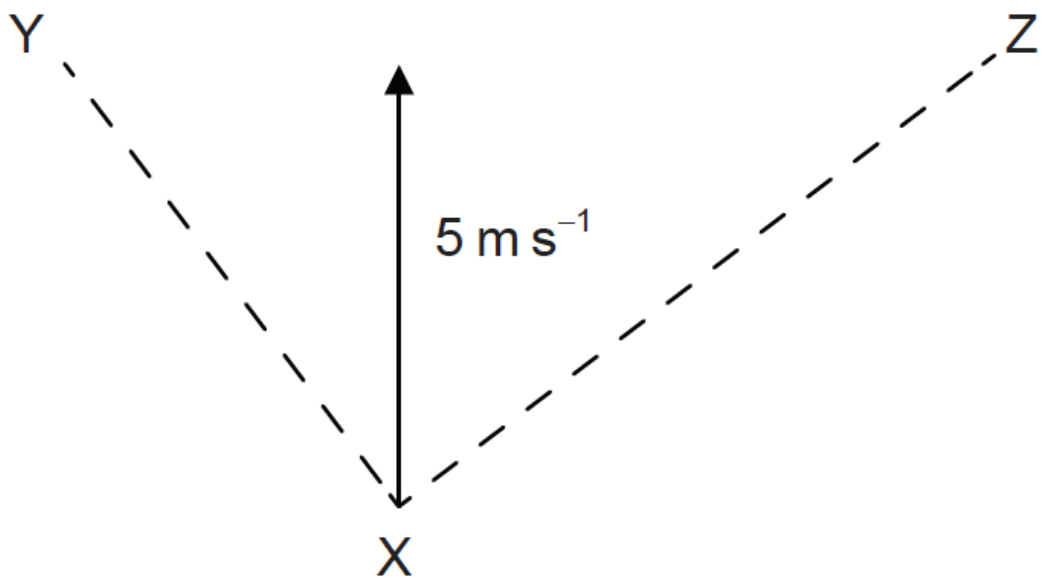
T1 *[154 marks]*

1. A velocity of 5 m s^{-1} can be resolved along perpendicular directions XY and XZ. *[1 mark]*



The component of the velocity in the direction XY is of magnitude 4 m s^{-1}. What is the magnitude of the component in the direction XZ?

A. 4 m s^{-1}

B. 3 m s^{-1}

C. 2 m s^{-1}

D. 1 m s^{-1}

2. What is the unit of energy density? *[1 mark]*

A. J kg^{-1}

B. J kg^{-1} m^3

C. J mol^{-1}

D. J K^{-1}

3. Which of the following expresses the watt in terms of fundamental units? *[1 mark]*

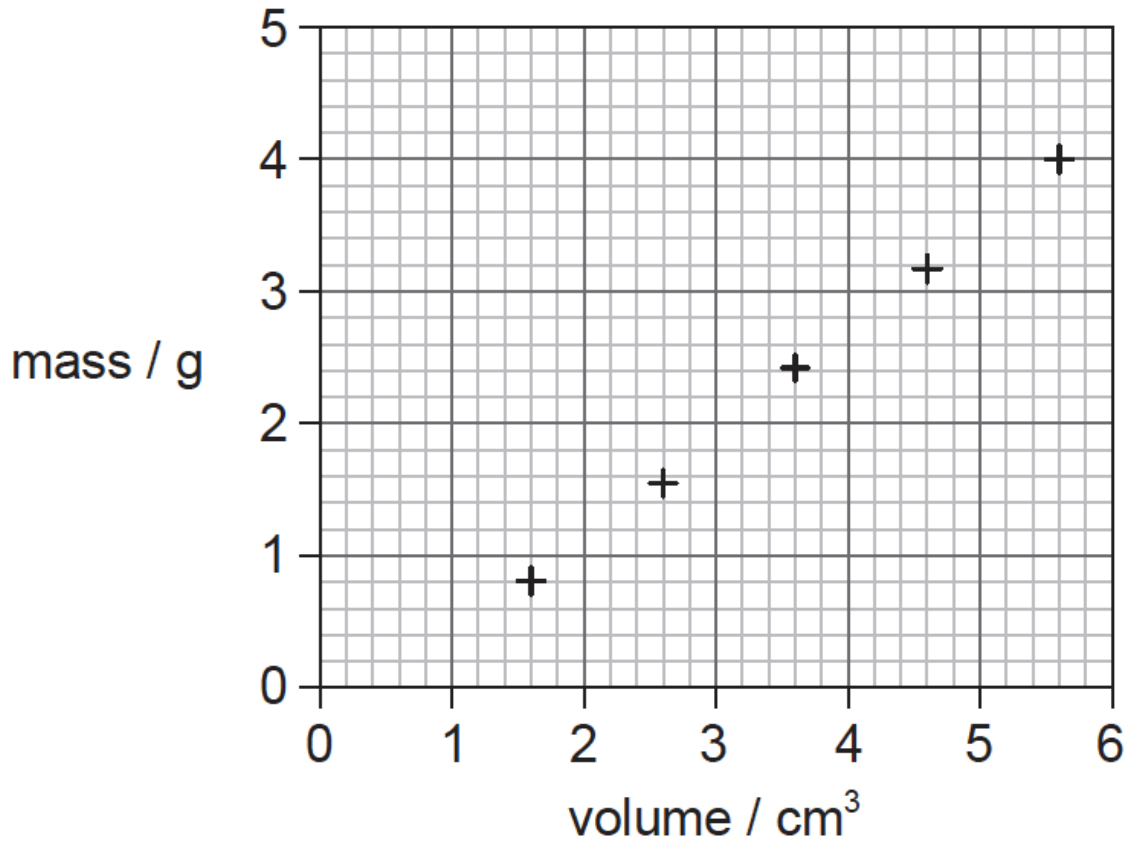
A. kg m^2 s

B. kg m^2 s^{-1}

C. kg m^2 s^{-2}

D. kg m^2 s^{-3}

4. The graph shows a set of experimental results to determine the density of oil. The results have systematic errors and random errors. *[1 mark]*



Using the information on the graph, what can be said about the measurements used to find the density of oil?

	Systematic errors	Random errors
A.	small	small
B.	small	large
C.	large	small
D.	large	large

5. Which of the following expresses the units of capacitance in terms of fundamental units? *[1 mark]*

A. $s^4 A^2 m^{-2} kg^{-1}$

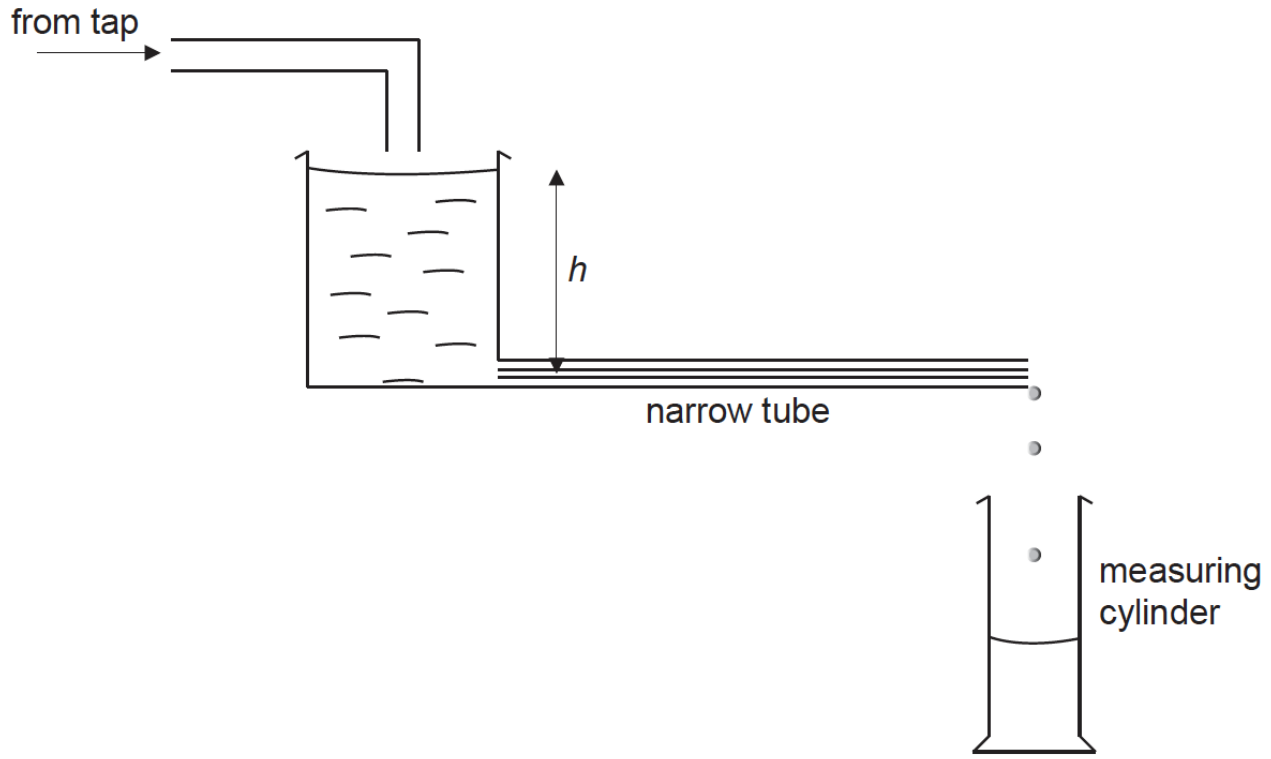
B. $s^2 A m^{-2} kg^{-1}$

C. $s^4 A^2 m^{-2}$

D. $s^2 A m^{-2}$

This question is about the flow of liquids.

A student carries out an experiment to investigate how the rate of flow R of water through a narrow tube varies with the pressure difference across the tube. The pressure difference is proportional to the height h shown in the diagram. The student measures h in cm with a metre ruler. R is obtained by measuring the volume of water collected in a measuring cylinder in a time of 100s.



6a. The equation of the trend line shown in (b) is given by *[4 marks]*

$$R = -0.0005h^2 + 0.0843h - 1.5632.$$

(i) Calculate the value of R for $h = 0$.

(ii) State why this value of R is not physically possible.

(iii) State the number of significant figures that you have used for your value in (c)(i).

(iv) Comment, with reference to the experimental data, on the number of significant figures that you have used for your value in (c)(i).

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6b. The student estimates that the uncertainty in timing 100s is ±1s. Using the data on the graph, deduce the absolute uncertainty in the volume of water collected when R = 2.1 units. *[4 marks]*

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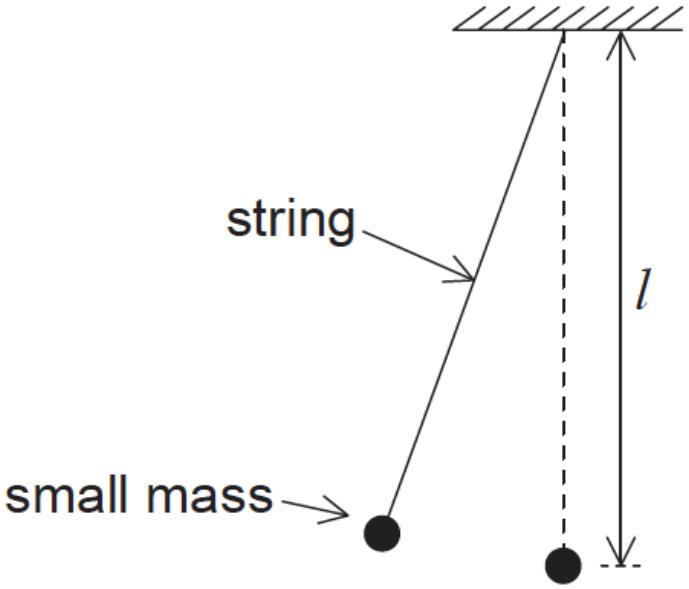
Data analysis question.

A simple pendulum of length *l* consists of a small mass attached to the end of a light string.



The time *T* taken for the mass to swing through one cycle is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where *g* is the acceleration due to gravity.

7. A student measures *T* for one length *l* to determine the value of *g*. Time $T = 1.9s \pm 0.1s$ and length $l = 0.880m \pm 0.001m$. Calculate the fractional uncertainty in *g*. *[2 marks]*

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8. The radius of a sphere is measured with an uncertainty of 2%. What is the uncertainty in the volume of the sphere? *[1 mark]*

A. 2%
B. 4%
C. 6%
D. 8%

9. The force of air resistance F that acts on a car moving at speed v is given by $F=kv^2$ where k is a constant. What is the unit of k? *[1 mark]*

A. kg m^{-1}
B. kg $m^{-2}s^2$
C. kg m^{-2}
D. kg $m^{-2}s^{-2}$

10. The volume V of a cylinder of radius R and height H is given by $V = \pi R^2 H$. The volume of the cylinder was measured with an uncertainty of 10% and the height was measured with an uncertainty of 6%. What is the uncertainty in the radius of the cylinder? *[1 mark]*

A. 1%
B. 2%
C. 4%
D. 8%

11. Which of the following is a unit of energy? *[1 mark]*

A. kg m^{-1} s^{-1}
B. kg m^2 s^{-2}
C. kg m s^{-2}
D. kg m^2 s^{-1}

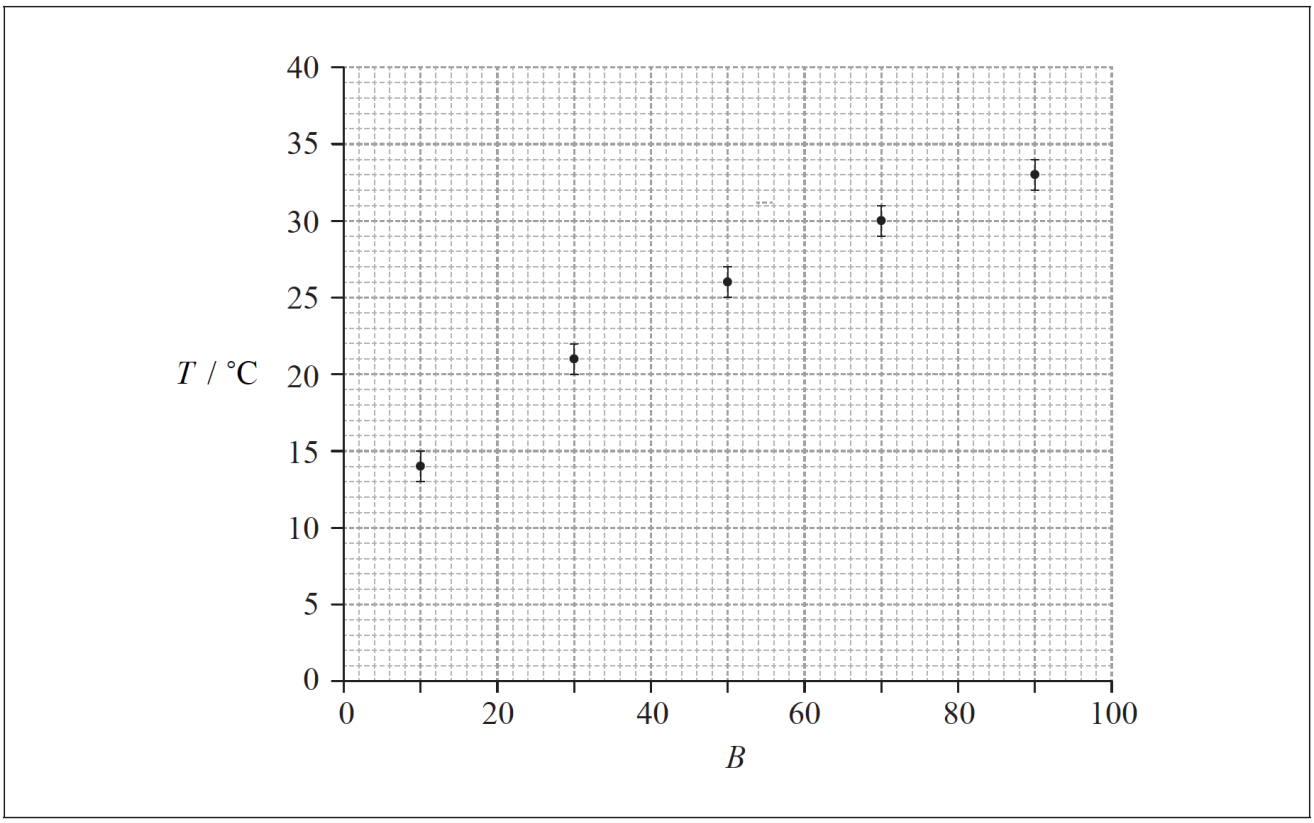
Data analysis question.

Connie and Sophie investigate the effect of colour on heat absorption. They make grey paint by mixing black and white paint in different ratios. Five identical tin cans are painted in five different shades of grey.

10 % black paint | 30 % black paint | 50 % black paint | 70 % black paint | 90 % black paint

Connie and Sophie put an equal amount of water at the same initial temperature into each can. They leave the cans under a heat lamp at equal distances from the lamp. They measure the temperature increase of the water, T, in each can after one hour.

12a. Connie suggests that T is proportional to B, where B is the percentage of black in the paint. To test this hypothesis, she plots a graph of T against B, as shown on the axes below. The uncertainty in T is shown and the uncertainty in B is negligible. *[6 marks]*



(i) State the value of the absolute uncertainty in T.

(ii) Comment on the fractional uncertainty for the measurement of T for B=10 and the measurement of T for B=90.

(iii) On the graph opposite, draw a best-fit line for the data.

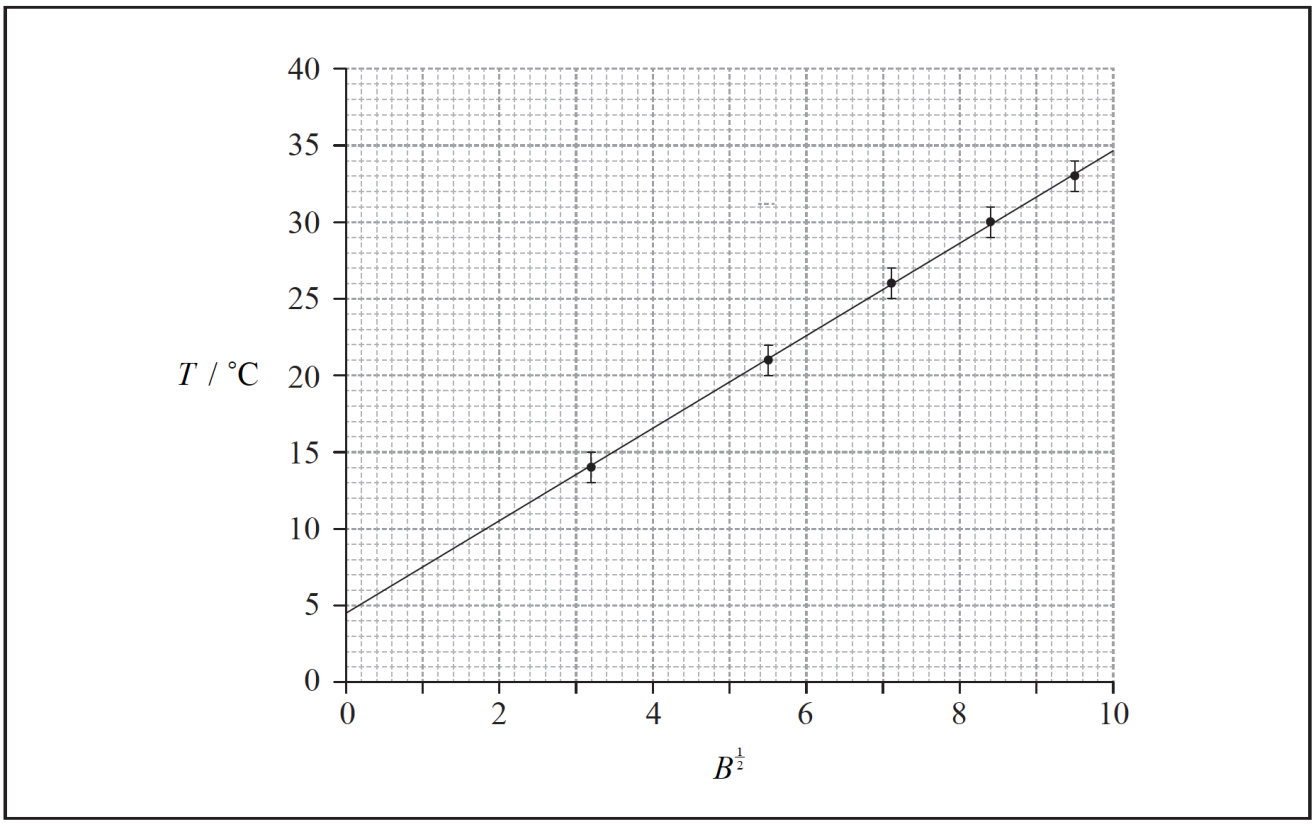
(iv) Outline why the data do not support the hypothesis that T is proportional to B.

12b. Sophie suggests that the relationship between T and B is of the form *[5 marks]*

$$T = kB^{\frac{1}{2}} + c$$

where k and c are constants.

To test whether or not the data support this relationship, a graph of T against $B^{\frac{1}{2}}$ is plotted as shown below. The uncertainty in T is shown and the uncertainty in $B^{\frac{1}{2}}$ is negligible.



(i) Use the graph to determine the value of c with its uncertainty.

(ii) State the unit of k.

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13. Which of the following is a fundamental unit? *[1 mark]*

A. Ampere

B. Coulomb

C. Ohm

D. Volt

14. The maximum acceleration a_{max} of an oscillator undergoing simple harmonic motion (SHM) has a percentage uncertainty of 12%. The amplitude x_0 of the oscillation has a percentage uncertainty of 20%. If $k = \sqrt{\frac{a_{max}}{x_0}}$ what is the percentage uncertainty in the constant k? *[1 mark]*

A. 4%

B. 8%

C. 16%

D. 32%

15. The sides of a square are measured to be 5.0 ± 0.2 cm. Which of the following gives the area of the square and its uncertainty? *[1 mark]*

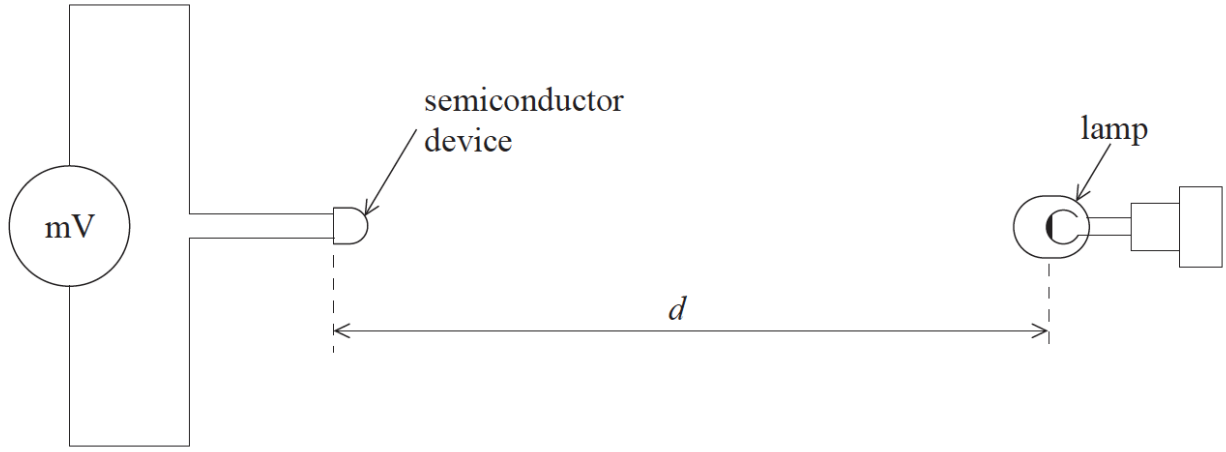
A. 25.0 ± 0.2 cm^2
B. 25.0 ± 0.4 cm^2
C. 25 ± 2 cm^2
D. 25 ± 4 cm^2

16. Which of the following lists two vector quantities and one scalar quantity? *[1 mark]*

A. force, mass, time
B. acceleration, energy, momentum
C. distance, impulse, power
D. density, pressure, temperature

Data analysis question.

A particular semiconductor device generates an emf, which varies with light intensity. The diagram shows the experimental arrangement which a student used to investigate the variation with distance *d* of the emf *ε*. The power output of the lamp was constant. (The power
supply for the lamp is not shown.)



The table shows how *ε* varied with *d*.

d / cm	*ε* / mV
19.1	5.5
18.0	6.0
16.0	8.6
14.0	11.9
12.0	19.7
10.0	37.5

17a. Outline why the student has recorded the *ε* values to different numbers of significant digits but the same number of decimal places. *[2 marks]*

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17b. On looking at the results the student suggests that ε could be inversely proportional to d. He proceeds to multiply each d value by the corresponding value of ε. *[5 marks]*

(i) Explain why this procedure can be used to disprove the student's suggestion but it cannot prove it.

(ii) Using the data for d values of 19.1 cm, 16.0 cm and 10.0 cm discuss whether or not ε is inversely proportional to d.

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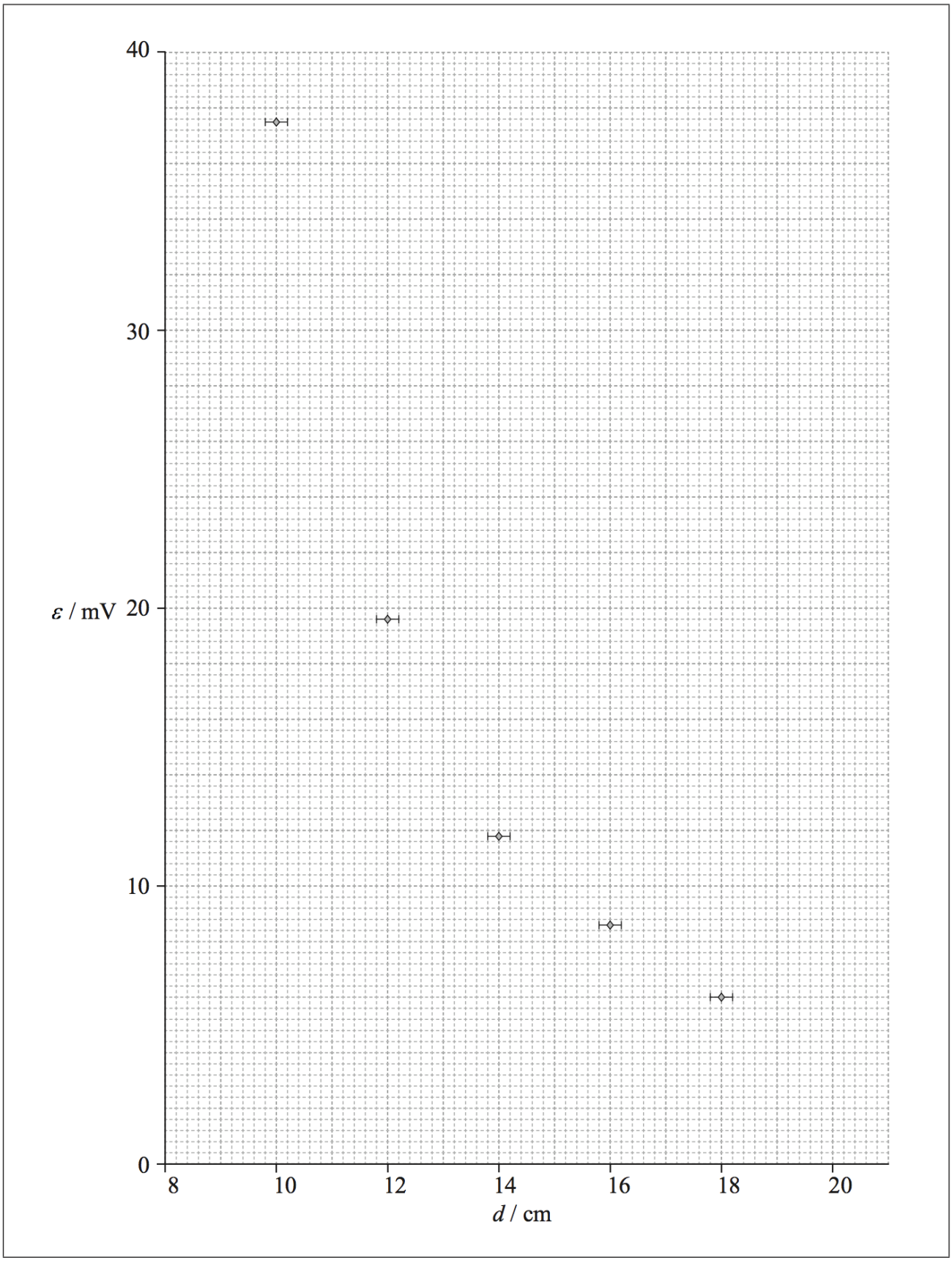
17c. The graph shows some of the data points with the uncertainty in the d values. *[3 marks]*
On the graph

(i) draw the data point corresponding to the value of d=19.1 cm.

(ii) assuming that there is a constant absolute uncertainty in measuring all values of d, draw the error bar for the data point in (c)(i).

(iii) sketch the line of best-fit for all the plotted points.



17d. All values of ε have a percentage uncertainty of ±3%. Calculate the percentage uncertainty in the product $d\varepsilon$ *[2 marks]* for the value of d=18.0cm.

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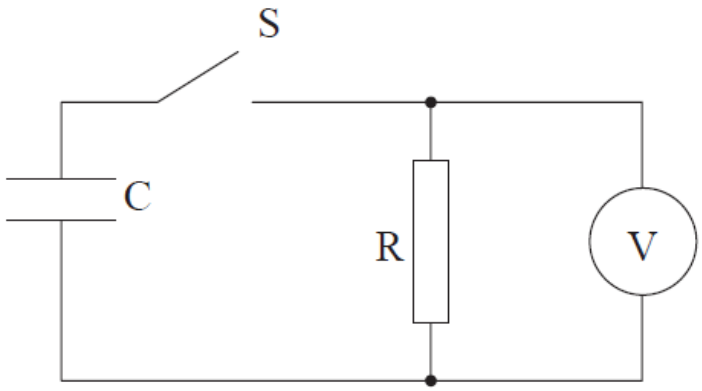
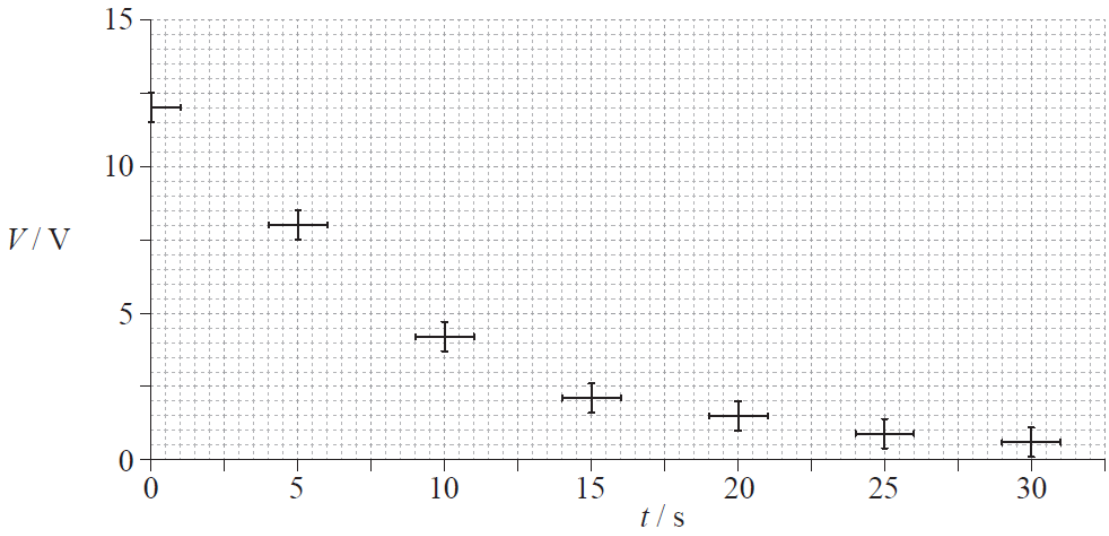
Data analysis question.

A capacitor is a device that can be used to store electric charge.

18a. An experiment was undertaken to investigate one of the circuit properties of a capacitor. A capacitor C was connected via a switch S to a resistance R and a voltmeter V. *[6 marks]*



The initial potential difference across C was 12V. The switch S was closed and the potential difference *V* across R was measured at various times *t*. The data collected, along with error bars, are shown plotted below.



(i) On the graph opposite, draw a best-fit line for the data starting from $t = 0$.

(ii) It was hypothesized that the decay of the potential difference across the capacitor is exponential. Determine, using the graph, whether this hypothesis is true **or** not.

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18b. The time constant τ of the circuit is defined as the time it would take for the capacitor to discharge were it to keep discharging at its initial rate. Use the graph in (a) to calculate the *[3 marks]*

(i) initial rate of decay of potential difference V.

(ii) time constant τ.

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18c. The time constant $\tau = RC$ where R is the resistance and C is a property called capacitance. The effective resistance in the circuit is 10 MΩ. Calculate the capacitance C. *[1 mark]*

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19. The length of the side of a cube is 10.0 ±0.3cm. What is the uncertainty in the volume of the cube? *[1 mark]*

A. $\pm 0.027\ cm^3$

B. $\pm 2.7\ cm^3$

C. $\pm 9.0\ cm^3$

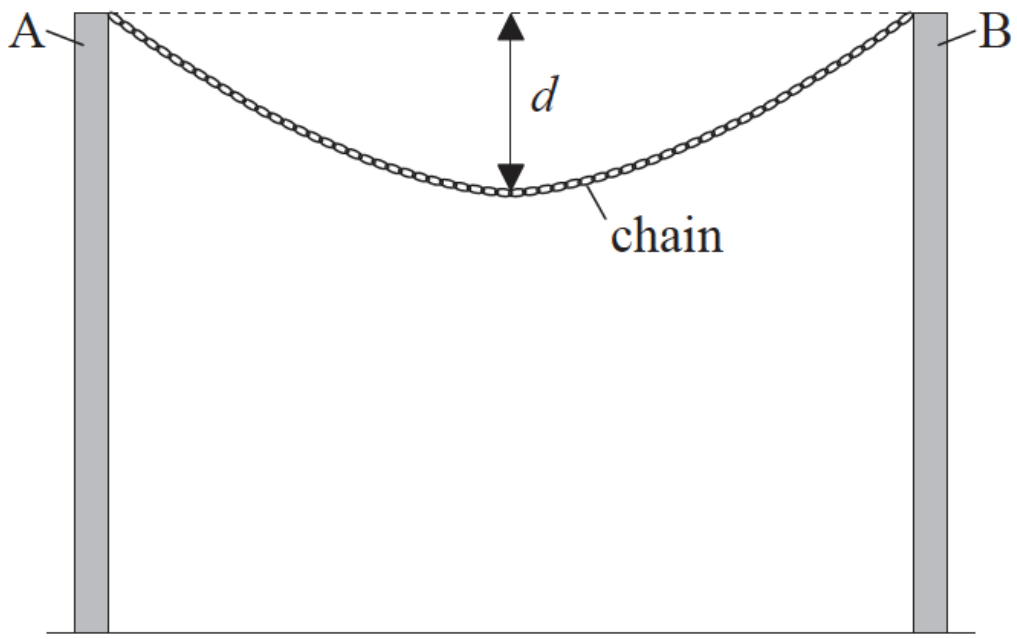
D. $\pm 90\ cm^3$

20. Which of the following lists three vector quantities? *[1 mark]*

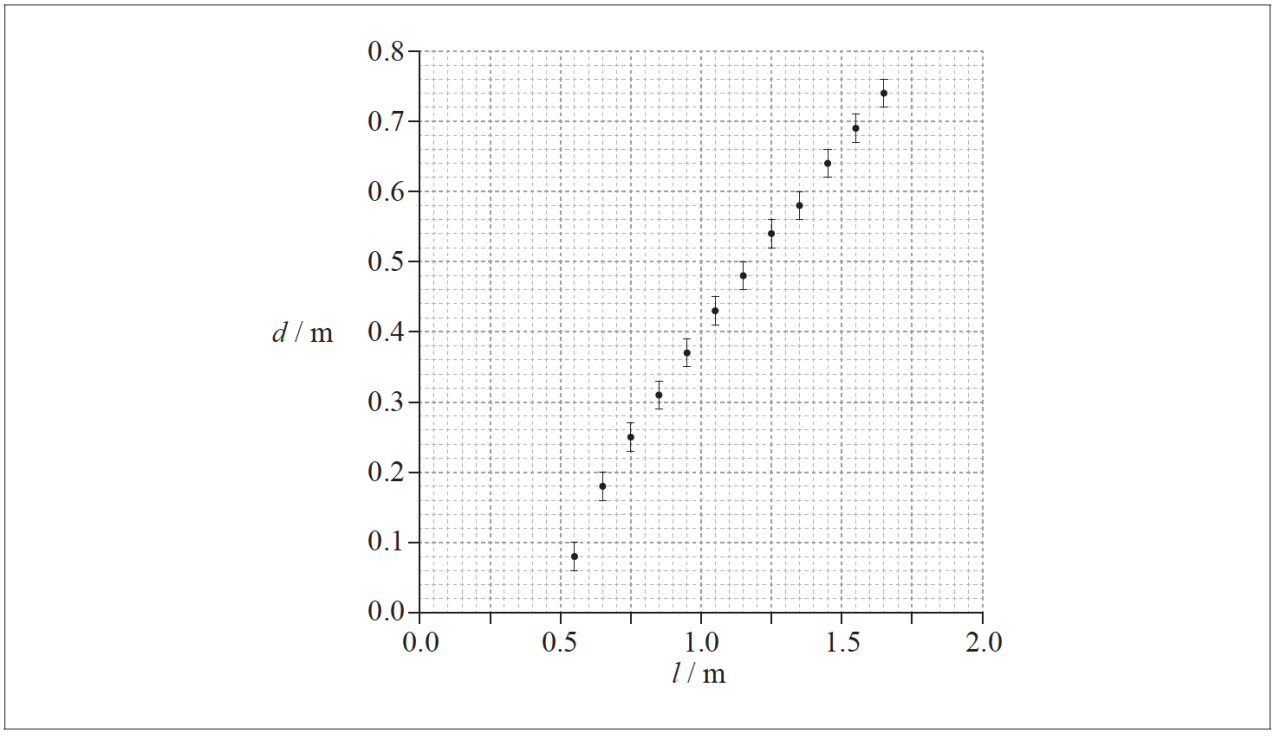
A. momentum, electric field strength, displacement
B. momentum, displacement, pressure
C. pressure, electric current, displacement
D. electric current, electric field strength, impulse

Data analysis question.

A chain is suspended between two vertical supports A and B. The chain is made of a number of identical metal links.



The length *l* of the chain can be increased by adding extra links. An experiment was undertaken to investigate how the sag *d* of the midpoint of the chain, measured from the horizontal between A and B, varies with *l*. The data obtained are shown plotted below. The uncertainties in *l* are too small to be shown.



21a. Draw a best-fit line for the data points on the graph opposite. *[1 mark]*

21b. With reference to your answer to (a), *[4 marks]*

(i) explain why the relationship between d and l is not linear.

(ii) estimate the horizontal distance between the supports A and B.

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21c. Before the experiment was carried out, it was hypothesized that d depends on $\sqrt{l}$. Determine, using your answer to (a), whether this hypothesis is valid. *[4 marks]*

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22. The resistive force F acting on a sphere of radius r travelling with speed v through a liquid is given by the equation *[1 mark]*

$$F = 6\pi\eta r v$$

where η is a constant. What are the SI units of η?

A. $kgm^{-1}s^{-2}$
B. $kgm^{2}s^{-1}$
C. $kgm^{-1}s^{-1}$
D. $kg^{-1}s^{-3}$

23. A small object is attached to a string and rotated in a circle of constant radius in a horizontal plane. The tension T in the string is measured for different speeds v. Which of the following plots should give a straight-line graph? *[1 mark]*

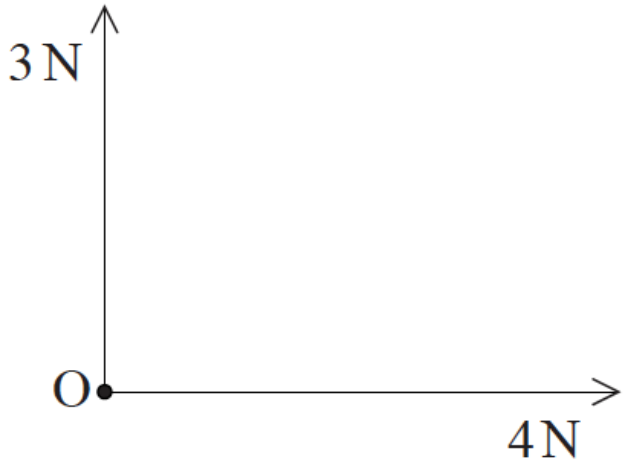
A. T against v

B. T^2 against v

C. T against v^2

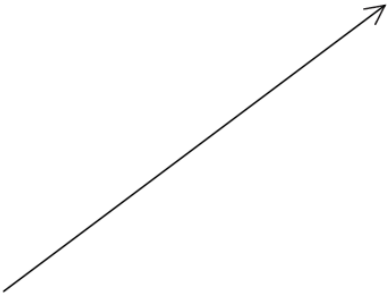
D. T^2 against v^2

24. The vector diagram shows two forces acting on a point object O. The forces are in the plane of the page. *[1 mark]*

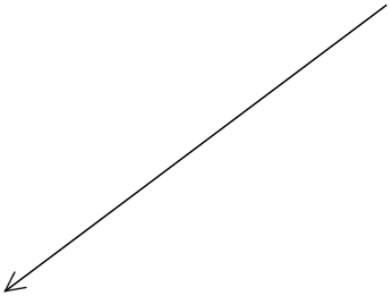


Another 5 N force is applied to O in the plane of the page. Which of the following gives the direction of this force to ensure that O is in equilibrium?

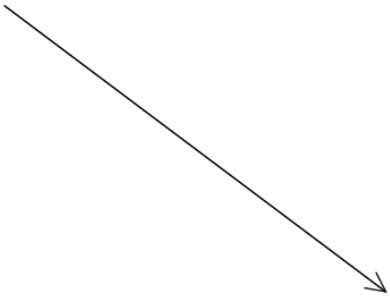
A.



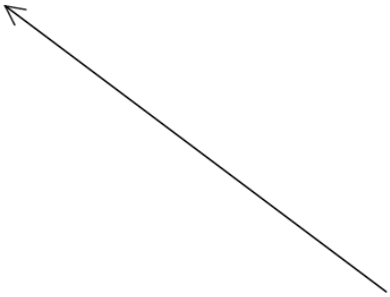
B.



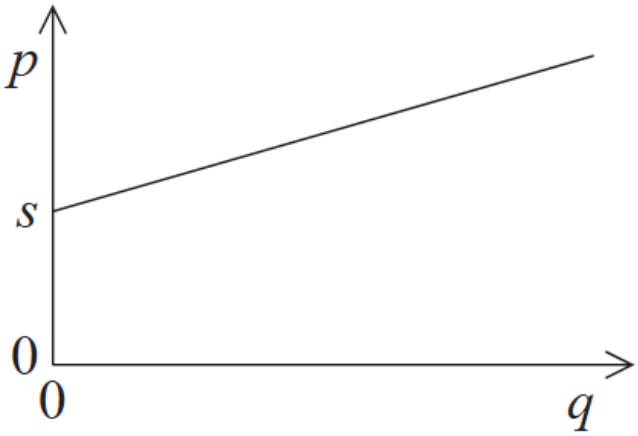
C.



D.



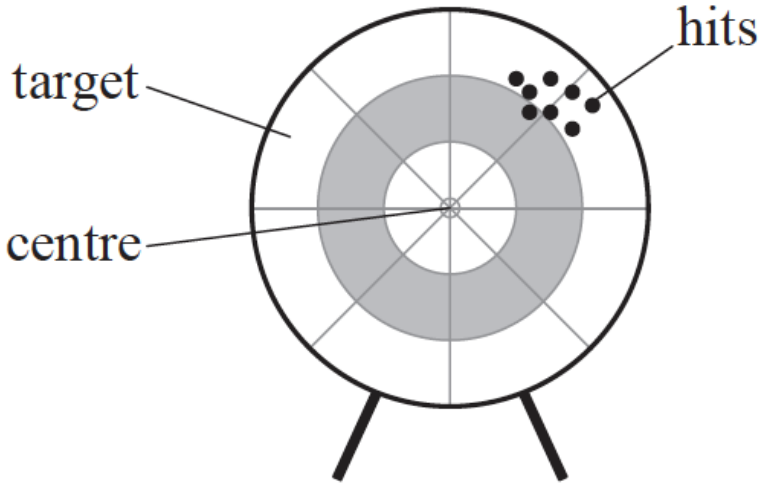
25. The graph shows the relationship between two quantities p and q. The gradient of the graph is r and the intercept on the p axis is s. *[1 mark]*



Which of the following is the correct relationship between p and q?

A. $p = sq+r$
B. $p = rq+s$
C. $p = rq-s$
D. $p = rs+q$

26. Aiming for the centre of a target, an archer fires arrows which produces a pattern of hits as shown below. *[1 mark]*



The pattern suggests the presence of

A. random and systematic uncertainties.
B. random uncertainties but no systematic uncertainties.
C. systematic uncertainties but no random uncertainties.
D. neither random nor systematic uncertainties.

27. The acceleration of free fall g is determined by the relationship $g = \frac{4\pi^2 l}{t^2}$. The uncertainty in the value of l is 2% and the uncertainty in the value of t is 5%. What is the uncertainty in g? *[1 mark]*

A. 3%
B. 7%
C. 8%
D. 12%

28. What is the correct SI unit for momentum? *[1 mark]*

A. kg $m^{-1}s^{-1}$
B. kg $m^{2}s^{-1}$
C. kg ms^{-1}
D. kg ms^{-2}

29. Which of the following is a fundamental SI unit? *[1 mark]*

A. Ampere
B. Joule
C. Newton
D. Volt

30. What is the order of magnitude of the mass, in kg, of an apple? *[1 mark]*

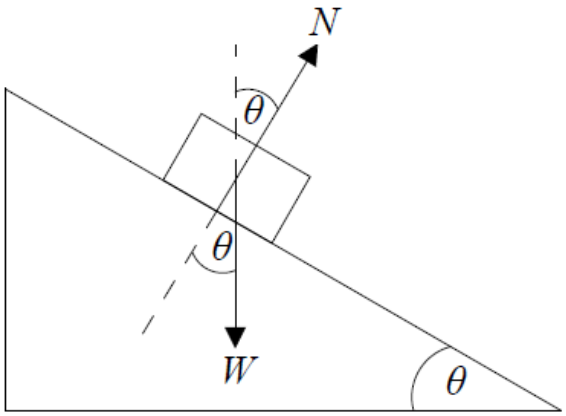
A. 10^{-3}

B. 10^{-1}

C. 10^{+1}

D. 10^{+3}

31. The diagram below shows the forces acting on a block of weight W as it slides down a slope. The angle between the slope and the horizontal is θ, the normal reaction force on the block from the slope is N and friction is negligible. *[1 mark]*



Which of the following gives the resultant force on the block?

A. $W \sin \theta$

B. $W \cos \theta$

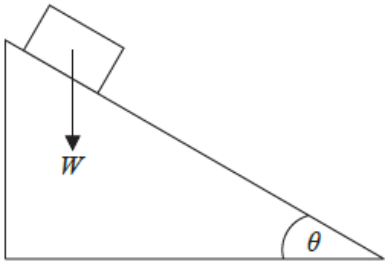
C. $N \sin \theta$

D. $N \cos \theta$

32. Which of the following will reduce random errors in an experiment? *[1 mark]*

A. Using an instrument having a greater precision
B. Checking the calibration of the instrument used
C. Checking for zero error on the instrument used
D. Repeating readings

33. An object slides down an inclined plane that makes an angle θ with the horizontal. The weight of the object is W. *[1 mark]*



Which of the following is the magnitude of the component of the weight parallel to the plane?

A. $W \sin \theta$

B. $\frac{W}{\sin \theta}$

C. $W \cos \theta$

D. $\frac{W}{\cos \theta}$

34. A ball is thrown with velocity u at an angle of 55° above the horizontal. Which of the following is the magnitude of the horizontal component of velocity? *[1 mark]*

A. $u \cos 55°$
B. $u \sin 55°$
C. u
D. $u \tan 55°$

35. A body accelerates from rest with a uniform acceleration a for a time t. The uncertainty in a is 8% and the uncertainty in t is 4%. The uncertainty in the speed is *[1 mark]*

A. 32%.

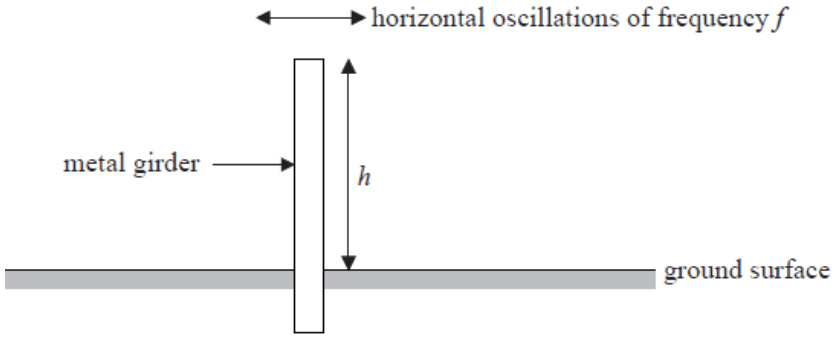
B. 12%.

C. 8%.

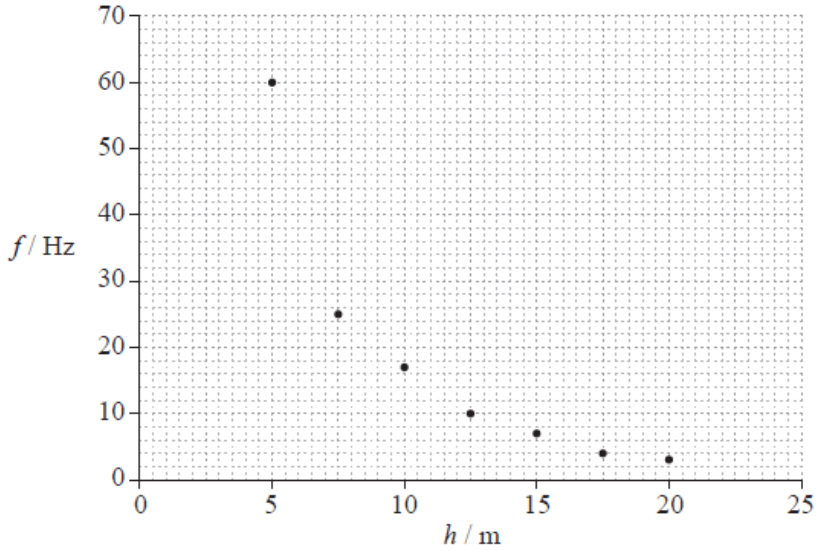
D. 2%.

Data analysis question.

Metal girders are often used in buildings that have been constructed to withstand earthquakes. To aid the design of these buildings, experiments are undertaken to measure how the natural frequency f of horizontal oscillations of metal girders varies with their dimensions. In an experiment, f was measured for vertically supported girders of the same cross-sectional area but with different heights h.



The graph shows the plotted data for this experiment. Uncertainties in the data are not shown.



36a. Draw a best-fit line for the data. *[1 mark]*

36b. It is hypothesized that the frequency f is inversely proportional to the height h. *[4 marks]*

By choosing **two** well separated points on the best-fit line that you have drawn in (a), show that this hypothesis is incorrect.

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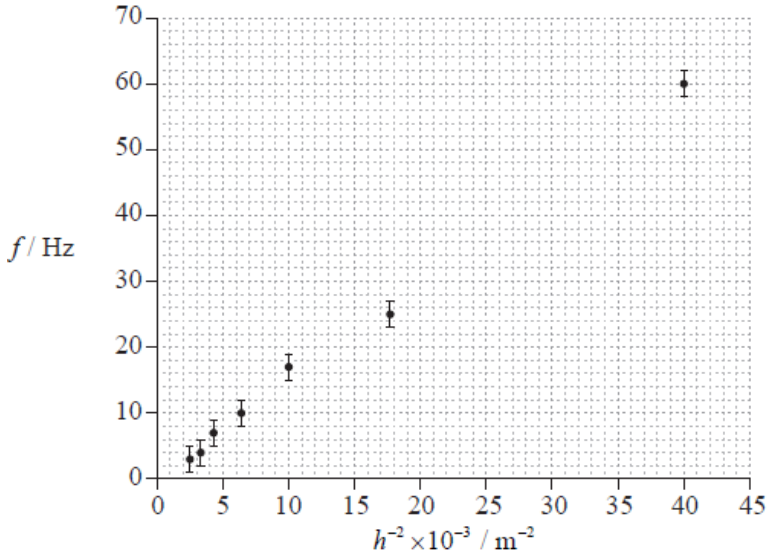
36c. Another suggestion is that the relationship between f and h is of the form shown below, where k is a constant. *[5 marks]*

$$f = \frac{k}{h^2}$$

The graph shows a plot of f against h^{-2}.



The uncertainties in h^{-2} are too small to be shown.

(i) Draw a best-fit line for the data that supports the relationship $f = \frac{k}{h^2}$.

(ii) Determine, using the graph, the constant k.

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36d. State **one** reason why the results of the experiment could not be used to predict the natural frequency of oscillation for girders of height 50 m. *[1 mark]*

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37. The student hypothesises that there may be an exponential relationship between ε and d of the form shown below, where a and k are constants. *[4 marks]*

$$\varepsilon = ae^{-kd}$$

(i) Deduce a suitable unit for k.

(ii) Suggest the graph that the student should plot in order to get a straight-line graph if the hypothesis is valid.

(iii) Explain how k can be obtained from the graph in (d)(ii).

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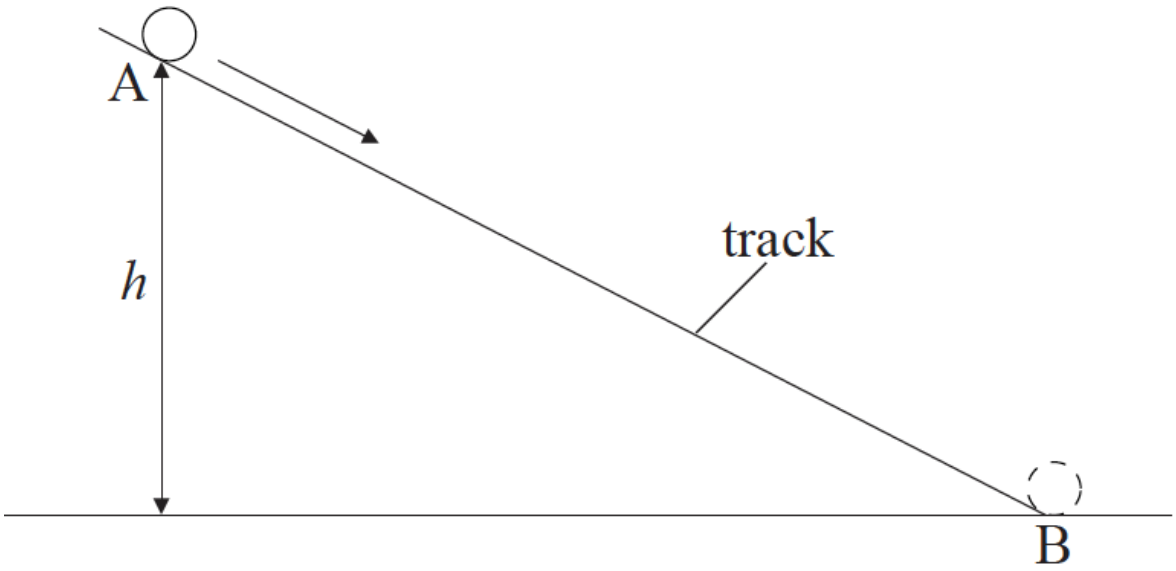
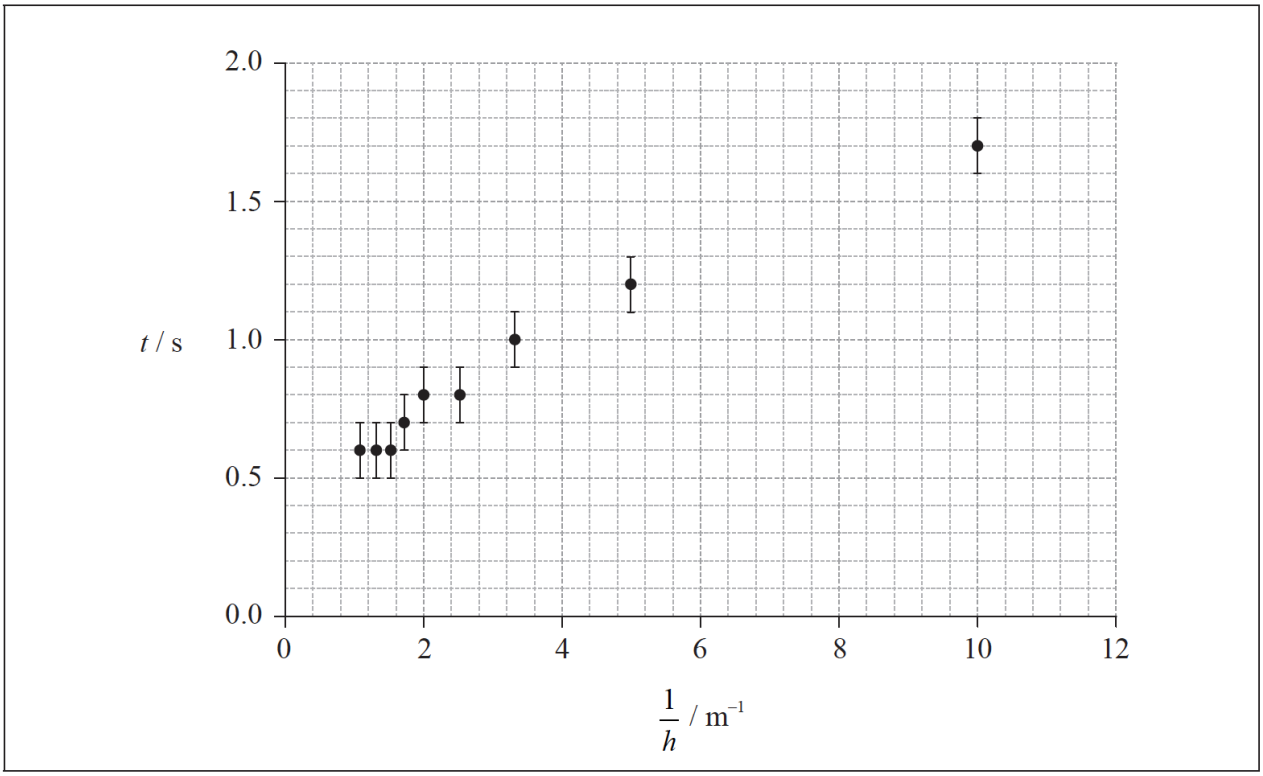
Data analysis question.
A small sphere rolls down a track of constant length AB. The sphere is released from rest at A.
The time t that the sphere takes to roll from A to B is measured for different values of height h.



A student suggests that t is proportional to $\frac{1}{h}$. To test this hypothesis a graph of t against $\frac{1}{h}$ is plotted as shown on the axes below. The uncertainty in t is shown and the uncertainty in $\frac{1}{h}$ is negligible.



38a. (i) Draw the straight line that best fits the data. *[2 marks]*

(ii) State why the data do not support the hypothesis.

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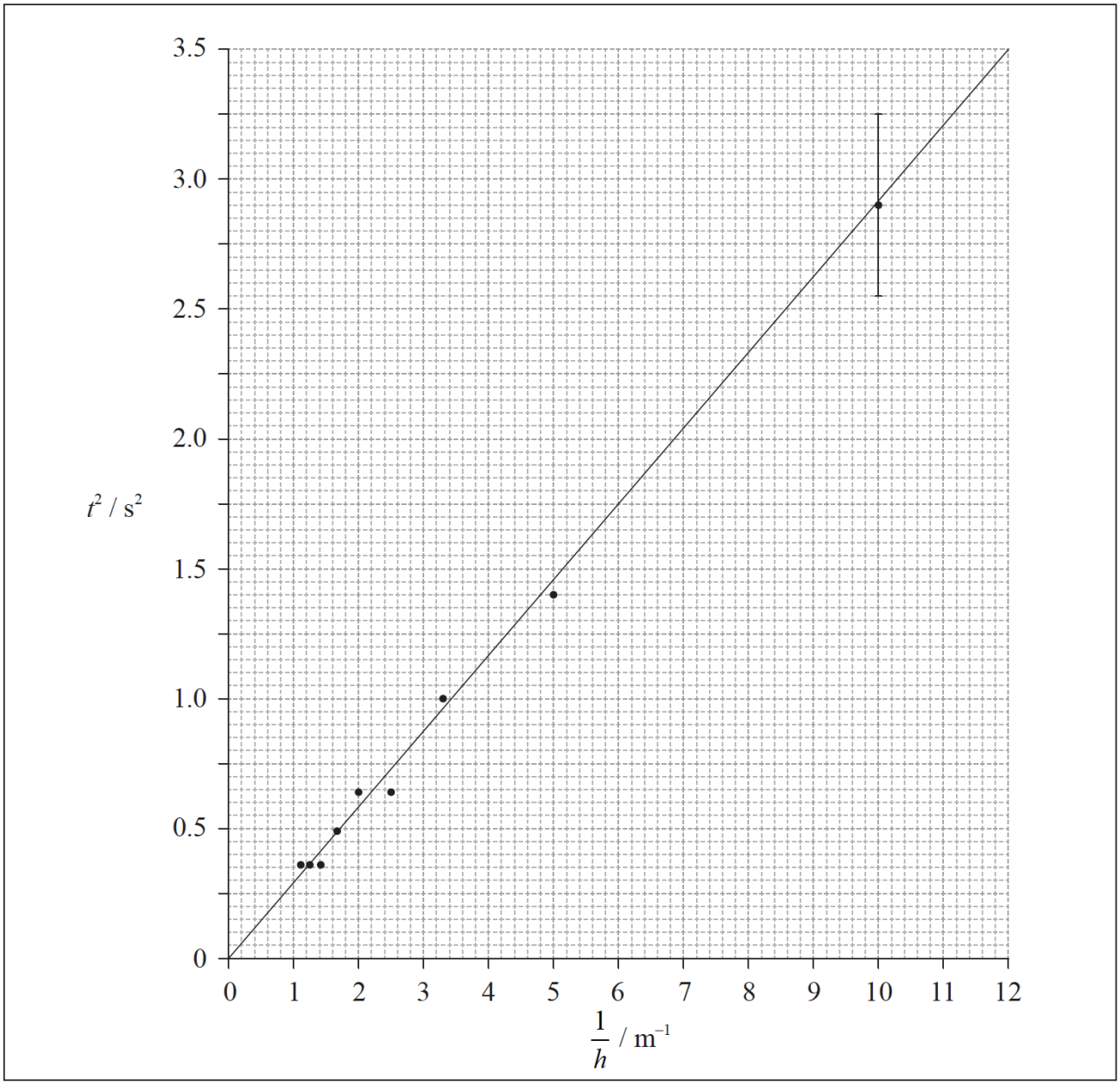
38b. Another student suggests that the relationship between t and h is of the form *[9 marks]*

$$t = k\sqrt{\frac{1}{h}}$$

where k is a constant.

To test whether or not the data support this relationship, a graph of t^2 against $\frac{1}{h}$ is plotted as shown below.

The best-fit line takes into account the uncertainties for all data points.



The uncertainty in t^2 for the data point where $\frac{1}{h} = 10.0\text{m}^{-1}$ is shown as an error bar on the graph.

(i) State the value of the uncertainty in t^2 for $\frac{1}{h} = 10.0\text{m}^{-1}$.

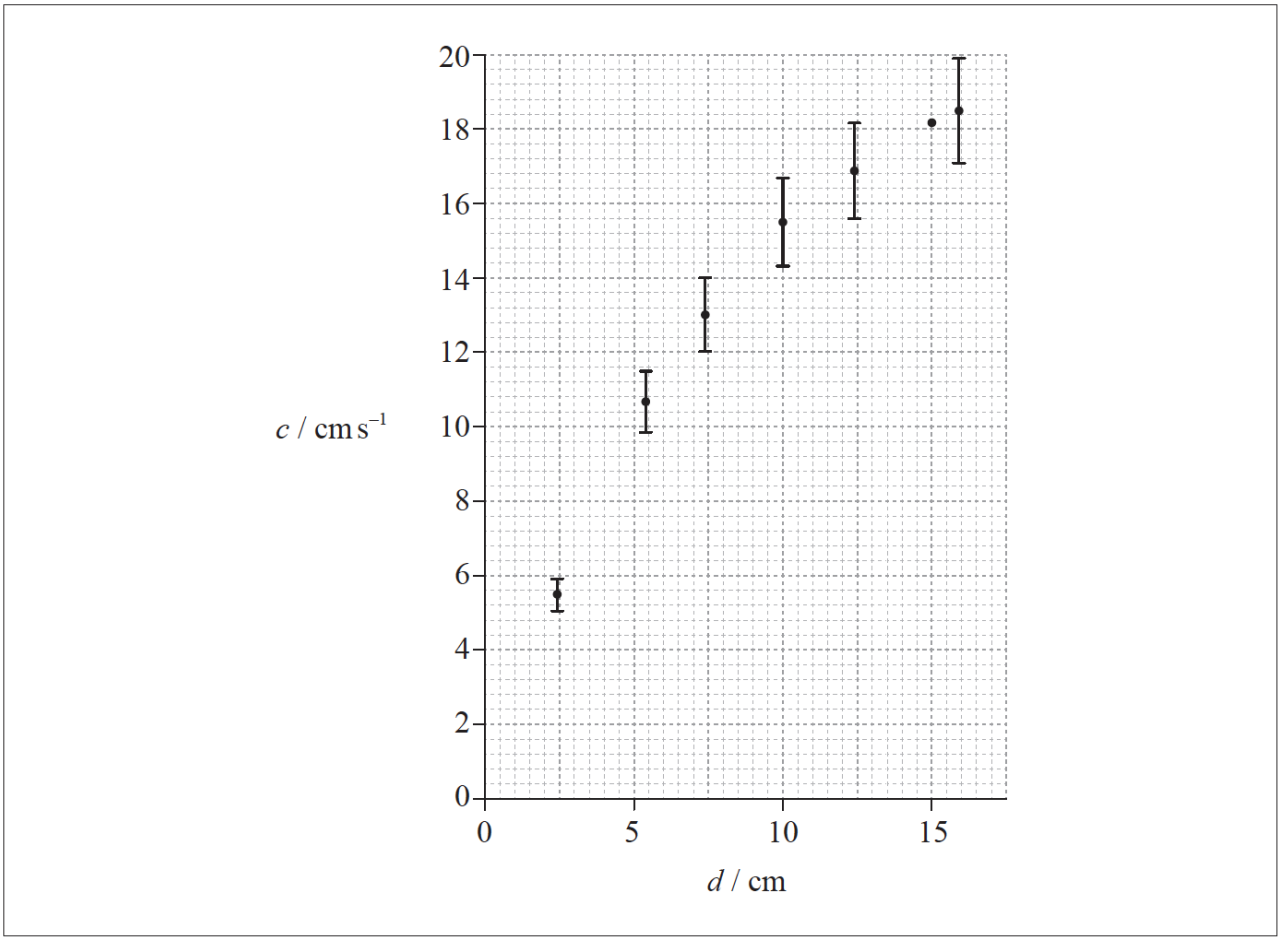
(ii) Calculate the uncertainty in t^2 when t = 0.8 ± 0.1s. Give your answer to an appropriate number of significant digits.

(iii) Use the graph to determine the value of k. Do not calculate its uncertainty.

(iv) State the unit of k.

Data analysis question.

Caroline carried out an experiment to measure the variation with water depth d of the wave speed c of a surface water wave. Her data are shown plotted below.



The uncertainty in the water depth d is too small to be shown. Uncertainties in the measurement of the wave speed c are shown as error bars on the graph except for the data point corresponding to d=15 cm.

39a. Caroline calculated the wave speed by measuring the time t for the wave to travel 150 cm. The uncertainty in this distance is 2 cm. For the reading at a water depth of 15 cm, the time t is 8.3 s with an uncertainty 0.5 s. *[4 marks]*

(i) Show that the absolute uncertainty in the wave speed at this time is 1.3 cm s^{-1}.

(ii) On the graph opposite, draw the error bar for the data point corresponding to d=15 cm.

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39b. Caroline hypothesized that the wave speed c is directly proportional to the water depth d. *[3 marks]*

(i) On the graph opposite, draw a line of best-fit for the data.

(ii) Suggest if the data support this hypothesis.

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39c. Another student proposes that c is proportional to $d^{0.5}$. *[1 mark]*

State a suitable graph that can be plotted to test this proposal.

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39d. There is a systematic error in Caroline's determination of the depth. *[2 marks]*

(i) State what is meant by a systematic error.

(ii) State how the graph in (c) would indicate that there is a systematic error.

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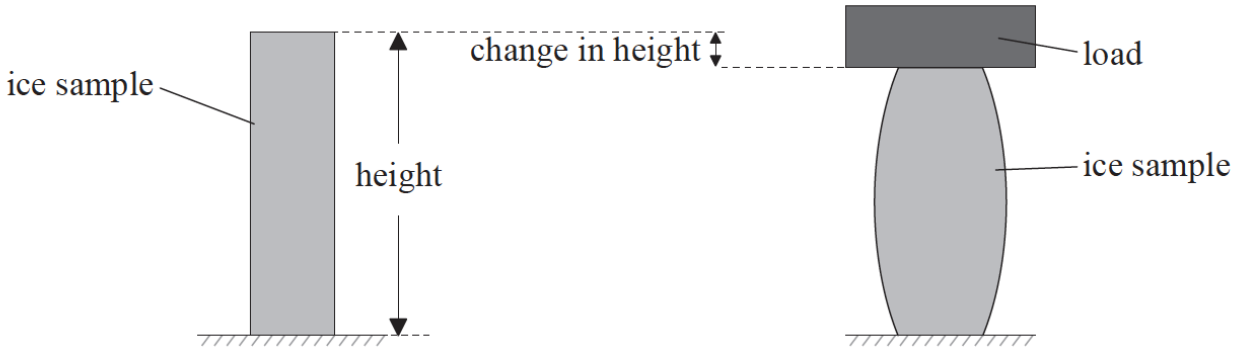
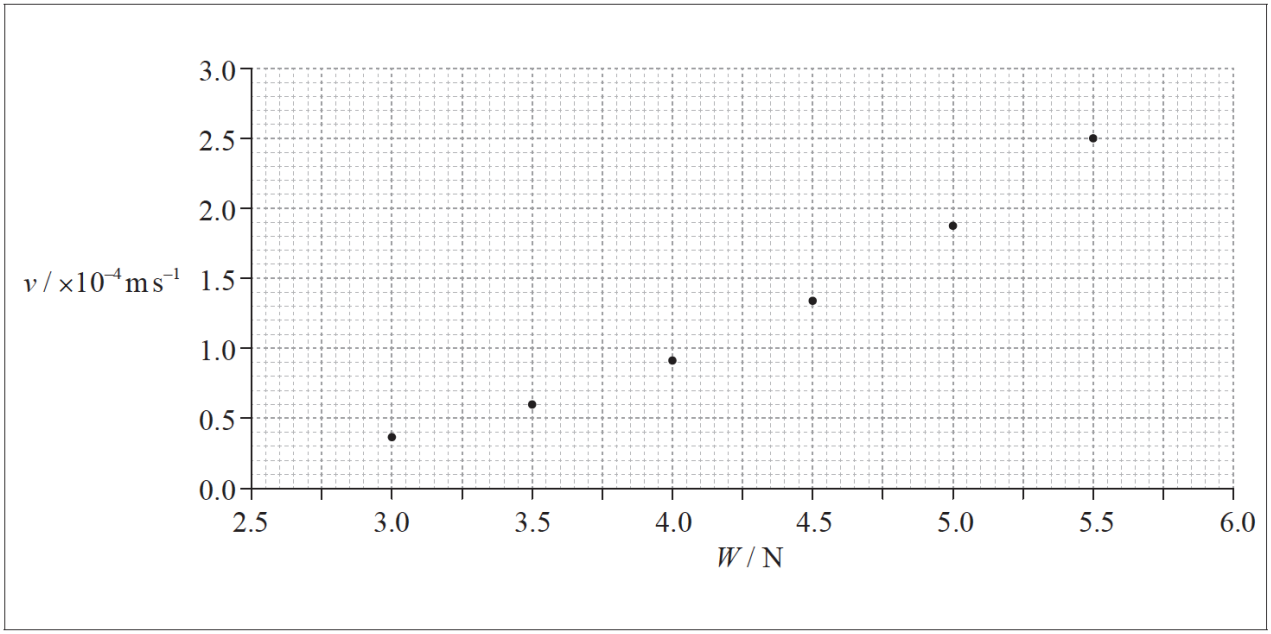
Data analysis question.

The movement of glaciers can be modelled by applying a load to a sample of ice.



After the load has been applied, it is observed to move downwards at a constant speed v as the ice deforms. The constant speed v is measured for different loads. The graph shows the variation of v with load W for a number of identical samples of ice.

The data points are plotted below.



The uncertainty in v is ±20 μm s^{-1} and the uncertainty in W is negligible.

40a. (i) On the graph opposite, draw error bars on the first and last points to show the uncertainty in v. *[2 marks]*

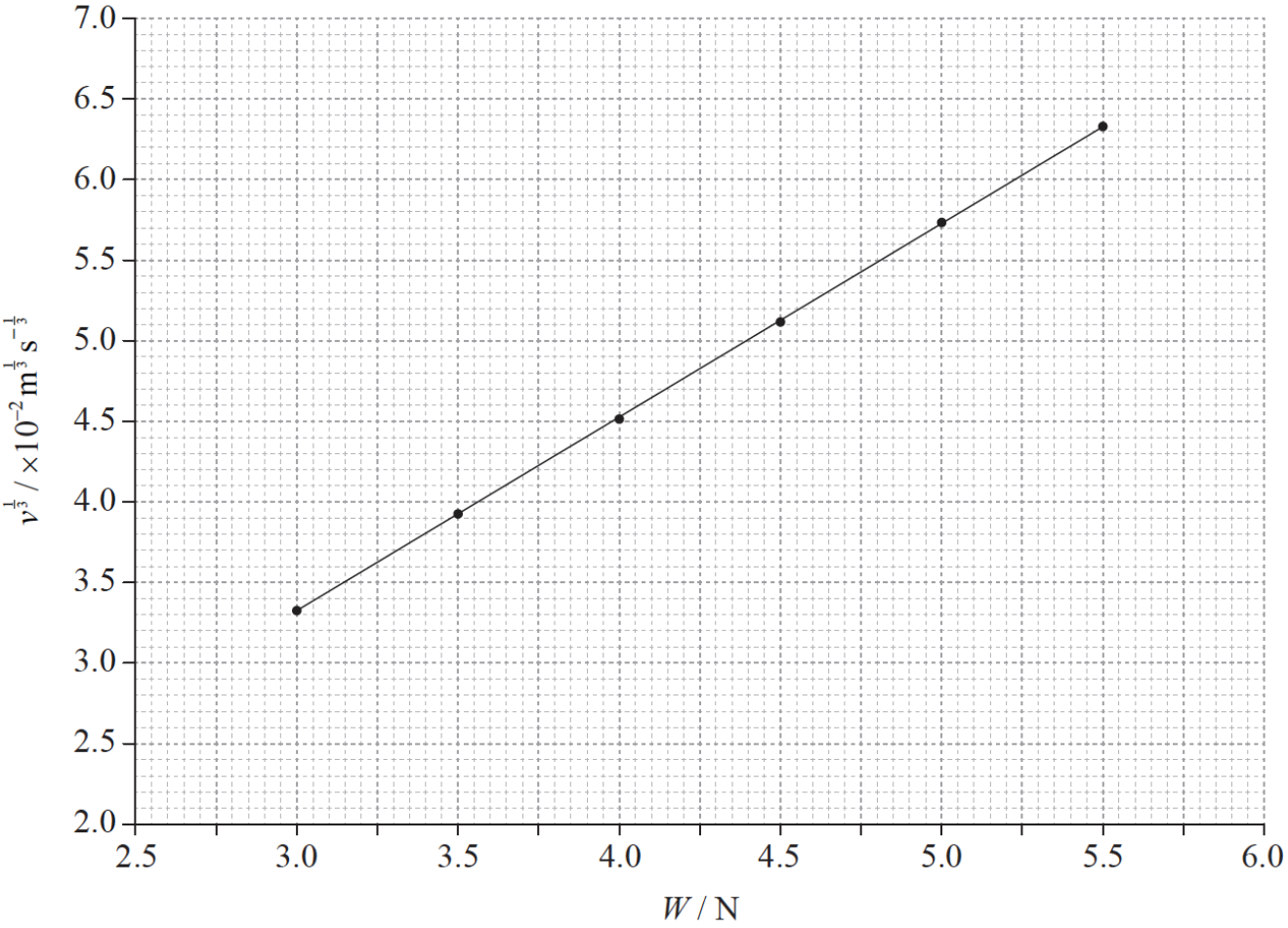
(ii) On the graph opposite, draw the line of best-fit for the data points.

40b. Theory suggests that the relation between v and W is *[3 marks]*

$$v = kW^3$$

where k is a constant.

To test this hypothesis a graph of $v^{\frac{1}{3}}$ against W is plotted.



At W=5.5 N the speed is 250±20 μm s^{-1}.

Calculate the uncertainty in $v^{\frac{1}{3}}$ for a load of 5.5 N.

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40c. (i) Using the graph in (c), determine *k* without its uncertainty. *[5 marks]*

(ii) State an appropriate unit for your answer to (d)(i).

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41. Which of the following contains one fundamental and one derived unit? *[1 mark]*

A.	ampere	kilogram
B.	ampere	coulomb
C.	joule	newton
D.	joule	coulomb

42. The current *I* through a resistor is measured with a digital ammeter to be 0.10 A. The uncertainty in the calculated value of I^2 will be *[1 mark]*

A. 1 %.
B. 2 %.
C. 5 %.
D. 20 %.

43. Which of the following lists **two** scalar quantities? *[1 mark]*

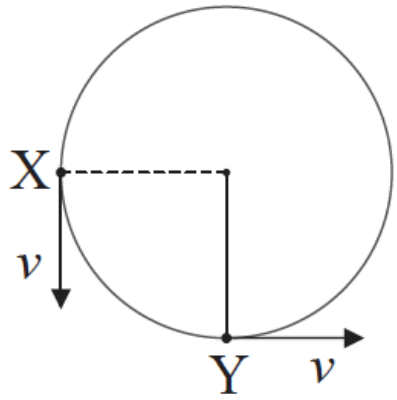
A. emf, momentum

B. emf, weight

C. impulse, kinetic energy

D. temperature, kinetic energy

44. A stone attached to a string is moving in a horizontal circle. The constant speed of the stone is *v*. The diagram below shows the stone in two different positions, X and Y. *[1 mark]*



Which of the following shows the direction of the change of velocity of the stone when moving from position X to position Y?

A. 

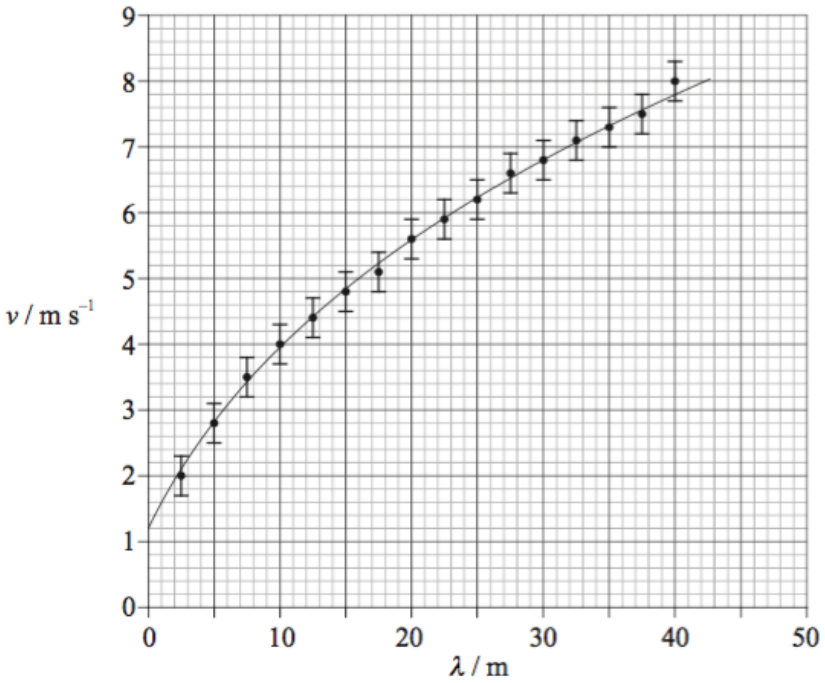
B. 

C. 

D. 

Data analysis question.

The speed v of waves on the surface of deep water depends only on the wavelength λ of the waves. The data gathered from a particular region of the Atlantic Ocean are plotted below.



The uncertainty in the speed v is ± 0.30 m s^{-1} and the uncertainty in λ is too small to be shown on the diagram.

State, with reference to the graph,

45a. (i) why v is not directly proportional to λ. *[2 marks]*

(ii) the value of v for λ=39m.

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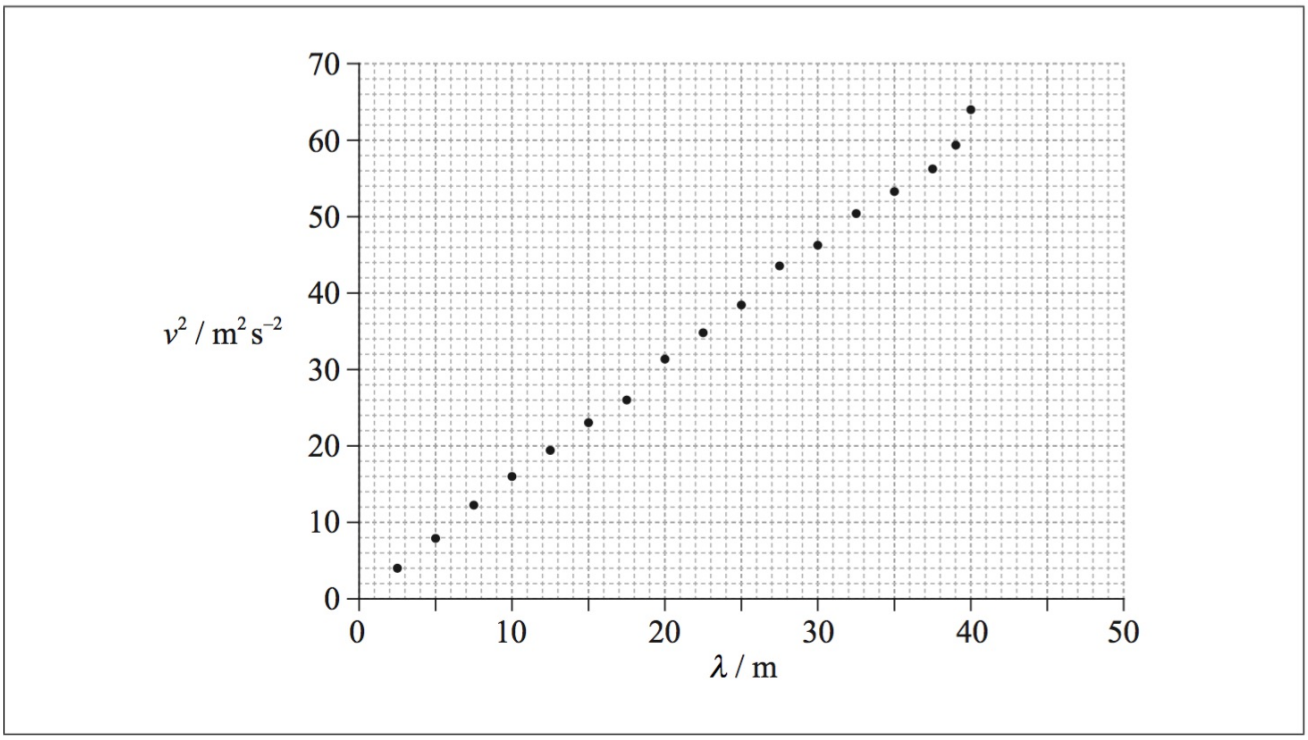
45b. It is suggested that the relationship between v and λ is of the form *[9 marks]*

$$v = a\sqrt{\lambda}$$

where a is a constant. To test the validity of this hypothesis, values of v^2 against λ are plotted below.



(i) Use your answer to (a)(ii) to show that the absolute uncertainty in v^2 for a wavelength of 39 m is ±5 m^2 s^{-2}.

(ii) The absolute uncertainty in v^2 for a wavelength of 2.5 m is ± 1m^2 s^{-2}. Using this value and the value in (b)(i), construct error bars for v^2 at the data points for λ=2.5 m and 39 m.

(iii) State why the plotted data in (b)(ii) suggest that it is likely that v is proportional to $\sqrt{\lambda}$.

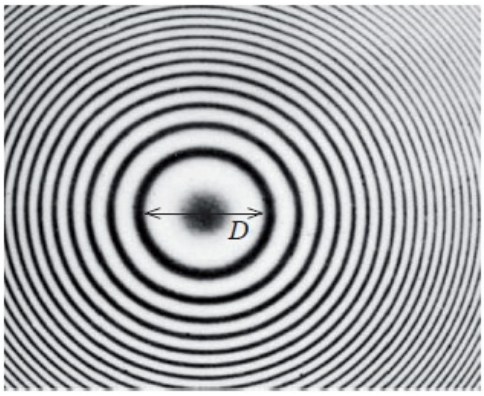
(iv) Use the graph opposite to determine the constant a.

(v) Theory shows that $a = \sqrt{\frac{k}{2\pi}}$. Determine a value for k.

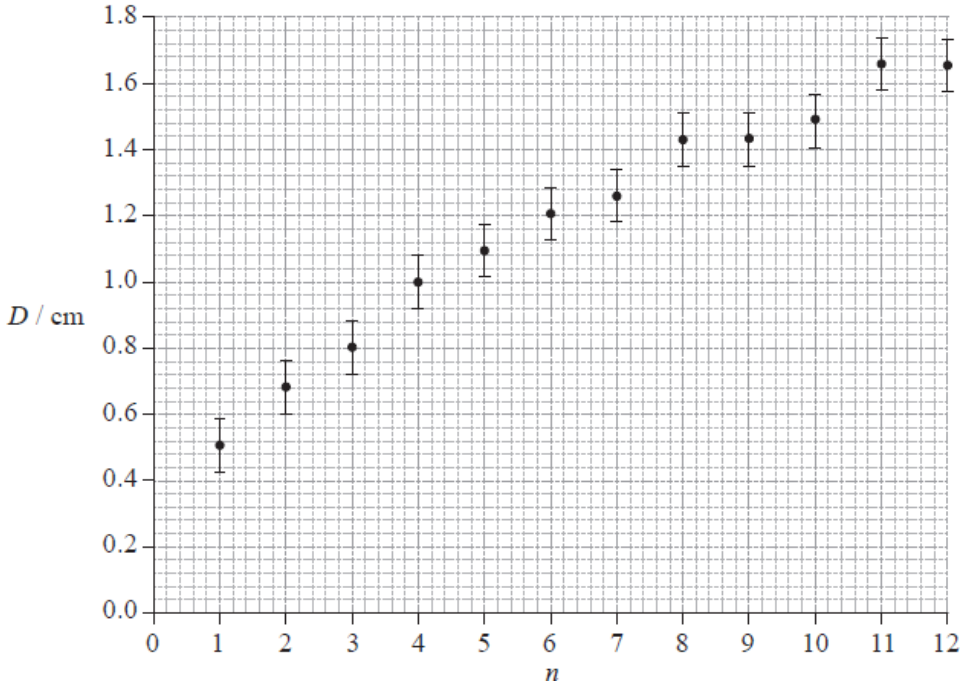
46a. State **one** piece of evidence that shows that D is not proportional to n. *[1 mark]*

Data analysis question.

The photograph below shows a magnified image of a dark central disc surrounded by concentric dark rings. These rings were produced as a result of interference of monochromatic light.

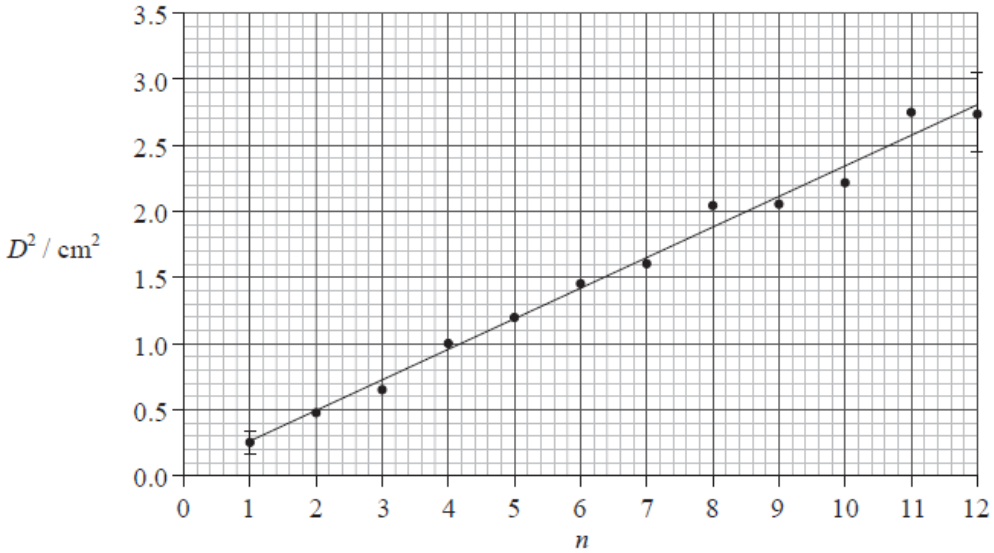


The graph below shows how the ring diameter D varies with the ring number n. The innermost ring corresponds to n = 1. The corresponding diameter is labelled in the photograph. Error bars for the diameter D are shown.



46b. Theory suggests that $D^2 = kn$. *[8 marks]*

A graph of D^2 against n is shown below. Error bars are shown for the first and last data points only.



(i) Using the graph on page 2, calculate the percentage uncertainty in D^2, of the ring n = 7.

(ii) Based on the graph opposite, state **one** piece of evidence that supports the relationship $D^2 = kn$.

(iii) Use the graph opposite to determine the value of the constant k, as well as its uncertainty.

(iv) State the unit for the constant k.

47. It is suggested that the relationship between D and n is of the form *[3 marks]*

$$D = cn^p$$

where c and p are constants.
Explain what graph you would plot in order to determine the value of p.