2.5 s

The Moon of mass m orbits the Earth of mass M in a circular path of radius r with a period T . By setting the centripetal force on the Moon equal to its gravitational attraction to the Earth, show that

$$G = \left(\frac{4\pi^2}{M} \right) \frac{r^3}{T^2}$$

[3]

- (b) The mass M of the Earth can be estimated from its radius R and its density ρ .

Use the data for radius and density in the table to show that they give a value of M which is about $3 \times 10^{24} \text{ kg}$.

[2]

- (c) The distance r from the centre of the Earth to the centre of the Moon can be estimated by timing the return of laser pulses reflected from the Moon's surface.

The relationship $r = \frac{c\Delta t}{2}$ can be used to estimate a value for r from the time interval Δt between the emission and return of a laser pulse.

- (i) State **two** assumptions required for the relationship to be valid.

[2]

- (ii) Use the data from the table to calculate a value for r and hence show that the value of G obtained from (a) and (b) is very different from the accepted value of $6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$.

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

$$G = \text{-----} \text{ N m}^2 \text{ kg}^{-2} \text{ [2]}$$

- (iii) Suggest a reason why your calculated value of G is very different from the accepted value. Justify your answer.

[2]

8 This question is about strain gauges that can be fixed to an object to measure its extension or compression.

To make a sensing circuit, a student connects a potential divider circuit with the strained gauge **X** connected in series with another identical, unstrained strain gauge **Y** as shown in Fig. 38.3.

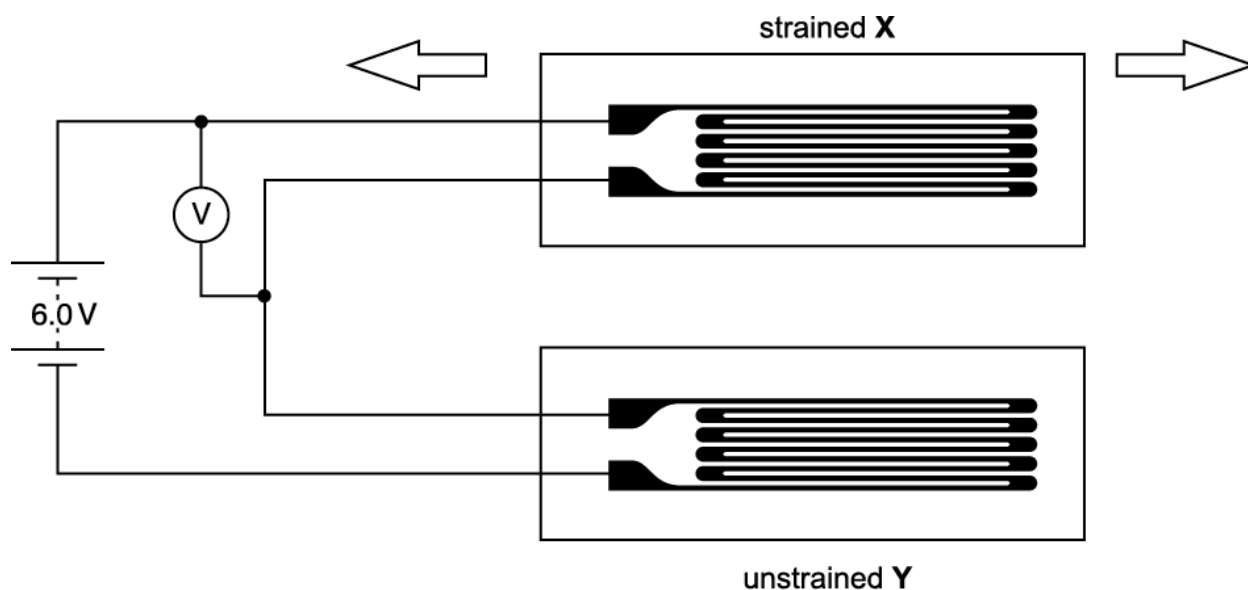


Fig. 38.3

(i) Fig. 38.4 shows the calibration graph for this strain sensor.

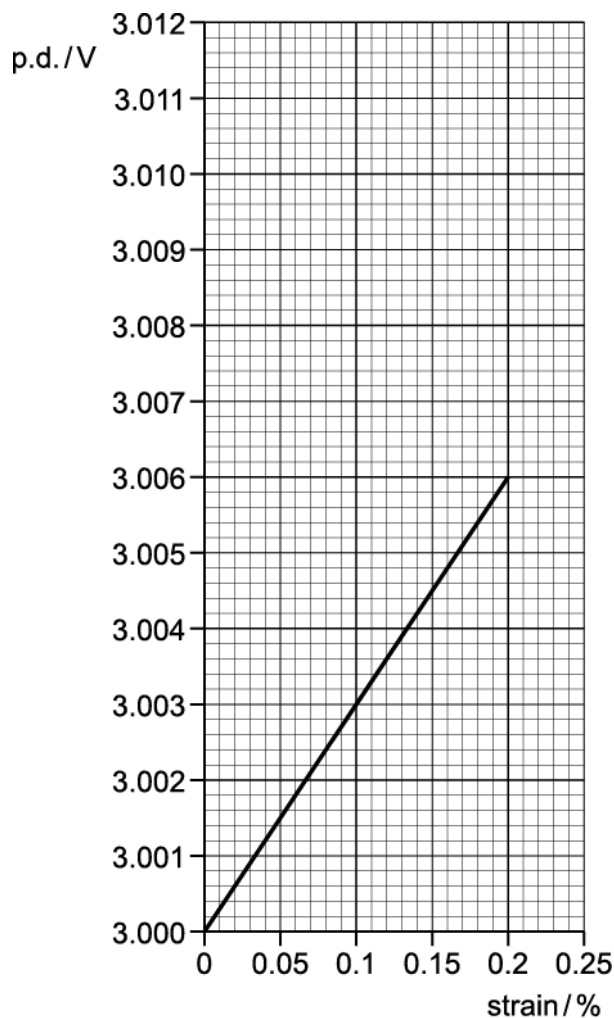


Fig. 38.4

Use data from Fig. 38.4 to calculate the sensitivity of the strain gauge sensor.

sensitivity = _____ V unit strain⁻¹ [2]

- (ii) Explain how there can be a systematic error in strain measurement if the strained gauge X is in a hotter environment than the unstrained gauge Y.

Use these order of magnitude statements about metal properties to help you answer:

fractional change in resistivity per kelvin $\frac{\Delta\rho}{\rho\Delta T} \approx +10^{-3} \text{ K}^{-1}$ and

fractional change in length per kelvin $\frac{\Delta L}{L\Delta T} \approx +10^{-5} \text{ K}^{-1}$.

[4]

- (iii) In the case of a bending beam the upper surface is stretched and the lower surface is compressed as shown in Fig. 38.5.

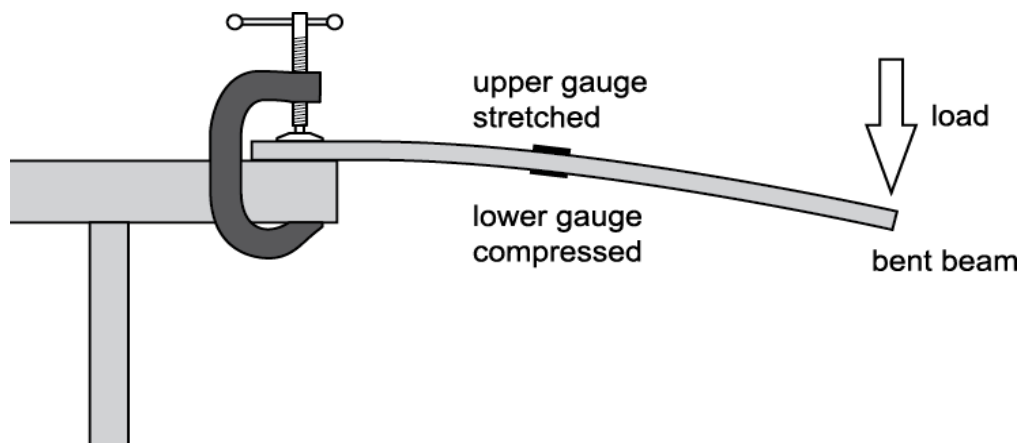


Fig. 38.5

The circuit in Fig. 38.3 is used with the strain gauge X attached to the upper surface of the beam, and strain gauge Y on the lower surface.

Draw on Fig. 38.4 the calibration graph you would expect for this arrangement of gauges.

[1]

9(a) This question is about the determination of the specific thermal capacity of aluminium.

An electrical heater is used to raise the temperature of a 1.0 kg aluminium block in the circuit shown in Fig. 1.1.

The switch is closed, switching the heater on for ten minutes before the switch is opened, which turns the heater off.

The temperature of the block is recorded at one minute intervals for fifteen minutes.

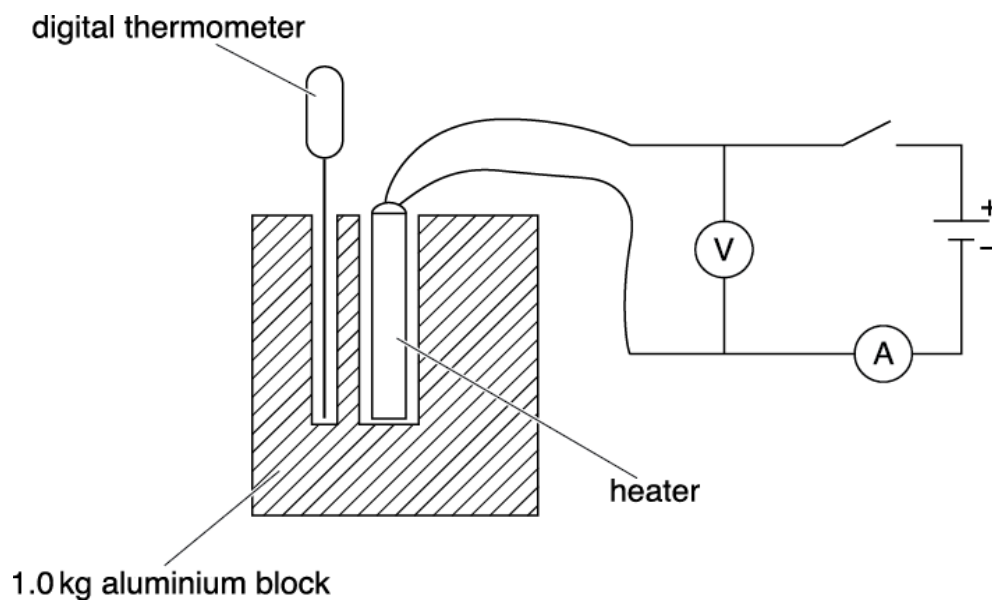


Fig. 1.1

Readings are taken of potential difference across the heater and current through the heater every two minutes. The results are shown in the table.

Time t / minutes	Potential difference V / V	Current I / A	Power P / W
0		2.30	19.8
2	8.67	2.35	20.4
4	8.74		20.3
6	8.75	2.42	21.0
8	8.69	2.39	20.8
10	8.70	2.41	

(i) Complete the missing values in the table.

(ii) Calculate the mean power. Include the uncertainty in the value.

mean power = _____ $\pm$ _____ W [2]

Fig. 1.2 shows a graph of temperature against time.

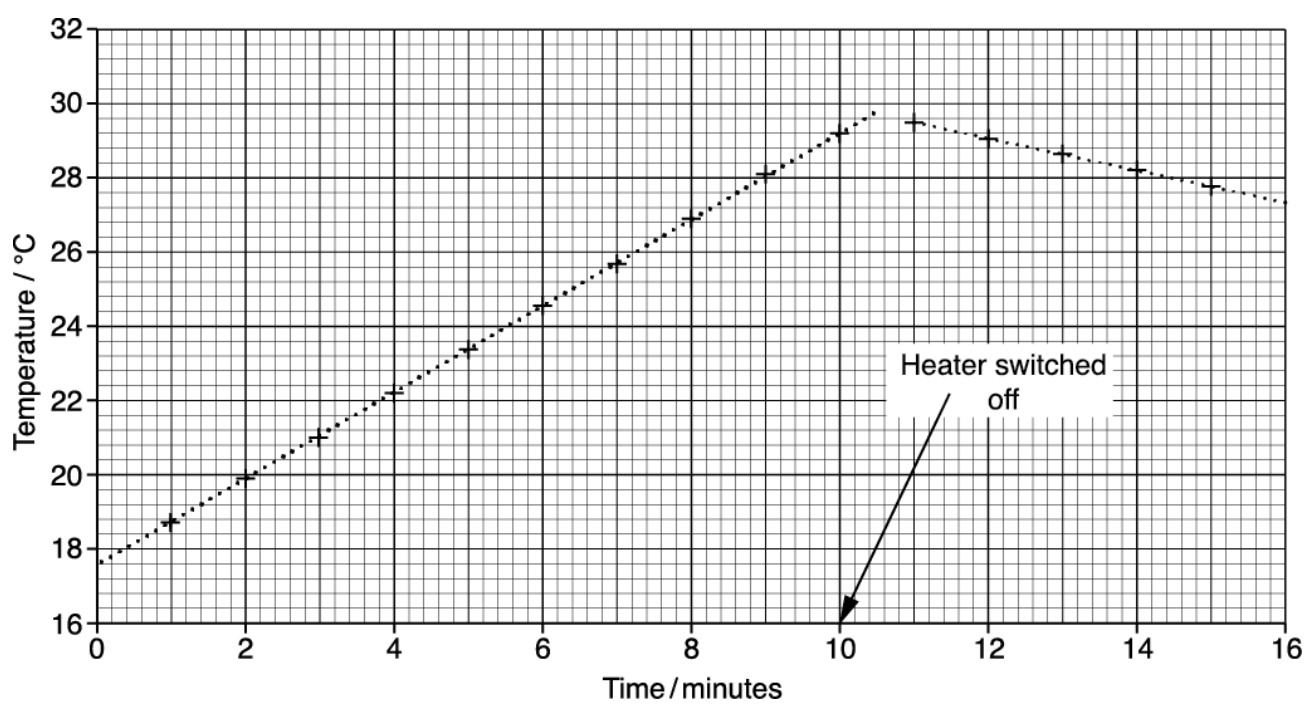


Fig. 1.2

(b)

- (i) Use data from the first ten minutes of the graph and your answer to (a)(ii) to show that the specific thermal capacity of aluminium is about $1000 \text{ J kg}^{-1} \text{ K}^{-1}$.

[3]

- (ii) Use Fig. 1.2 to estimate the maximum rate of cooling when the switch is opened.

maximum rate of cooling = _____ K min^{-1} [2]

- (c) The total percentage uncertainty in the investigation is found to be 5 %. The accepted value of the specific thermal capacity of aluminium is $897 \text{ J kg}^{-1} \text{ K}^{-1}$.

Calculate the percentage difference between your calculated value from (b)(i) and the accepted value and use this to comment on the accuracy of the investigation. Suggest reasons for the difference between the investigation value and the accepted value.

[4]

10 This question is about investigating the terminal velocity of paper cupcake cases.

A paper cupcake case is dropped from a height of 2.0 m and the time taken t to fall to the ground is recorded using a stopwatch.

Fig. 2.1 shows a dot-plot recording the values obtained for t .

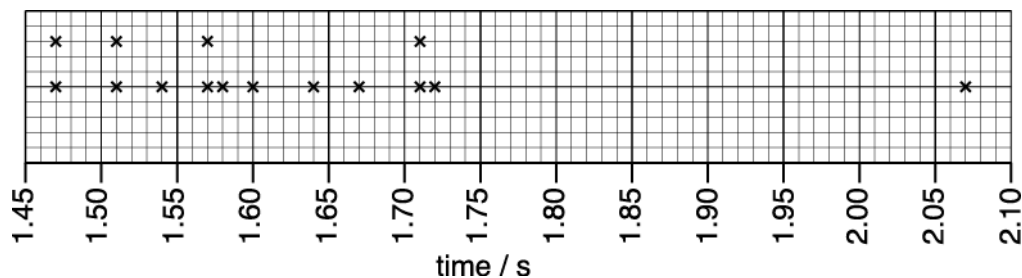


Fig. 2.1

Suggest a practical reason for the outlying result of 2.07 s.

[1]

11 This question is about an experiment to determine the Planck constant using LEDs.

Fig. 3.1 shows the circuit which is used in a school laboratory.

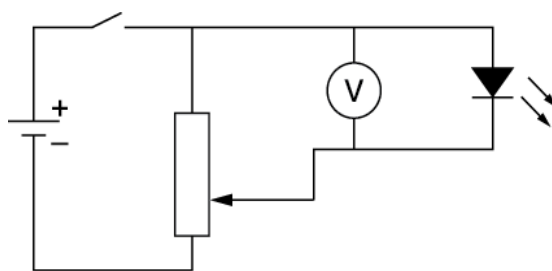


Fig. 3.1

The voltage across each LED is increased until the light emitted from the LED is just visible. This voltage V_t is recorded. V_t is found for seven LEDs emitting light of different wavelengths.

Fig. 3.2 shows a graph of V_t against $1/\lambda$ with uncertainty bars. The line of best fit has been drawn through the points. The gradient of the line is 2.0×10^{-6} .

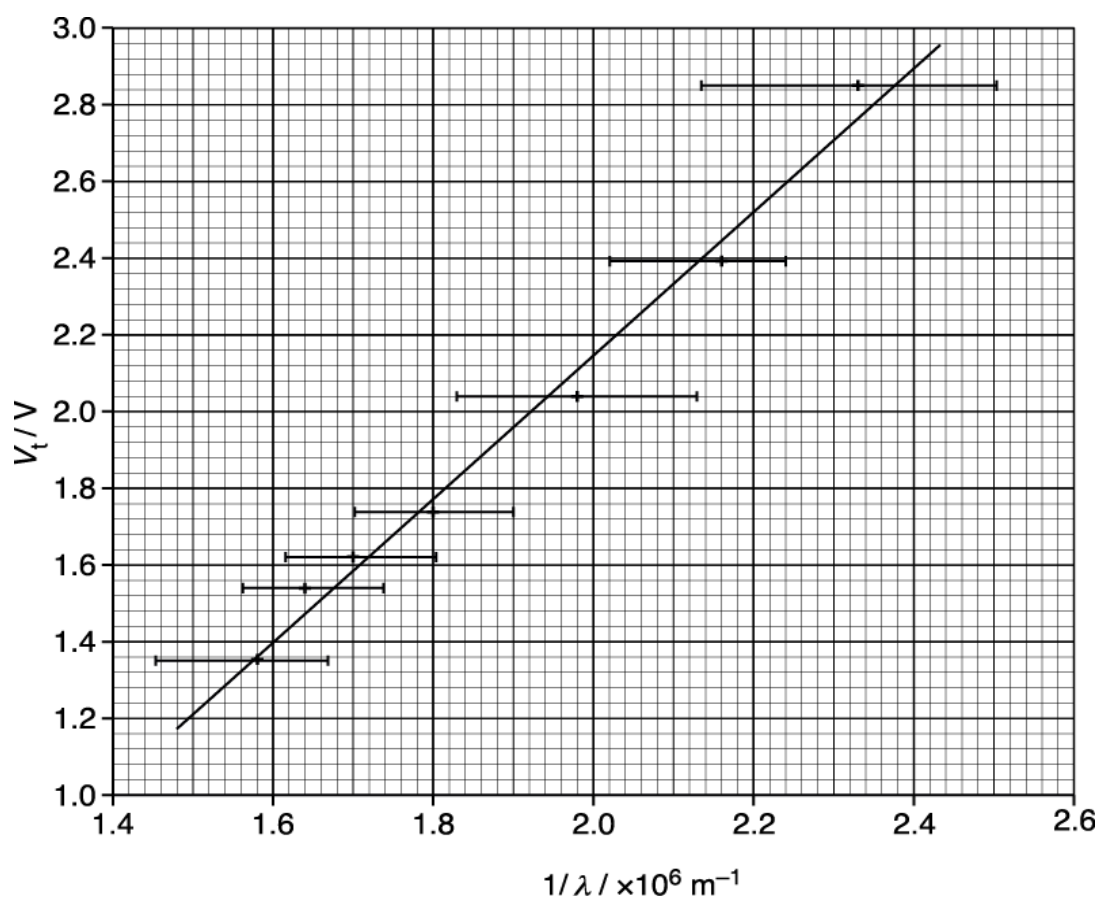


Fig. 3.2

- (i) Using the energy-frequency relationship for photons show that the gradient of the line represents

$$\frac{hc}{q}$$

where h is the Planck constant, c is the speed of light in a vacuum and q is the charge on the electron.

[2]

- (ii) Hence show that h is found to be about 1.1×10^{-33} J s.

[1]

- (iii) A *worst-fit* straight line is one which represents the steepest or least steep possible straight line to pass through all the uncertainty bars. Draw a worst-fit straight line on the graph and calculate a second value for the Planck constant.

[3]

- (iv) *Compare the calculated values for h with the accepted value (6.6×10^{-34} J s) and comment on the accuracy of the experiment. Describe the sources of uncertainty in the experiment and suggest improvements.

[6]

12(a) (See Insert for H557/02, Scientific literacy in physics (AS/A level), June 2017) This question is about an experiment to estimate the resolution of the human eye.

Two vertical, parallel black lines are drawn on a piece of card. The separation between the lines is 2.0 ± 0.5 mm. The card is fixed to a wall at head height.

A group of students look at the card whilst each covering one eye. They walk back from the card until they can no longer separate the two lines. The distance L between the eye and the card is measured.

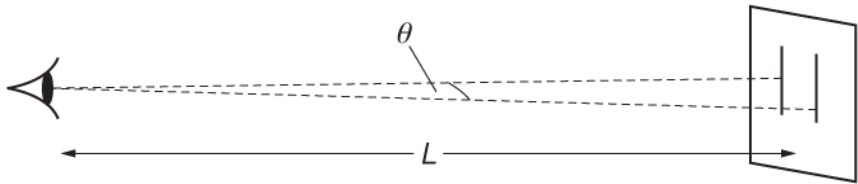


Fig. 9.1

Here are the results from five students:

student	A	B	C	D	E
maximum distance L /m	6.2	5.8	6.1	5.9	6.1

(i) State the spread of the distance values.

spread = $\pm$ m [1]

(ii) A student suggests that the uncertainty in the distance values can be ignored when calculating the minimum angle that can be resolved because of the uncertainty in the separation of the lines on the card. Comment on this suggestion, explaining whether or not you agree.

[2]

- (iii) Calculate a value for the minimum angle that can be resolved. Include an estimate of the uncertainty in your value. Explain how you estimated the uncertainty.

minimum angle that can be resolved = ... $\pm$ rad [3]

- (b) An approximate value for the minimum resolvable angle $\theta_{\min}$ can be obtained from the equation

$$\theta_{\min} = \frac{\text{wavelength of light}}{\text{diameter of pupil of the eye}}.$$

The students estimated the diameter of the pupil to be 3 mm and the wavelength of light to be 5×10^{-7} m. Use the data to estimate the minimum resolvable angle and compare your answer with the value obtained in (a)(iii).

minimum angle that can be resolved = ... rad [2]

- 13 (See Insert for H557/02, Scientific literacy in physics (AS/A level), June 2017) This question is about measuring stellar distances by parallax.

The parallax of the star Sirius is 0.38 arc seconds.

One light year is the distance light travels in one year.

Calculate the distance to Sirius in light years.

$$\text{Earth-Sun distance} = 1 \text{ AU} = 1.5 \times 10^{11} \text{ m}$$

$$1 \text{ year} = 3.2 \times 10^7 \text{ seconds}$$

distance = ----- light year [3]

- 14 Which quantity is followed by a reasonable estimate of its order of magnitude?

- | | | |
|---|-----------------------------------|---------------------|
| A | weight of an apple | 10^0 N |
| B | volume of a table tennis ball | 10^3 cm^3 |
| C | wavelength of infra-red radiation | 10^4 m |
| D | temperature of Sun's surface | 10^5 K |

Your answer

[1]

- 15 This question is about the measurement of the **B**-field between a pair of slab magnets.
- Fig. 3.1 shows the arrangement of the apparatus used in the experiment. It consists of a pair of slab magnets, with opposite poles facing one another, fixed onto a piece of U- shaped soft iron.
- The magnet assembly sits on top of an electronic balance. A rigidly fixed wire is shaped to carry a current I between the magnetic poles. The force created alters the balance reading.

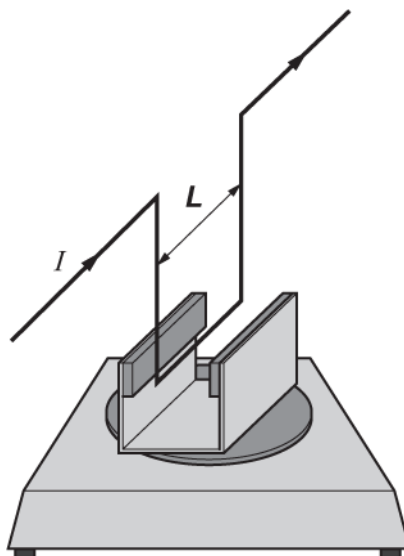


Fig. 3.1

The longest length of wire that could be used is 5.0 cm. The current I is varied and the change in the balance reading is recorded as shown in Fig. 3.3.

	Change in balance reading / g				
I / A	Trial 1	Trial 2	Trial 3	Mean change / g	$F / \times 10^{-3}$ N
0.5	0.08	0.05	0.06	0.06	0.59
1.0	0.14	0.16	0.16	0.15	1.5
1.5	0.22	0.20	0.23	0.22	2.2
2.0	0.31	0.29	0.31	0.30	2.9
2.5	0.38	0.39	0.35		
3.0	0.44	0.48	0.48		

Fig. 3.3

- (i) Complete the table by calculating the mean change in balance reading and the corresponding values of force F for the last two current values.

$$g = 9.8 \text{ N kg}^{-1}$$

[2]

- (ii) Use the table to determine the uncertainty in F . Explain your reasoning.

(iii) Plot the last two points from the table, Fig. 3.3, on the graph Fig. 3.4. Draw a line of best fit.

[2]

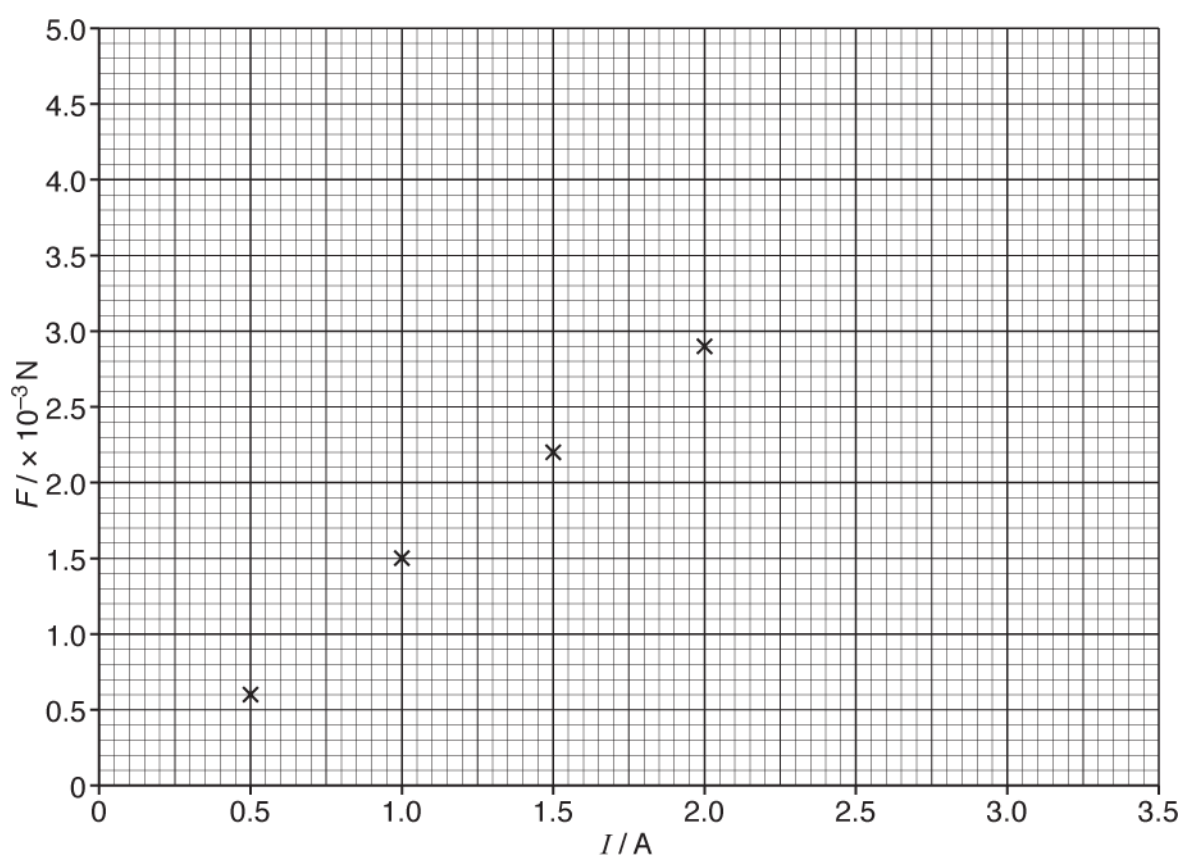


Fig. 3.4

(iv) Use the graph to estimate the value of the **B**-field between the faces of the slab magnets.

$B =$ _____ mT [3]

16(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.

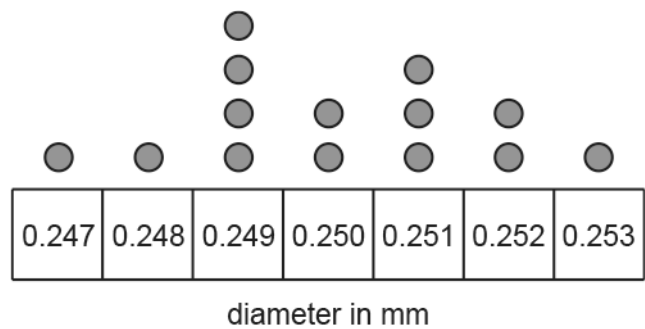


Fig. 4.1

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

mean D = ----- mm $\pm$ ----- % [3]

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

A = ----- $\pm$ ----- 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 shows the force–extension graph for the wire.

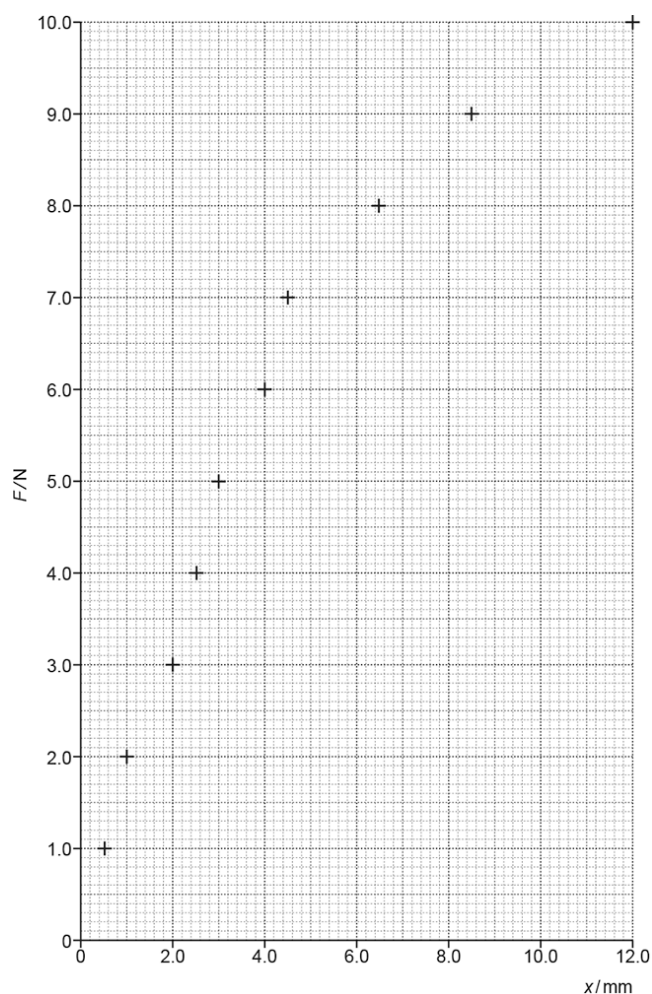


Fig. 4.2

(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]



[6]

This image shows a blank sheet of white paper designed for handwriting practice. It features ten sets of horizontal dashed lines, each set consisting of two parallel lines. These lines are evenly spaced across the page to guide letter height and placement. There are no margins, text, or other markings on the paper.

17(a) Manufacturers of spectacles (glasses) are keen to develop new materials for lenses. The refractive index of such materials is an important property to consider.

This question is about a method to determine the refractive index of a transparent polymer.

A ray box is used to shine a narrow beam of light through a block of the polymer. Fig. 1 shows the path of the light.

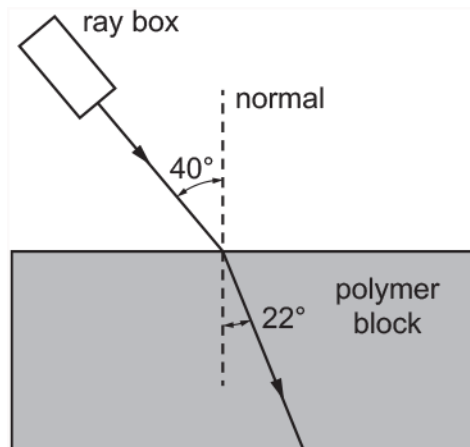


Fig. 1 (not to scale)

The angle of incidence is 40° and the angle of refraction is 22° .

- (i) Calculate the refractive index n of the polymer.

$n = \dots\dots\dots$ [2]

- (ii) The absolute uncertainty in the measurement of each angle is $\pm 4^\circ$.

Complete the table below with maximum and minimum values of the measured angles, and hence determine the absolute uncertainty in the calculated value of refractive index n .

Angle	Maximum value/°	Minimum value/°
angle of incidence, i		
angle of refraction, r		

absolute uncertainty in $n = \pm \dots\dots\dots$ [3]

- (b) * Describe the method which could be used in this experiment to reduce the uncertainty in the calculated value of the refractive index of the polymer.

In your answer, include details of the experimental procedure and the analysis of data.

[6]

18 Which quantity is followed by a reasonable estimate of its order of magnitude?

- | | | |
|---|--|----------------------------|
| A | momentum of a bee in flight | 10^0 kg m s^{-1} |
| B | speed of an air molecule at room temperature | 10^6 m s^{-1} |
| C | wavelength of red light | 10^{-6} m |
| D | wavelength of X-rays | 10^{-15} m |

Your answer

[1]

19 The resistance R of an unknown resistor is found by measuring the potential difference V across the resistor and the current I through it, using the equation

$$R = \frac{V}{I}.$$

The voltmeter reading has a 2% uncertainty and the ammeter reading has a 3% uncertainty.
What is the best estimate of the uncertainty in the calculated resistance?

- A 0.7%
- B 3%
- C 5%
- D 6%

Your answer

[1]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
1		i	<table><tr><td>0.40</td><td>8.0</td></tr><tr><td>0.40</td><td>8.0</td></tr><tr><td>0.60</td><td>12.0</td></tr><tr><td>0.40</td><td>8.0</td></tr><tr><td>0.20</td><td>4.0</td></tr></table> 3 Δv values correct 5 $\Delta v/\Delta t$ values correct	0.40	8.0	0.40	8.0	0.60	12.0	0.40	8.0	0.20	4.0	2	Correct values entered into table
0.40	8.0														
0.40	8.0														
0.60	12.0														
0.40	8.0														
0.20	4.0														
		ii	$g = (\Delta v/\Delta t)_{\text{average}} (\pm \frac{1}{2} \text{ range})$ $= 8.0 \checkmark$ $\pm 4 \text{ (ms}^{-2}\text{)} \checkmark$	2	 accept $\pm 2 / 3 / 4 \text{ (ms}^{-2}\text{)}$ on uncertainty estimate										
		iii	Δt from strobe is $\pm 10\%$ (and is used twice to find $\Delta v/\Delta t$) $\checkmark$ may contribute up to about $\pm 20\%$ and is largest % uncertainty $\checkmark$	2	accept improve y measurement because $\pm \%$ on Δy varies between $\pm 5\%$ when y smallest to $\pm 1\%$ when y largest, (but lower y values could be ignored) both required										
			Total	6											
2		i	$h_{\text{image}} = (v/u) \times h_{\text{object}}$ or $= (26 / 35) \times 2.5 \checkmark$ $= 1.9 \text{ (cm)} \checkmark$	2	1.9 (cm) gains both marks										
		ii	$(P = 1/f = 1/v - 1/u) = 1/(0.35) - 1/(-0.26) \checkmark$ $(= 2.86 + 3.85) = 6.7 \text{ (D)} \checkmark$	2	method mark for adopting the correct method and evaluation mark for getting the correct answer. 6.7 (D) gets both marks										
		iii	Justifies ignoring Δu as Δv is much greater $\checkmark$ uses $v = 26.5$ or $25.5 \checkmark$ evaluation $\Delta P = 0.08 \text{ (D)}$ from 25.5 or 0.07 (D) from 26.5 $\checkmark$	3	allow $\Delta P/P = \Delta v/v$ giving $\Delta P = 0.1 \text{ (D)}$ <i>alternative method</i> This method makes no simplifying assumption Attempt to find P_{max} or P_{min} using $\Delta u = 0.1$ & $\Delta v = 0.5 \checkmark$ in same direction, both to increase P or both to decrease P (e.g. 35.1 cm & 26.5 cm or 34.9 cm & 25.5 cm) $\checkmark$ evaluation $\Delta P = 0.09 \text{ (D)} \checkmark$										
			Total	7											
3	a	i	Particles collide (with the surface) and exert a force;	1	Accept there is a force generated by the colliding particles										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		i	More particles collide with the bottom surface (per second) than the top surface;	1	not particles move slower on top Reject no collisions on the top surface or no downward force. Reject The outside force > inside force (direction needed).
		i	There is a net upwards force / $F_{up} > F_{down}$;	1	QWC: award third mark only if reason for net upwards force clearly linked to particles. Examiner's Comments There were some good answers to this question but not as many as would have been indicated by the answers to Qu11(c)(iii) – the earlier good descriptions of kinetic theory did not seem to translate to this question. It was disappointing to see the number of candidates that referred to the inside of the tube as being a vacuum, particularly when the questions stated that the pressure is simply reduced. Also, many arguments were based on outside molecules "... trying to move to the area of lower pressure" or "... being sucked towards the vacuum cleaner", suggesting a poor grasp of the underlying mechanisms. Descriptions of how pressure arises due to the collision of particles was quite poor.
		ii	$F = mg = 0.2 \times 9.8 = 1.96\text{N}$;	1	accept any mass from 0.20 kg to 0.29 kg e.g. 0.25 kg for 2.45 N and 21 kPa for [1]
		ii	pressure (difference) = $F/A = 1.96/\pi \times (6 \times 10^{-3})^2 = 1.7 \times 10^4 \text{ Pa}$;	1	Rounding the area to $1.1 \times 10^{-4} \text{ m}^2$ gives 18kPa leading to 82kPa[3]

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	net pressure = $100 - 17 = 83 \text{ kPa}$; ----- Alternative answer: based on forces: $F = mg = 0.2 \times 9.8 = 1.96 \text{ N}$; $(F_{\text{up}} = 100 \times 10^3 \pi (6 \times 10^{-3})^2 = 11.3 \text{ N})$ $\Delta F = 11.3 - 1.96 = 9.35 \text{ N}$; net pressure = $\frac{9.35}{\pi(6 \times 10^{-3})^2} = 83 \text{ kPa}$;	1	Note: If diameter is used as the radius, the net pressure = 96 kPa [2] max Accept $100 - 20 = 80 \text{ kPa}$ for [1]max No ECF on incorrect F. Examiner's Comments Generally well answered although it was very disappointing to see a large number of candidates were unable to calculate the area of a circle given its diameter – this was another example of many candidates not having a grasp of basic geometry.
	b		The ratio of the areas = $\frac{30^2}{12^2} = 6(.25)$ OR the ratio of the masses is $\frac{1.2}{0.2} = 6(.25)$; With the same absolute uncertainty in mass (e.g., 0.1), the precision in the pressure measurement improves by 6(.25);	1 1 1	new mass is $1.7 \times 10^4 \times \pi \times (15 \times 10^{-3})^2 / 9.8 = 1.2 \text{ kg}$ Full ECF on pressure calculated in (a)(ii) [1]max available for a qualitative argument along the lines: • Larger area leads to ... • Larger load ... • And a greater precision on the measurement of P Allow ECF from the area / mass calculation. Examiner's Comments This was very poorly answered. It was interesting to note that many answers to this question were descriptive when the question clearly instructed that a calculation of some sort was needed. The candidates did not understand this question although some tried to translate 'precision' as 'uncertainty' and gave some sensible attempts. Remarks about the pressure in the hose being more uniform once the nozzle had been removed revealed some of their misconceptions about pressure and kinetic theory.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4			C	1	
			Total	1	
5			A	1	
			Total	1	
6			evidence of suitable test e.g. is pT constant; test applied to all data to 2 s.f. or 3 s.f.; $273 \times 1.29 = 352$ (350) $283 \times 1.25 = 354$ (350) $293 \times 1.20 = 352$ (350) $303 \times 1.16 = 351$ (350)	1 1	accept calculations to more than 3 s.f with a conclusion which mentions that numbers are either not the same to 3 s.f. or the same to 2 s.f. ignore any conclusion about the truth of the relationship Examiner's Comments Many weak candidates ignored the data and tried to justify the formula. Those who used the data often failed to use all of it to test the relationship. Only a minority of strong candidates used an appropriate number of s. f. in their calculations.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7	a		$\frac{mv^2}{r} = \frac{GMm}{r^2}$	1	accept $m\omega^2$ as $\frac{mv^2}{r}$ not $\frac{mv^2}{r} = -\frac{GMm}{r^2}$
			evidence of $v = \frac{2\pi r}{T}$	1	accept $\omega = \frac{2\pi}{T}$, $v = r\omega$, $\omega = 2\pi f$
			algebraic manipulation to final formula;	1	look for clear steps ignore loss of minus sign in final manipulation
	b		$V = \frac{4}{3}\pi r^3 = 1.098 \times 10^{21} \text{ m}^3$	1	look for correct formula or evaluation
			$M = \rho V = 2.7 \times 10^3 \times 1.098 \times 10^{21} = 2.96 \times 10^{24} \text{ kg}$	1	accept 3.0×10^{24} with full working for [2] accept $V = 1.1 \times 10^{21} \text{ m}^3$ gives $2.97 \times 10^{24} \text{ kg}$ for [2]
	c	i	any two points from: - time for pulse to reach moon = time for pulse to return; - radius of Moon / Earth is comparably negligible; - speed of pulse is constant (throughout the journey) or Earth's atmosphere does not affect speed of pulse or pulse travels at speed of light in a vacuum ($3 \times 10^8 \text{ m s}^{-1}$) or speed of light is constant;	2	not distance for time, accept (laser) light for pulse not just travels at the speed of light
		ii	$r = \frac{3.0 \times 10^8 \times 2.5}{2} = 3.75 \times 10^8 \text{ m}$	1	no ecf for incorrect value of r $r = 3.8 \times 10^8 \text{ m}$ gives $G = 1.25 \times 10^{-10}$ or 1.3×10^{-10}
		ii	$G = \left(\frac{4\pi^2}{3.0 \times 10^{24}} \right) \frac{(3.75 \times 10^8)^3}{(2.4 \times 10^6)^2} = 1.2 \times 10^{-10} \text{ Nm}^2 \text{ kg}^{-2};$	1	
		iii	density / mass of Earth incorrect;	1	accept mass / density is too great

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	need to use density of whole Earth / core and mantle are made of different material / density increases with increasing depth;	1	accept orbit may not be circular for [1] ignore references to radius of Earth and Moon Examiner's Comments This question about estimating a value for G proved to be very straightforward for most candidates. However, in part (a), a large proportion of weak candidates could not do the algebraic manipulation; those who started off with the correct relationships often erroneously included a minus sign which had to be quietly forgotten at a late stage. The two-part calculation of part (b), although involving complicated formulae, proved to be quite straightforward for the most candidates. Similarly, few candidates were unable to state one assumption behind the Earth-Moon distance calculation for part (c)(i), but only about half were able to give two. A common error was the assumption that the Moon had to be stationary for the method to work. Part (c)(ii) was another two-part calculation which was well answered by the majority of candidates. However, only a minority of strong candidates were able to identify the mass of the Earth as the source of the error for part (c)(iii).
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8		i	sensitivity = $\Delta V / \Delta \epsilon$ OR = 0.006 / 0.002 ✓	M	method accept in numbers / gradient
		i	= 3.0 (V per unit strain) ✓	H	evaluation allow 1 mark for 0.030 POT
		ii	T increases ρ and R ✓	L	not just T affects ρ and R accept % increase in A is $2 \times$ % increase in L ($R \propto L / A$) accept % expansion $K^{-1} \approx 1/100$ % increase ρK^{-1} so could be ignored to first approximation
		ii	T increases dimensions of wire ✓	L	
		ii	R would decrease due to expansion alone because % increase in L is $\frac{1}{2}$ % increase in A ($R \propto L / A$) ✓	S&C	
		ii	fractional change in $\rho K^{-1} \approx$ strain OR fractional change L in the gauge so this effect could be important ✓ OR fractional change in $\rho K^{-1} \gg$ fractional change $L K^{-1}$ so expansion is a less important temperature than change in ρ	S&C	
		iii	Fig. 37.4 $\propto$ line added of $2 \times$ gradient of original ✓	M	expect line through {0, 3.000} and {0.2, 3.012}, gradient = 0.0060
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9	a	i	top row: 8.61 (V) ✓	1	Accept 20.97 to 4 sf
		i	Third row: 2.32 (A) ✓	1	
		i	Bottom row: 21.0 (W) ✓	1	
		ii	Mean Power = 20.6 W ✓	1	
		ii	Uncertainty (half range), (21.0 – 19.8)/2 = ± 0.60 W ✓	1	
	b	i	Use of $E = m c \Delta\theta$ and $P = E/t$ to give $c = P t / m \Delta\theta$ ✓	1	Allow ECF from (a)(ii) $t / \Delta\theta = \text{gradient} = \text{cm} / P$
i		Use two readings off the graph and substitute. ✓ e.g. $c = 20.6 \times (10 - 2) \times 60/ 1 \times (29.1 - 19.9)$ $= 1070 \text{ J Kg}^{-1} \text{ K}^{-1}$ ✓	1		
i			1	Ignore sign	
		ii	Find gradient of cooling line of best fit from graph $= -0.45 \text{ K min}^{-1}$ ✓	1	Acceptable range = -0.43 to -0.47 K min^{-1}
		ii	Two plots read off correctly, at least half the length of the line apart. ✓	1	
	c		Percentage difference = $(1070 - 897) \times 100/897 = 19 \%$ ✓	1	Allow ecf from (b)(i)
			Percentage difference is larger than the percentage uncertainty so experiment is not very accurate ✓	1	
			Any two from: ✓ ✓ The block is cooling at rate calculated in b(ii), which means that it should have had a larger temp difference; Heater not 100 % efficient; Energy has gone into heating heater/wires/digital thermometer; Temperature of the block may not have been uniform; Etc.	2	
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10			Suggested reason which would result in a larger time interval: ✓ Eg operator error in starting or stopping watch, released too high, etc.	1	Reject cupcake case given initial force/velocity unless clear that it is upwards
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11		i	Combining $E = V q$ and $c = f \lambda$ with $E = h f$ to give $V q = h c / \lambda$ ✓	1	
		i	Hence $V = (h c / q) (1 / \lambda)$, (so gradient = $h c / q$) ✓	1	
		ii	Hence $h = \text{gradient} \times q / c$ $(= 2.0 \times 10^{-6} \times 1.6 \times 10^{-19} / 3.0 \times 10^8) = 1.07 \times 10^{-33} \text{ J s.}$ ✓	1	
		iii	Second line drawn within all horizontal error bars ✓	1	
		iii	Gradient calculated correctly from two read offs ✓	1	
		iii	Value for h calculated from gradient value ✓	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Level 3 (5-6 marks) ✓✓ Detailed quantitative comparison, explanation of the sources of error and improvements. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.</i> Level 2 (3-4 marks) ✓✓ Some quantitative comparison, explanation of the sources of error and improvements OR detailed quantitative comparison and explanation of the sources of error or improvements OR detailed explanation of the sources of error and improvements. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1-2 marks) ✓✓ Limited quantitative comparison OR explanation of the sources of error OR improvements. <i>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.</i> 0 marks No response or no response worthy of credit.	6	Indicative Scientific points may include: Comparison of values: • Percentage difference calculated • Compare with percentage differences in V and λ. Sources of error • Difficult to tell exactly when LED turns on. • Eye may be more sensitive to some colours than others. • Uncertain of precise wavelength will be emitted when just visible. Improved technique • Use a darkened room/tube to view • Record V against I for each LED • Plot values of V and I on graph to find a better value for threshold value. • Sketch graph showing V-I characteristics for LED and how to find threshold voltage from graph.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12	a	i	0.2 m ✓	1	Examiner's Comments This question was about the resolution of the eye. Part (a)(i) required candidates to give the spread of a group of data. A sizeable minority of responses confused spread with range.
		ii	One mark from: % uncertainty in distance measurement ~ 3% ✓ uncertainty in separation = 25% ✓ Second mark: both uncertainties correctly given and sensible comparison drawn.	2	ECF from (a) (i): 0.4 m give % uncertainty ~ 7% Examiner's Comments Part (a)(ii) involved comparing uncertainties. To gain marks in this question the candidates had to give at least one percentage uncertainty. Many did not do this and gave rather descriptive responses that did not have sufficient merit to be awarded a mark.
		iii	Minimum angle = $(2 \times 10^{-3} \text{ m}) / (6 \text{ m}) = 0.0003 \text{ rad}$ ✓ Uncertainty of the order $\pm 0.0001 \text{ rad}$ ✓ Evidence of how uncertainty estimated ✓ SF penalty if uncertainty s.f. not consistent with value s.f. of angle.	3	Look for calculating maximum and / or minimum possible final values. Accept argument from % uncertainty Examiner's Comments Part (a) (iii) proved to be challenging. Many candidates did not use radian angles directly but calculated an angle in degrees before converting it to radians. This could still gain a mark if the answer was correct but it is, at best, an inelegant method. The better responses described how the percentage uncertainty was used to find the absolute uncertainty or how the range of angles was found from the spread of the data. Lastly, many candidates failed to gain the third mark through giving the uncertainty with excessive significant figures.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		Calculation of resolution to 0.0002 radian✓ (1 sf) Comment: suggests better resolution than eye but agree to 1 sf with smallest angle from experimental data (with uncertainty taken into account) ✓	2	Ignore s.f. error Second point needs to make a clear link to range of experimental results. Examiner's Comments Part (b) was also challenging. Once again, the calculation was straightforward and the candidates performed it with ease. Linking the results to the experimental data was rarely clearly described, with most responses merely pointing out the difference rather than considering the reason.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13			Either: angle in radian = $1.8(4) \times 10^{-6}$ rad ✓ distance = $(1.5 \times 10^{11} \text{ m}) / 1.8(4) \times 10^{-6} = 8.15 \times 10^{16} \text{ m}$ ✓ = 8.5 light years ✓ Or: sin (or tan) 0.38 arc seconds used ✓ distance = $1.5 \times 10^{11} / \sin (0.38/3600) = 8.14 \times 10^{16} \text{ m}$ ✓ = 8.5 light years ✓ Or: Distance in parsecs = $1/0.38 = 2.63 \text{ pc}$ ✓ Calculation of 1 parsec = $3.1 \times 10^{16} \text{ m}$ ✓ Distance in light years = $2.63 \times 3.1 \times 10^{16} \text{ m} / 10^{16} \text{ m} = 8.2 \text{ light years}$.	3	If data sheet value of 1 light year is approximately 10^{16} m gives values 8.15 light years. Bald correct answer gains 3 marks as do alternative methods leading to correct answer Data sheet value of 1 light year = 10^{16} m If $9.6 \times 10^{15} \text{ m}$ used answer via parsecs = 8.5 light years. Examiner's Comments This question asked candidates to calculate a distance in light years when given the parallax angle. Some candidates clearly knew the number of parsecs in a light year. Others calculated the distance by a number of different, acceptable methods. A common error was to calculate a sine (or tangent) of an angle when the calculator was set on radians. This gave a distance to the star of 0.15 light years. Although such responses gained 2 out of 3 marks it was surprising that the candidates believed such answers when the distance to the nearest star is given (albeit in metres) in the article.
			Total	3	
14			A	1	Examiner's Comment Here candidates had to handle order of magnitude estimates for a wide variety of quantities. Most candidates correctly chose the weight of an apple at 10^0 N. Perhaps the candidates that chose other answers did not realise that $10^0 \text{ N} \equiv 1 \text{ N}$. A common incorrect answer was D.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15		i	Mean change of both balance readings to 2sf Both values of F	1 1	0.37; 0.47 2sf only – stand alone sf penalty 3.6 or 3.7; 4.6 Allow ecf from incorrectly rounded figures for mean change in balance reading. (3.7 and 4.5) Examiner's Comments In part (b)(i) most candidates successfully completed the table, with only a few candidates making rounding errors.
		ii	Largest difference between mean value and max (or min) is 0.03 OR largest half range = 0.02 Either: $\Delta F = \Delta m g = \pm 0.3 \times 10^{-3} \text{ N}$ or $\pm 0.2 \times 10^{-3} \text{ N}$ depending on previous answer. Or: relative uncertainty in balance reading = $\Delta m / m$ for whichever of the bottom two rows used, to give absolute uncertainty in force = $\pm 0.3 \times 10^{-3} \text{ N}$ or $\pm 0.2 \times 10^{-3} \text{ N}$	1 1	Identification of max variation in data. Allow ecf from incorrect value in bottom row of table. Assuming g has zero uncertainty. Accept multiplying raw data in bottom row by g before finding difference in F values. $0.02/0.47 = 4.3\%$, $0.02/0.37 = 5.4\%$, $0.03/0.47 = 6.4\%$ Allow ecf from wrong rounding. Examiner's Comments In part (b)(ii) there was some confusion between absolute and percentage uncertainties, as well as some weaker candidates using the whole range of readings for all values of l, instead of the range across individual rows of the table.
		iii	Both points correctly plotted (to within $\frac{1}{2}$ small square) LoBF drawn	1 1	(2.5, 3.6) and (3.0, 0.46) or ecf from table. Line must extend across the range of points shown. No more than 2 small squares vertically from any plotted point. Examiner's Comments Candidates could plot the points on the graph well in part (iii), but drawing the best fit line was not so good. Some candidates forced the line through the origin so it was too far from the top plot.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Gradient calculated from points on line $B = \text{gradient} / L$ or $B = \text{gradient}/0.05$ or 5) $B = 30 \text{ mT}$	1 1 1	Ignore POT Acceptable range of gradient: $1.4 \text{ mNA}^{-1} < m < 1.7 \text{ mNA}^{-1}$ ecf from their LoBF Correct POT in final answer. Accept values within range: $28 \text{ mT} < B < 34 \text{ m}$ Examiner's Comments In part (iv) most candidates were able to calculate a value for B to the correct power of ten. However many of them used a point on the graph rather than the gradient of the line.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	a	i	Mean value = $[(0.247 + 0.248 + (4 \times 0.249) + (2 \times 0.250) + (3 \times 0.251) + (2 \times 0.252) + 0.253) \div 14 = 3.501 \div 14] = \underline{0.250} \text{ mm} \checkmark$ Spread = $\pm \frac{1}{2} \text{ range} \checkmark$ $[= \pm \frac{1}{2} (0.253 - 0.247) = 0.003]$ % uncertainty = $(0.003 \div 0.250) \times 100 = \underline{1(2)\%} \checkmark$	3	Mean must be to <u>3sf</u>. ecf incorrect mean used to calculate %uncertainty, but not ecf incorrect spread. Examiner's Comments Most candidates correctly calculated the mean value of D as 0.250 mm and the percentage error. A few left the value for D to only 2 significant figures and some candidates used the whole range of values (0.006) rather than the spread (0.003) to calculate the percentage uncertainty.
		ii	Area = $\pi d^2 \div 4 = \underline{4.9(1) \times 10^{-8} \text{ m}^2} \checkmark$ EITHER % error in area measurement (= $2 \times \%$ error in d) = $2.4\% \checkmark$ Absolute uncertainty = $[4.9(1) \times 10^{-8} \times 0.024 =] \underline{1(2) \times 10^{-9} \text{ m}^2} \checkmark$ OR Maximum = $5.03 \times 10^{-8} \text{ m}^2$ and/or minimum = $4.79 \times 10^{-8} \text{ m}^2 \checkmark$ Absolute error in area = $[\frac{1}{2} (\text{max} - \text{min})$ OR max – actual OR actual – min] $= \underline{\pm 0.1(2) \times 10^{-8} \text{ m}^2} \checkmark$	3	Use of $r = 0.250 \text{ mm}$ gives $A = 1.96 \times 10^{-7} \text{ m}^2$. ALLOW % uncertainty is twice % uncertainty in diameter calculated in (a)(i). ALLOW ecf for uncertainty on incorrect calculation of A. $[\pm 4.8 \times 10^{-9}$ for $A = 1.96 \times 10^{-7} \text{ m}^2]$ Examiner's Comments Most candidates were able to correctly calculate the area from the diameter, but there were a number who either forgot to convert to metres, or used the value for diameter as the radius. Similarly to question 1(a)(ii) a number of methods were used to find the absolute uncertainty and similar mistakes occurred.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	x-error bars at ± 0.5 ✓ y-error bars at ± 0.2 ✓ Elastic region labelled at the straight section of the graph ($F \leq 7$ N by eye) AND Plastic region labelled at the curved section of the graph ($F \geq 7$ 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. ✓	4	At least 6 correct to $\frac{1}{2}$ small square in total line length. At least 6 correct to $\frac{1}{2}$ 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. <u>Examiner's Comments</u> Nearly all the candidates correctly identified the elastic and plastic deformations regions of the graph, and many correctly added error bars in both x and y directions. There were more mistakes in the horizontal error bars than vertical bars. Many candidates incorrectly and unnecessarily forced the line of best fit through the origin and ended up with too many plots to the left of the line. In practice it would be rare for the graph obtained from this experiment in a school laboratory would pass through the origin as it is difficult to eliminate all the kinks in the wire before loading.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Calculate gradient using two points on their line which are at least half the length of their line apart. ✓ Use of Young Modulus = F/Ax or stress/strain [= gradient $\times (l/A)$] ✓ 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 $\Delta F \geq 5.0$ 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 $1 \times 10^{11} \geq E \geq 1.4 \times 10^{11}$ Pa. ALLOW ecf of incorrect A in part (a)(ii). [If $A = 1.96 \times 10^{-7} m^2$ 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.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	c	Level 3 (5–6 marks) ✓✓ - 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. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> 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. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> 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.	6	Indicative scientific points may include: Determining the uncertainty in E: 'worst fit' line drawn using error bars. - Gradient of worst fit line calculated correctly. % uncertainty in gradient worked out. - Addition of % uncertainties in gradient, area and length for overall % uncertainty in E. - Max value for E calculated using max gradient, max length and min area AND/OR min value for E from min gradient, min length and max area. % uncertainty in E worked out. - Expect % uncertainties as follows: E in region of 30% - Gradient in region of 20 to 25% - Area 2.4% (ecf from (a)(ii)) - Length 0.5% - Force up to 20% (depending on value) - Extension up to 100% (depending on value) - Use data point value to estimate % uncertainty in F (using smallest value of F to give largest uncertainty) - Use data point value to estimate % uncertainty in F (using smallest value of x to give largest uncertainty). - Finding max and min values of E from equation $E = F l \div A x$ and appropriate substitution. Identifying sources of uncertainty and improvements: - Uncertainties in load: - variation in 100g masses - weigh masses individually on scales/balance - Uncertainty in area/diameter. - variation in thickness of wire - not cylindrical/ not circular cross section. - uncertainty in diameter give larger uncertainty in area as it is squared. - Diameter measured in different

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		<u>planes/directions</u> (NOT different places along wire). ◦ Use of thicker wire will reduce % uncertainty in diameter • Uncertainty in length ◦ kinked wire ◦ not initially straight/taut ◦ use fresh wire ◦ pre-load wire (to remove kinks) • Uncertainty in extension ◦ small measurement so large % uncertainty ◦ Explanation of zero errors ◦ Extension provides the largest source of error. ◦ longer wire so larger extensions ◦ use of travelling microscope/Vernier scale. • if thicker wire used then extension will be smaller so % uncertainty increases in extension. • Measure extension loading and unloading (for elastic deformation only). Examiner's Comments Several approaches to finding the percentage uncertainty in the value for Young Modulus were used, but a number were not well set out and identified. Many candidates added the individual percentage uncertainty in the four variables – force, area, extension and length, whilst others found the gradient of a steep and/or shallow worst fit line, and then used that to find a maximum and/or minimum value for E. Whilst many candidates did realise that the variable with by far the greatest uncertainty was the extension, not all of them were able to describe appropriate mitigation in sufficient detail to gain Level 3. Many candidates' explanations made vague suggestions about using more precise measuring instruments without naming suitable ones. Candidates need to realise that rulers with smaller divisions would be unusable, and that using larger

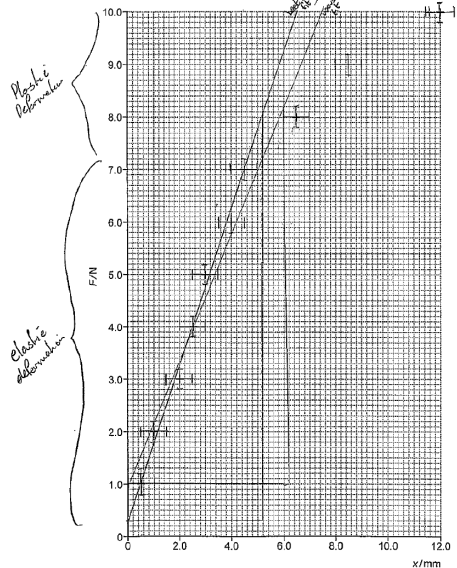
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					forces would result in plastic deformation, so this type of suggestions were not credited. The most obvious solution of increasing the length of the wire causes practical problems to do with space in the laboratory, which needed to be mentioned to gain higher level marks. Other valid suggested improvements included increasing the area of the wire, but again candidates needed to mention that this would actually cause less extension so probably not worth doing in practice. Weighing any masses used with digital balance or using a digital Newton-meter were acceptable suggestions. Some candidates suggested using a different material wire, but this would defeat the object if they needed to find the properties of a particular material. As it was clear from part (a), that a micrometer screw gauge was used to find several readings of the diameter of the wire, this was not credited in this question. If further details such as measuring diameter in different planes or directions to check that the wire was cylindrical, then credit could be given. Suggesting repeat readings also needed clear description to gain credit here. Candidates could suggest recording values of extension whilst loading and unloading the wire, or repeat the whole experiment on a new piece of the same wire and finding an average value for E, but not repeating readings of extension and finding the average as each wire will behave in a slightly different manner.

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			Exemplar 5 improve on this, a longer length of wire could be used. This would increase the value of the ~~percentage error~~ extension and so the $\pm 0.5 \text{ mm}$ uncertainty would be ~~proportionally~~ ^{proportionally} lower, reducing overall uncertainty. To reduce uncertainty from the force, weigh each weight on a digital balance before adding onto the end of the wire. Percentage error ~~input~~ ^{decrease as force is a small} high resolution of the digital balance ($\pm 0.05 \text{ g}$). To improve experiment further, the extension can be measured by using a tracking microscope and a vernier scale which would reduce uncertainty to $\pm 0.01 \text{ mm}$, ~~keeping~~ a fifth of the current technique. Alongside a longer length of wire, a ~~thinner~~ ^{thinner} wire would also increase the extension - this may reduce percentage ~~error~~ ^{uncertainty} from x, but may increase the uncertainty of A. To reduce the uncertainty from A, ~~using~~ ^{area} could be calculated from density, ~~as~~ length and mass - density will be a given value, length and mass have smaller percentage uncertainties. Highest uncertainty $\rightarrow$ lowest: Extension, Area, Force, Length $(x \pm 0.65 \times 100 = \pm 8\%, F = \pm 0.2 \times 100 = \pm 2\%)$ $\frac{6.6}{10}$ This candidate has used the graph to find a lowest possible gradient and thence to a percentage uncertainty for the gradient. This is then combined with the percentage uncertainties of the length and the area. The list of uncertainties at the end of the text clearly identifies extension as having the largest uncertainty. In order to mitigate the uncertainties several suggestions are made; using a longer length of wire, weighing the individual masses on a digital balance and using a thinner wire. The latter suggestion is analysed in terms of increasing the uncertainty of the area, but as this is lower than the uncertainty in the extension it is still beneficial. This gains Level 3.

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			Exemplar 6  Fig. 4.2 $\% \text{ uncertainty (x)} = \frac{\Delta x}{x} = \frac{8.2 - 1}{8.2} = 11.61\%$ for worst gradient = $\frac{1500 - 1161}{62 \times 10^{-3}} \times 100 = 22.23\%$ $\therefore \% \text{ uncertainty in gradient} = 1500 - 1161 \times 100 = 22.23\%$ $\% \text{ uncertainty in } L = \frac{0.001}{0.002} \times 100 = 0.5\%$ $\% \text{ uncertainty in } A = 1.2\%$ $\therefore \text{Overall } \% \text{ uncertainty} = 22.6 + 0.8 + 1.2 = 24.3\%$ $\approx 24\%$ The largest uncertainty comes from the gradient which is made from the extension and the force so these are the areas that we aim to improve. For the extension, we can improve reduce the uncertainty by either using a more precise measuring device like a digital vernier calliper or by increasing the values. For the force, we can increase the values for a certain force and so decrease the % uncertainty. In relation to the force, we can increase the % uncertainty by using a more precise digital top pan balance. The worst % uncertainty in the extension is $\frac{0.5}{0.002} \times 100 = 100\%$ in comparison to that of the force: $22\% \times 100 = 20\%$. $\therefore$ The main source of uncertainty that is needed to be improved upon is the extension. 13 A This response is Level 3. The percentage uncertainty in the gradient is calculated from an acceptable line of worst fit drawn on the graph in Fig 4.2. The percentage uncertainty for length is correctly determined, but the candidate has used the percentage uncertainty in diameter instead of the percentage uncertainty in area. Nevertheless, all the percentage uncertainties are correctly combined and

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					the largest ones clearly identified. Appropriate suggestions for mitigating the uncertainty in both extension and force are explained.
			Total	21	

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17	a	i	$(n = \sin i \div \sin r =) \sin 40 \div \sin 22$	1	If radians are used answer = -84 (award 1 mark for correct method even if working is missing). Answer correct to 2sf. Don't penalise 1.71. Raw answer of 1.7 gains both marks. <u>Examiner's Comments</u> This seemed a straightforward start for most candidates. Nearly all got this correct; with only a handful of candidates using their calculator in radians mode and hence getting an incorrect value for refractive index.
			$(n =) 1.7(2)$	1	

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		ii	<table><tr><td>angle</td><td>Maximum value/°</td><td>Minimum value/°</td></tr><tr><td>angle of incidence, <i>i</i></td><td>44</td><td>36</td></tr><tr><td>angle of refraction, <i>r</i></td><td>26</td><td>18</td></tr></table>	angle	Maximum value/°	Minimum value/°	angle of incidence, <i>i</i>	44	36	angle of refraction, <i>r</i>	26	18	1	All 4 values needed for the mark.
angle	Maximum value/°	Minimum value/°												
angle of incidence, <i>i</i>	44	36												
angle of refraction, <i>r</i>	26	18												
			Find max value of $n = \sin 44 \div \sin 18$ (= 2.248) AND/OR Find min value of $n = \sin 36 \div \sin 26$ (= 1.3408)	1	Allow ecf of incorrect max and/or min values of angles from table.									
			Uncertainty = 2.25 – 1.72 = 0.53 [max value – 1.7] OR Uncertainty = 1.72 – 1.34 = 0.38 [1.7 – min value] OR Uncertainty = $\frac{1}{2}(2.25 - 1.34)$ = 0.46 or 0.45 (depending on rounding) [$\frac{1}{2}(\text{max} - \text{min})$]	1	ALLOW correct use of the their max and/or min values and value of n calculated in part (i). eg. $\sin 44 \div \sin 26 = 1.6$ and $\sin 36 \div \sin 18 = 1.9$, so uncertainty = 0.2 or 0.1. ALLOW answers to 1sf. Do not credit a raw answer of 0.5, which can be achieved by adding percentage uncertainties of angle <i>i</i> and angle <i>r</i> – an incorrect method. <u>Examiner's Comments</u> Nearly all candidates completed the table correctly. Most candidates used the correct combination of angles to find the largest and/or smallest values possible for n and then correctly found the absolute uncertainty. Common errors were to use an incorrect pair of angles, for example the largest value for angle of incidence with the largest value for angle of refraction. Others just tried adding percentage uncertainties of the angles, without any reference to finding the sine of the angle.									
	b		Level 3 (5-6 marks) ✓ ✓ Detailed description of experimental procedure and/or analysis with meaningful description of the other strand. For example, a response having a detailed description of the analysis but only limited experimental procedure can get a level 3. <i>There is a well-developed line of reasoning</i>	1 x 6	Indicative scientific points may include: Experimental procedure: • vary angle of incidence and measure angle of refraction • angle of incidence goes up increments (eg 5° or 10°) • draw round block on paper and mark path of light with points, then draw lines									

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	<i>which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3-4 marks) ✓ ✓ Workable description of experimental procedure and/or analysis. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1-2 marks) ✓ ✓ Limited description of experimental procedure and/or analysis. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		through points with ruler (especially inside block) • place block on top of large protractor • measure angles when light enters and when light leaves rectangular block (as a repeat) • use set square/protractor to mark normal • use a large/higher resolution protractor to measure angles or trigonometry (measure length of opposite side) • use a very narrow ray of light with parallel sides or laser • dark room and/or bright light source • use monochromatic light source Analysis: • calculate $n = \sin i \div \sin r$ • <u>compare</u> values of n from different values of i. • plot graph of $\sin i$ against $\sin r$ • draw straight line of best fit • find gradient of line and hence refractive index • use 'large triangle' to find gradient • add error bars to plotted points • draw 'worst-fit' lines • use gradient of 'worst-fit' lines to find min and max values of n. <u>Examiner's Comments</u> Many candidates showed little knowledge of practical techniques which could be employed to measure the angles of incidence and refraction in this experiment. Many did suggest using a monochromatic laser and a digital angle measurer, without any reference as to how these would be used in practice. They do still need to record the path of a ray of light whether it is a laser beam or a narrow beam from a ray-box and many candidates omitted any such method. A detailed method which would help someone with some science knowledge to carry out the experiment could achieve Level 3. Some candidates did correctly suggest that a number of different values for angle of incidence

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					should be used, and the corresponding values of refraction recorded, but only some of these went on to suggest that a graph should be plotted. A level 3 response should suggest plotting a graph of $\sin i$ against $\sin r$ and calculating a gradient to find refractive index as well as some discussion of how to find uncertainty in the calculated value. Exemplar 1 <i>Place the polymer block on A3 paper. Draw an outline of the block and place it there. Use a thin slit and a ray box to produce as narrow a beam of light as possible. Use a set square to accurately draw ~~the~~ normals from the outline. ~~Remove~~ Turn off the lights of the room in order to remove as much background lighting as possible. Draw over the incident ray of light and the refracted ray leaving the block. Draw normals at these points of intersection. Use a protractor to measure the angles between the lines and the normals. ~~Take~~ Make the angles of incidence as large as possible to reduce the percentage uncertainty of the angles. Calculate the refractive index. Draw a line between the two intersections to find the angle of refraction. Calculate the refractive index using $n_1 \sin \theta_1 = n_2 \sin \theta_2$. Place the polymer block such that the ray will travel along the furthest distance in the block to further reduce uncertainty of the angles. Repeat readings and take readings from a wide range of values. Calculating their respective refractive indices and then find an average.</i> This candidate has described a practical method for finding the angles. It includes drawing the normal lines using a set square and marking the paths of the rays of light as they travel through the block. The suggestion of dimming the lights will also aid the process. The candidate also explains how to calculate the refractive index and suggests repeating readings and using a range of values for the angle of incidence. This is a Level 2 response. In order to get up to Level 3, it needed to include a graphical method to find refractive index.
			Total	11	

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18			C	1	<u>Examiner's Comments</u> About half of candidates recognised the correct estimate as that of the wavelength of red light, but the range of other responses selected suggests that many candidates are not familiar with estimated order of magnitudes of everyday quantities as section 2(c)(iii) of the specification requires.
			Total	1	
19			C	1	<u>Examiner's Comments</u> The majority of candidates were able to recognise that they should add the uncertainties to give 5% in this arrangement of a formulae where data is combined by division.
			Total	1	