

# 1 Measurement and uncertainties

## 1.1 Measurements in physics

Name: .....

Date: .....

### Fundamental and derived units

- 1 A joule is equal to a newton metre and a newton is a kilogram metre per second<sup>2</sup>. Write a joule in its fundamental units.  
.....
- 2 Re-write 25 m/s in a preferable way.  
.....
- 3 A watt is equal to a joule per second. Write a watt in its fundamental units.  
.....
- 4 A watt is equal to a volt multiplied by an ampere. Write a volt in its fundamental units.  
.....
- 5 Electric charge (units are coulombs) is equal to electric current multiplied by time. Write a coulomb in its fundamental units.  
.....
- 6 A farad is equal to a coulomb per volt. Write a farad in its fundamental units.  
.....
- 7 An ohm is a volt per amp. Write an ohm in its fundamental units.  
.....
- 8 The units of electrical conductance are equal to the reciprocal of ohms. Write the fundamental units of electrical conductance.  
.....
- 9 A tesla equals a volt second per metre<sup>2</sup>. Write a tesla in its fundamental units.  
.....
- 10 What is the unit of amount of substance?  
.....

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## 1.1 Measurements in physics

Name: .....

Date: .....

### Orders of magnitude

1 State the order of magnitude of each of the following:

- a 565 .....
- b 29 .....
- c 0.000 656 .....
- d 248 789 .....
- e 0.1 .....

2 Determine the orders of magnitude in each of the following:

- a  $43 \div 26 =$  .....
- b  $892 \div 16 =$  .....
- c  $2555 \div 0.2365 =$  .....
- d  $2.23 \times 15.67 =$  .....
- e  $(1.6 \times 10^4) \times (7.6 \times 10^6) =$  .....

3 A pile of sand has a width that ranges from 38 m to 41 m and a length that is approximately 125 m. If the depth varies from 8.8 m to 9.1 m, what is the order of magnitude of the volume?

.....  
.....

4 325 pieces of steel, 6.5 cm thick on average, are vertically stacked. What is the order of magnitude of the total thickness?

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.....

5 Solve and state the order of magnitude:  $81 \mu\text{m} + 96 \text{ cm} + 21 \text{ pm} + 148 \text{ mm}$

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.....

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Name: .....

Date: .....

### Scientific notation and metric multipliers

1 Express the following in scientific notation.

a 237 .....

b 37529035903475 .....

c 0.00354 .....

d 0.02020202 .....

2 Convert the following to decimal form.

a  $2.369 \times 10^6$  .....

b  $7.85 \times 10^{-5}$  .....

3 Solve the following.

a  $1.25 \times 10^5 + 2.8 \times 10^4 =$  .....

b  $2.36 \times 10^3 \times 4.51 \times 10^3 =$  .....

c  $(2.22)^4 =$  .....

d  $1.26 \times 10^2 / 385 =$  .....

4 Express the following in scientific notation.

a  $13 \mu\text{m} + 18 \mu\text{m} =$  .....

b  $2.5 \text{ Mm} + 5600 \text{ km} =$  .....

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Name: .....

Date: .....

### Significant figures

1 State the number of significant figures in the following.

- a 205 .....
- b 1000 .....
- c 0.023 .....
- d 0.020 .....
- e  $2.30 \times 10^5$  .....

2 Solve the following.

- a  $\sin 35 =$  .....
- b  $14.28 + 5.13 + 2.222 =$  .....
- c  $16.25 \div 0.09 =$  .....
- d  $16 \text{ nm} \times 14 \text{ pm} =$  .....
- e  $5.62 \times 10^{12} / 2.717 \times 10^5 =$  .....

3 Round 0.00350681 to:

- a 1 significant figure .....
- b 2 significant figures .....
- c 3 significant figures .....
- d 4 significant figures .....
- e 5 significant figures .....

# 1 Measurement and uncertainties

## 1.2 Uncertainties and errors

Name: .....

Date: .....

### Error bars

- 1 A particular reading in an experiment shows  $s = 5.2 \pm 0.1$  m when  $t = 0.32 \pm 0.05$  s. What are the maximum and minimum values for  $s$  and  $t$ ?

.....

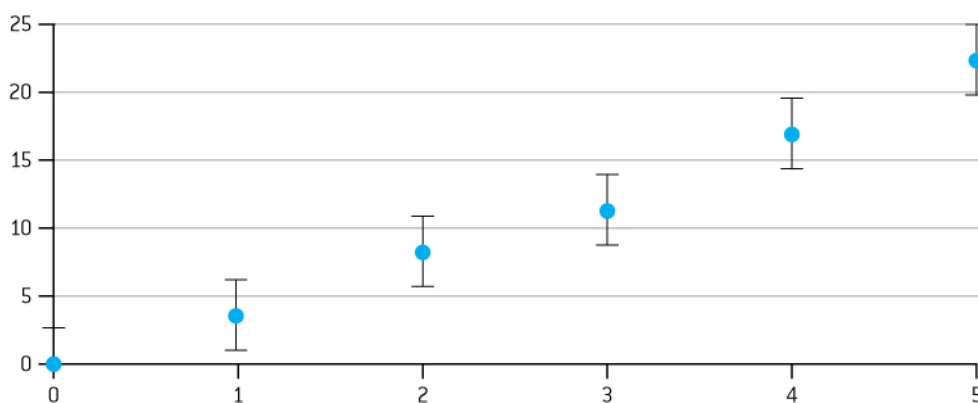
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- 2 Show this range in a sketch.

- 3 Draw a line of best fit on the graph below.



# 1 Measurement and uncertainties

## 1.2 Uncertainties and errors

Name: .....

Date: .....

### Random and systematic errors

- 1 Gerald is not happy with the results of an experiment. He knows what the actual value of his recorded data should be. The teacher says that there may be a systematic error. He decides to perform more trials with the same equipment using the same techniques. He does not check the equipment for calibration. Would this eliminate the systematic errors? Explain your answer.

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- 2 A student measures the width of an object several times and records the following data: 2.3 cm, 2.4 cm, 2.2 cm, 2.3 cm, 2.3 cm, 2.2 cm, and 2.8 cm. He decides to represent his data the following way:

$$2.3 + 2.4 + 2.2 + 2.3 + 2.3 + 2.2 + 2.8 = 16.5$$

$$16.5 \div 7 = 2.357 \text{ cm}$$

$$(2.8 - 2.2) \div 2 = 0.3 \text{ cm}$$

Therefore, the average value is  $2.4 \pm 0.3$  cm. A teacher tells the student that his report should read  $2.3 \pm 0.1$  cm. How did the teacher get this result and what type of error did the student commit?

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# 1 Measurement and uncertainties

## 1.2 Uncertainties and errors

Name: .....

Date: .....

### Absolute, fractional, and percentage uncertainties

- 1 a What is the absolute uncertainty for the following measurements?

5.8 cm, 5.6 cm, 5.7 cm, 5.4 cm, 5.4 cm, 5.6 cm

.....  
.....

- b Determine the fractional uncertainty in part a.

.....  
.....

- c Determine the percentage uncertainty in part a.

.....  
.....

- 2 The first length measured in a laboratory experiment is  $2.5 \pm 0.1$  m and the second length  $3.4 \pm 0.1$  m.

- a What is the sum of the lengths?

.....  
.....

- b What is the difference in the lengths?

.....  
.....

- c What is the percentage uncertainty in each a and b?

.....  
.....  
.....  
.....

- 3 The first length measured in a laboratory is  $2.9 \text{ m} \pm 3.4\%$  and the second length  $5.4 \text{ m} \pm 1.9\%$

- a What is the sum of the lengths?

.....  
.....

# 1.2 Uncertainties and errors

**b** What is the difference in the lengths?

.....  
.....

**c** What is the percentage uncertainty in each **a** and **b**?

.....  
.....

**4** What is the area of a rectangle measuring  $1.2 \pm 0.1$  m and  $1.7 \pm 0.1$  m?

.....  
.....

**5** What is the area of a rectangle measuring  $3.8 \text{ m} \pm 2.6\%$  and  $1.6 \text{ m} \pm 6.3\%$ ?

.....  
.....

**6** Evaluate  $(1.5 \pm 0.2 \text{ m})^3$ .

.....  
.....

**7** If  $H^3 = a \div b$  and the uncertainty in  $a$  is 15% and  $b$  is 6% when  $H = 1.25$ , find the uncertainty in  $H$ .

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# 1 Measurement and uncertainties

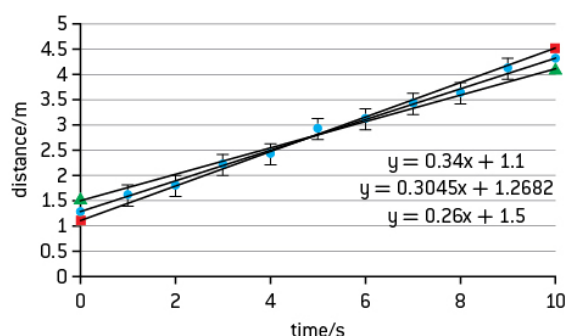
## 1.2 Uncertainties and errors

Name: .....

Date: .....

### Uncertainty of gradient and intercept

- 1 Use the following graph to state the gradient and  $y$ -intercept (with uncertainties). The values for time have 2 significant figures and no error bars shown and the values for distance have 2 significant figures with an uncertainty of  $\pm 0.2$  m.



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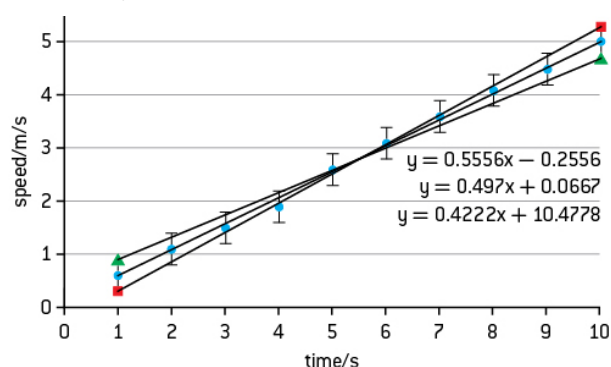
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- 2 Use the following graph to state the gradient and  $y$ -intercept (with uncertainties). The values for time have 2 significant figures and no error bars shown and the values for distance have 2 significant figures with an uncertainty of  $\pm 0.2$  m.



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## Questions

- 1 Express the following units in terms of the SI fundamental units.

- a) newton (N)
- b) watt (W)
- c) pascal (Pa)
- d) coulomb (C)
- e) volt (V)

(5 marks)

- 2 Express the following numbers to three significant figures.

- a) 257.52
- b) 0.002 347
- c) 0.1783
- d) 7873
- e) 1.997

(5 marks)

- 3 Complete the following calculations and express your answers to the most appropriate number of significant figures.

- a)  $1.34 \times 3.2$
- b)  $\frac{1.34 \times 10^2}{2.1 \times 10^3}$
- c)  $1.87 \times 10^2 + 1.97 \times 10^3$
- d)  $(1.97 \times 10^5) \times (1.0 \times 10^4)$
- e)  $(9.47 \times 10^{-2}) \times (4.0 \times 10^3)$

(5 marks)

- 4 Use the appropriate metric multiplier instead of a power of ten in the following.

- a)  $1.1 \times 10^4 \text{ V}$
- b)  $4.22 \times 10^{-4} \text{ m}$
- c)  $8.5 \times 10^{10} \text{ W}$
- d)  $4.22 \times 10^{-7} \text{ m}$
- e)  $3.5 \times 10^{-13} \text{ C}$

(5 marks)

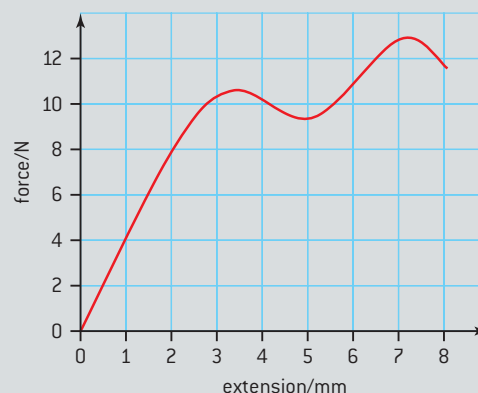
- 5 Write down the order of magnitude of the following (you may need to do some research).

- a) the length of a human foot
- b) the mass of a fly
- c) the charge on a proton
- d) the age of the universe
- e) the speed of electromagnetic waves in a vacuum

(5 marks)

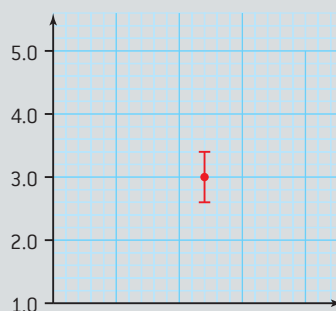
- 6 a) Without using a calculator estimate to one significant figure the value of  $\frac{2\pi \times 4.9}{480}$ .

- b) When a wire is stretched, the area under the line of a graph of force against extension of the wire gives the elastic potential energy stored in the wire. Estimate the energy stored in the wire with the following characteristic:



(4 marks)

- 7 The grid below shows one data point and its associated error bar on a graph. The x-axis is not shown. State the y-value of the data point together with its absolute and percentage uncertainty.



(3 marks)



- 8 A ball falls freely from rest with an acceleration  $g$ . The variation with time  $t$  of its displacement  $s$  is given by  $s = \frac{1}{2}gt^2$ . The percentage uncertainty in the value of  $t$  is  $\pm 3\%$  and that in the value of  $g$  is  $\pm 2\%$ . Calculate the percentage uncertainty in the value of  $s$ .

(2 marks)

- 9 The volume  $V$  of a cylinder of height  $h$  and radius  $r$  is given by the expression  $V = \pi r^2 h$ . In a particular experiment,  $r$  is to be determined from measurements of  $V$  and  $h$ . The percentage uncertainty in  $V$  is  $\pm 5\%$  and that in  $h$  is  $\pm 2\%$ . Calculate the percentage uncertainty in  $r$ .

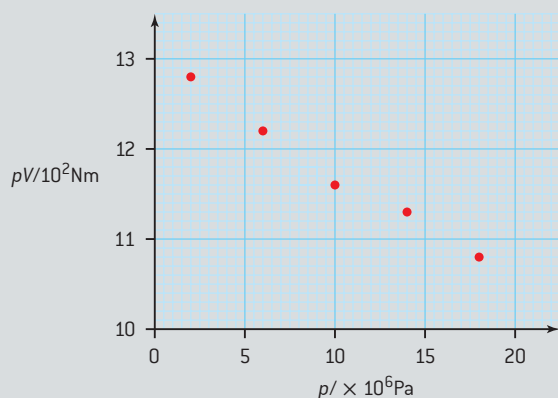
(3 marks)

10 (IB)

At high pressures, a real gas does not behave as an ideal gas. For a certain range of pressures, it is suggested that for one mole of a real gas at constant temperature the relation between the pressure  $p$  and volume  $V$  is given by the equation

$$pV = A + Bp \quad \text{where } A \text{ and } B \text{ are constants.}$$

In an experiment, 1 mole of nitrogen gas was compressed at a constant temperature of 150 K. The volume  $V$  of the gas was measured for different values of the pressure  $p$ . A graph of the product  $pV$  against  $p$  is shown in the diagram below.



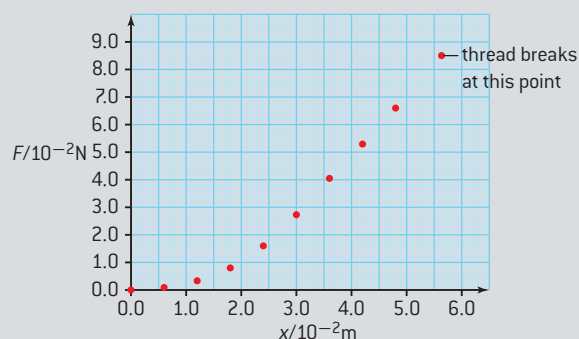
- a) Copy the graph and draw a line of best fit for the data points.
- b) Use your graph to determine the values of the constants  $A$  and  $B$  in the equation  $pV = A + Bp$

- c)  $p$  was measured to an accuracy of 5% and  $V$  was measured to an accuracy of 2%. Determine the absolute error in the value of the constant  $A$ .

(6 marks)

11 (IB)

An experiment was carried out to measure the extension  $x$  of a thread of a spider's web when a load  $F$  is applied to it.



- a) Copy the graph and draw a best-fit line for the data points.
- b) The relationship between  $F$  and  $x$  is of the form

$$F = kx^n$$

State and explain the graph you would plot in order to determine the value  $n$ .

- c) When a load is applied to a material, it is said to be *under stress*. The magnitude  $p$  of the stress is given by

$$p = \frac{F}{A}$$

where  $A$  is the cross-sectional area of the sample of the material.

Use the graph and the data below to deduce that the thread used in the experiment has a greater breaking stress than steel.

Breaking stress of steel =  $1.0 \times 10^9 \text{ N m}^{-2}$

Radius of spider web thread =  $4.5 \times 10^{-6} \text{ m}$

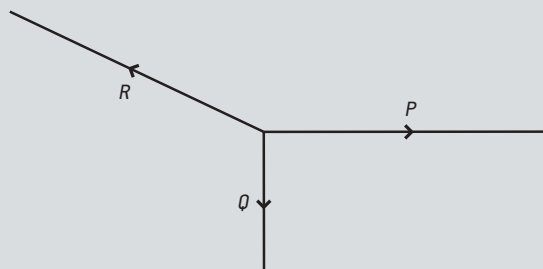
- d) The uncertainty in the measurement of the radius of the thread is  $\pm 0.1 \times 10^{-6} \text{ m}$ . Determine the percentage uncertainty in the value of the area of the thread.

(9 marks)

- 12** A cyclist travels a distance of 1200 m due north before going 2000 m due east followed by 500 m south-west. Draw a scale diagram to calculate the cyclist's final displacement from her initial position.

(4 marks)

- 13** The diagram shows three forces  $P$ ,  $Q$ , and  $R$  in equilibrium.  $P$  acts horizontally and  $Q$  vertically.



When  $P = 5.0 \text{ N}$  and  $Q = 3.0 \text{ N}$ , calculate the magnitude and direction of  $R$ .

(3 marks)

- 14** A boat, starting on one bank of a river, heads due south with a speed of  $1.5 \text{ m s}^{-1}$ . The river flows due east at  $0.8 \text{ m s}^{-1}$ .

a) Calculate the resultant velocity of the boat relative to the bank of the river.

b) The river is 50 m wide. Calculate the displacement from its initial position when the boat reaches the opposite bank.

(7 marks)

- 15** A car of mass 850 kg rests on a slope at  $25^\circ$  to the horizontal. Calculate the magnitude of the component of the car's weight which acts parallel to the slope.

(3 marks)

## Exam-style questions

1 What is the equivalent of 80 years in seconds?

- A  $10^7$       B  $10^9$       C  $10^{11}$       D  $10^{13}$

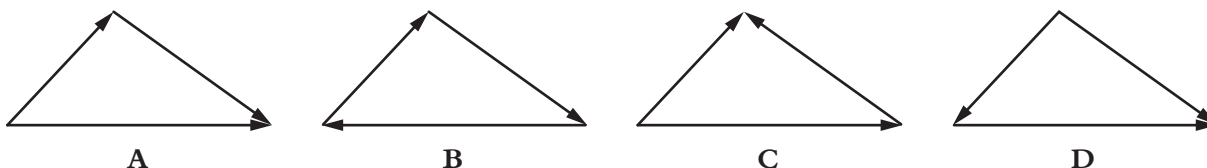
2 A book has 500 pages (printed on both sides). The width of the book excluding the covers is 2.5 cm. What is the approximate width in mm of one sheet of paper?

- A 0.01      B 0.1      C 0.5      D 1.0

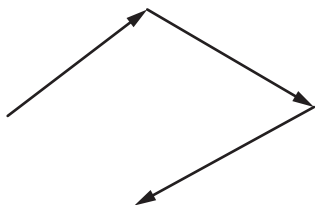
3 The speed of sound is approximately  $330 \text{ m s}^{-1}$ . A storm is 3 km away. Approximately how much later after seeing lightning will thunder be heard?

- A 0.1 s      B 1 s      C 3 s      D 10 s

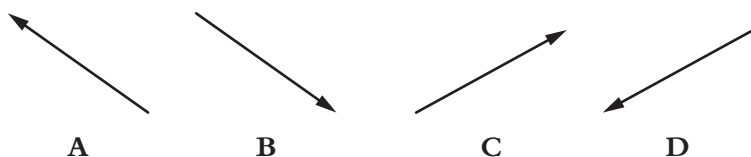
4 In which of the following diagrams do the three forces add up to zero?



5 Three forces act on a body as shown.



Which fourth force is required so that the four forces add up to zero?

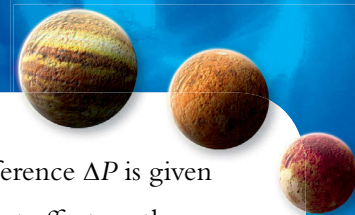


6 A force of 25 N acts normally on a surface of area  $5.0 \text{ cm}^2$ . What is the pressure on the surface in  $\text{N m}^{-2}$ ?

- A 5      B  $5 \times 10^4$       C 5.0      D  $5.0 \times 10^4$

7 The side of a cube is measured with an uncertainty of 2%. What is the uncertainty in the volume of the cube?

- A 2%      B 4%      C 6%      D 8%



- 8 The flow rate  $Q$  through a tube of length  $L$  and radius  $r$  whose ends are kept at a pressure difference  $\Delta P$  is given by  $Q = \frac{cr^4\Delta P}{L}$ , where  $c$  is a constant. The percentage uncertainty of which quantity has the largest effect on the percentage uncertainty in  $Q$ ?

- A  $r$
- B  $\Delta P$
- C  $L$
- D  $r, L$  and  $\Delta P$  each give the same contribution

- 9 The force of air resistance  $F$  on a car depends on speed  $v$  through the formula  $F = av^2 + bv$ , where  $a$  and  $b$  are constants. Which of the following graphs will result in a straight-line graph?

- A  $F$  against  $v$
- B  $F$  against  $v^2$
- C  $\frac{F}{v}$  against  $v$
- D  $\frac{F}{v}$  against  $\frac{1}{v}$

- 10 The diagram shows the temperature of a liquid before and after heating.



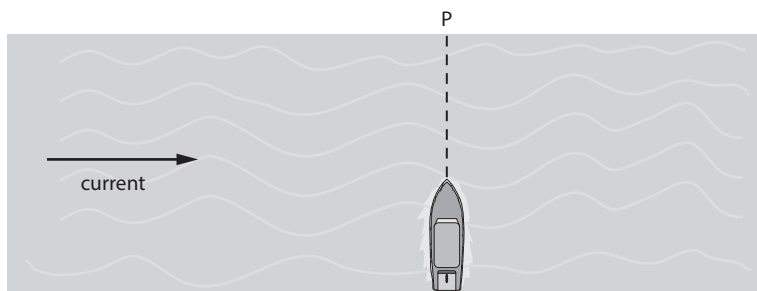
What is the best estimate for the temperature increase of the liquid?

- A  $(44.0 \pm 0.5)$  degrees
  - B  $(44 \pm 1.0)$  degrees
  - C  $(44 \pm 1)$  degrees
  - D  $(44.0 \pm 2.0)$  degrees
- 11 A student wishes to measure the acceleration of free fall by letting a ping pong ball drop from one fixed height from the floor. He measures the height. Using a stopwatch, he measures the time for the ball to drop to the floor. He then uses the equation  $h = \frac{1}{2}gt^2$  to calculate  $g$ .

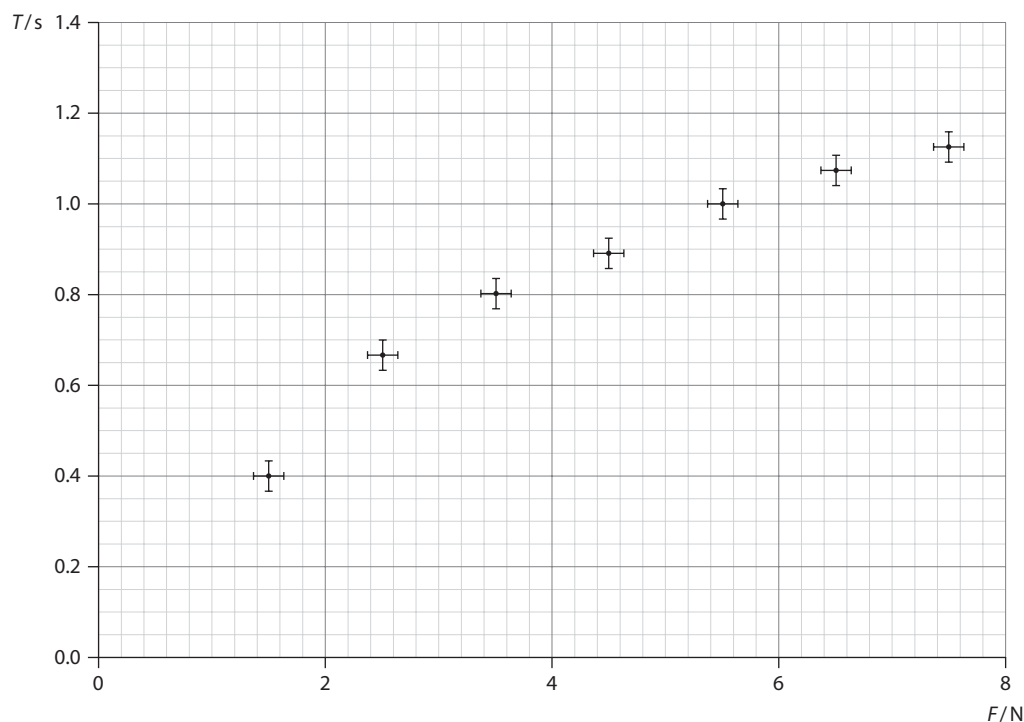
State and discuss **three** improvements to the student's lab experiment.

[6]

- 12 A man wants to cross a river with a motorboat. The speed of the motorboat in still water is  $4.0 \text{ m s}^{-1}$ . The river is 30 m wide. There is a current in the river whose speed with respect to the shore is  $3.0 \text{ m s}^{-1}$ .



- The man aims the boat towards P. Determine the distance from P at which he will reach the shore. [2]
  - A woman in an identical boat leaves from the same spot as the man but wants to land at P. Determine the direction in which she has to turn her boat to do this. [3]
  - Determine which person reaches the shore in the least time. [2]
- 13 A student investigated the oscillation period,  $T$ , of a clamped rod for various loads  $F$  applied to the rod. She graphed the following results.



- Copy the graph and draw the best-fit line for these data. [2]
- Predict the period of oscillation of the rod when no load is applied to it. [1]
- The student claims that  $T$  is proportional to  $F$ . Explain to the student how the results show she is not correct. [2]
- Determine the absolute uncertainty in  $T^2$  for the data point corresponding to  $F = 5.5 \text{ N}$ . [2]
- Another student suspects that  $T^2$  is proportional to  $F$ . By drawing a graph of  $T^2$  against  $F$  discuss whether this student's claim is correct. [4]
- Calculate the slope of the graph drawn in e, including its uncertainty. [3]

### Topic 1: Measurements and uncertainties

1. The order of magnitude of the weight of an apple is
  - A.  $10^{-4}$  N.
  - B.  $10^{-2}$  N.
  - C. 1 N.
  - D.  $10^2$  N.
2. The number of heartbeats of a person at rest in one hour, to the nearest order of magnitude is
  - A.  $10^1$ .
  - B.  $10^2$ .
  - C.  $10^3$ .
  - D.  $10^5$ .
3. The ratio  $\frac{\text{diameter of a nucleus}}{\text{diameter of an atom}}$  is approximately equal to
  - A.  $10^{-15}$ .
  - B.  $10^{-8}$ .
  - C.  $10^{-5}$ .
  - D.  $10^{-2}$ .
4. The volume of the Earth is approximately  $10^{12} \text{ km}^3$  and the volume of a grain of sand is approximately  $1 \text{ mm}^3$ . The order of magnitude of the number of grains of sand that can fit in the volume of the Earth is
  - A.  $10^{12}$ .
  - B.  $10^{18}$ .
  - C.  $10^{24}$ .
  - D.  $10^{30}$ .
5. Which **one** of the following contains three fundamental units?

A.	Metre	Kilogram	Coulomb
B.	Second	Ampere	Newton
C.	Kilogram	Ampere	Kelvin
D.	Kelvin	Coulomb	Second



6. Which **one** of the following lists a fundamental unit and a derived unit?

A.	ampere	second
B.	coulomb	kilogram
C.	coulomb	newton
D.	metre	kilogram

7. Sub-multiples of units may be expressed using a prefix. Which **one** of the following lists the prefixes in **decreasing** order of magnitude?

A.	centi-	micro-	milli-	nano-
B.	milli-	centi-	nano-	micro-
C.	centi-	milli-	micro-	nano-
D.	milli-	micro-	centi-	nano-

8. The resistive force  $F$  acting on a sphere of radius  $r$  moving at speed  $v$  through a liquid is given by

$$F = cvr$$

where  $c$  is a constant. Which of the following is a correct unit for  $c$ ?

- A. N  
 B.  $\text{N s}^{-1}$   
 C.  $\text{N m}^2 \text{s}^{-1}$   
 D.  $\text{N m}^{-2} \text{s}$
9. Which **one** of the following measurements is stated correctly to two significant digits?

- A. 0.006 m  
 B. 0.06 m  
 C. 600 m  
 D. 620 m

10. When a voltage  $V$  of 12.2 V is applied to a DC motor, the current  $I$  in the motor is 0.20 A. Which **one** of the following is the output power  $VI$  of the motor given to the correct appropriate number of significant digits?

- A. 2 W                      B. 2.4 W  
 C. 2.40 W                D. 2.44 W

11. An object has an acceleration of  $2.0 \text{ m s}^{-2}$ . Which of the following gives the change in the speed of the object after 7.00 s to the correct number of significant digits?
- A.  $14 \text{ m s}^{-1}$       B.  $14.0 \text{ m s}^{-1}$       C.  $14.00 \text{ m s}^{-1}$       D.  $14.000 \text{ m s}^{-1}$

12. The reading of a constant potential difference is made four times by a student. The readings are

1.176 V  
1.178 V  
1.177 V  
1.176 V

The student averages these readings but does not take into account the zero error on the voltmeter. The average measurement of the potential difference is

- A. precise and accurate.  
B. precise but not accurate.  
C. accurate but not precise.  
D. not accurate and not precise.
13. An ammeter has a zero offset error. This fault will affect
- A. neither the precision nor the accuracy of the readings.  
B. only the precision of the readings.  
C. only the accuracy of the readings.  
D. both the precision and the accuracy of the readings.
14. Both random and systematic errors are present in the measurement of a particular quantity. What changes, if any, would repeated measurements of this quantity have on the random and systematic errors?

	Random	Systematic
A.	reduced	reduced
B.	reduced	unchanged
C.	unchanged	reduced
D.	unchanged	unchanged

15. A student measures a distance several times. The readings lie between 49.8 cm and 50.2 cm. This measurement is best recorded as
- A.  $49.8 \pm 0.2 \text{ cm}$ .  
B.  $49.8 \pm 0.4 \text{ cm}$ .  
C.  $50.0 \pm 0.2 \text{ cm}$ .  
D.  $50.0 \pm 0.4 \text{ cm}$ .

16. When a force  $F$  of  $(10.0 \pm 0.2)$  N is applied to a mass  $m$  of  $(2.0 \pm 0.1)$  kg, the percentage uncertainty attached to the value of the calculated acceleration  $F/m$  is
- A. 2%. B. 5%. C. 7%. D. 10%.
17. The radius of a loop is measured to be  $(10.0 \pm 0.5)$  cm. Which of the following is the best estimate of the uncertainty in the calculated area of the loop?
- A. 0.25% B. 5% C. 10% D. 25%
18. The density of a metal cube is given by the expression  $\rho = \frac{M}{V}$  where  $M$  is the mass and  $V$  is the volume of the cube. The percentage uncertainties in  $M$  and  $V$  are as shown below.

$M$	12%
$V$	4.0%

The percentage uncertainty in the calculated value of the density is

- A. 3.0%. B. 8.0%. C. 16%. D. 48%.
19. The mass of a body is measured with an uncertainty of 2.0% and its volume with an uncertainty of 10%. What is the uncertainty in the density of the body?
- A. 0.2% B. 5.0% C. 12% D. 20%
20. The sides of a cube are each of length 1.00 m. Each side is measured with an uncertainty of 2%. The absolute uncertainty in the volume of the cube is
- A.  $0.02 \text{ m}^3$ . B.  $0.06 \text{ m}^3$ . C.  $0.2 \text{ m}^3$ . D.  $0.6 \text{ m}^3$ .
21. The volume  $V$  of a cylinder of height  $h$  and radius  $r$  is given by the expression

$$V = \pi r^2 h.$$

In a particular experiment,  $r$  is to be determined from measurements of  $V$  and  $h$ . The uncertainties in  $V$  and in  $h$  are as shown below.

$V$	7%
$h$	3%

The approximate uncertainty in  $r$  is

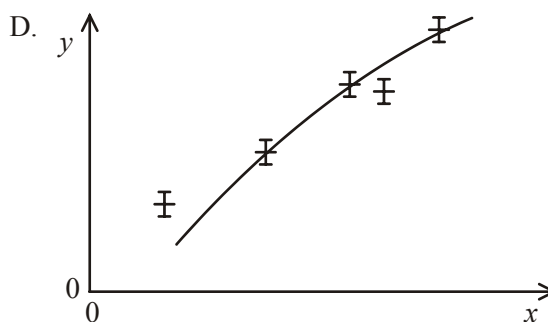
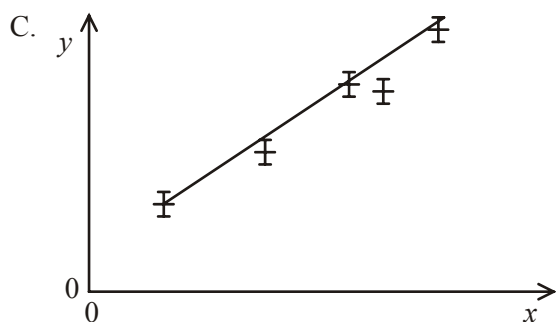
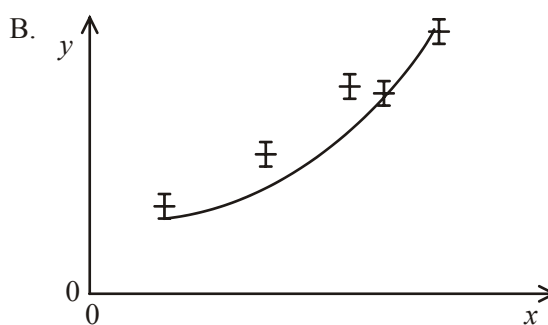
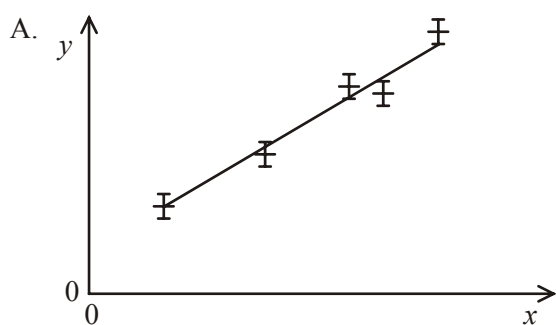
- A. 10%.
- B. 5%.
- C. 4%.
- D. 2%.

22. An object falls from rest with an acceleration  $g$ . The variation with time  $t$  of the displacement  $s$  of the object is given by

$$s = \frac{1}{2}gt^2.$$

The uncertainty in the value of the time is  $\pm 6\%$  and the uncertainty in the value of  $g$  is  $\pm 4\%$ . The best estimate for the uncertainty of the position of the object is

- A. 5%.  
 B. 8%.  
 C. 10%.  
 D. 16%.
23. Which of the following graphs shows the best-fit line for the plotted points?



24. The time period  $T$  of oscillation of a mass  $m$  suspended from a vertical spring is given by the expression

$$T = 2\pi \sqrt{\frac{m}{k}}$$

where  $k$  is a constant.

Which **one** of the following plots will give rise to a straight-line graph?

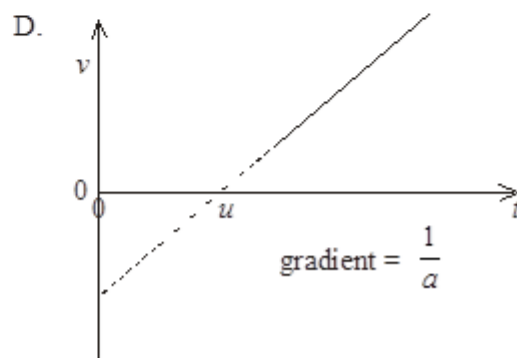
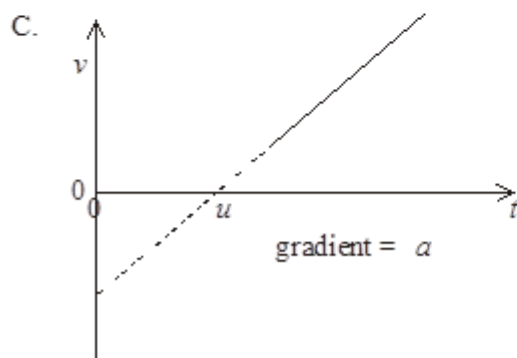
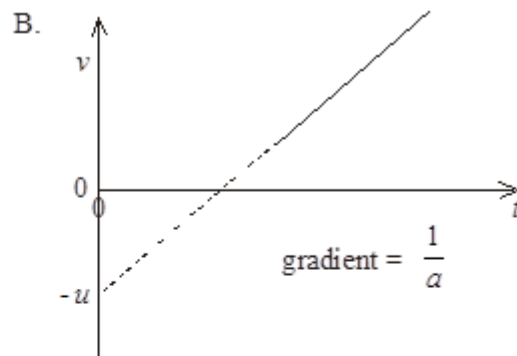
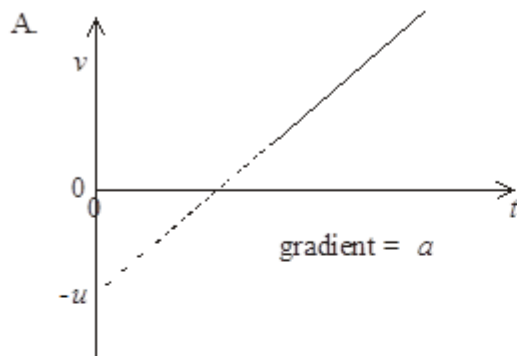
- A.  $T^2$  against  $m$   
 B.  $\sqrt{T}$  against  $\sqrt{m}$   
 C.  $T$  against  $m$   
 D.  $\sqrt{T}$  against  $m$

25. The variation with time  $t$  of the speed  $v$  of an object is given by the expression

$$v = u + at$$

where  $u$  and  $a$  are constants.

A graph of the variation with time  $t$  of speed  $v$  is plotted. Which **one** of the following correctly shows how the constants may be determined from this graph?



26. Which of the following contains three scalar quantities?

A.	mass	charge	speed
B.	density	weight	mass
C.	speed	weight	charge
D.	charge	weight	density

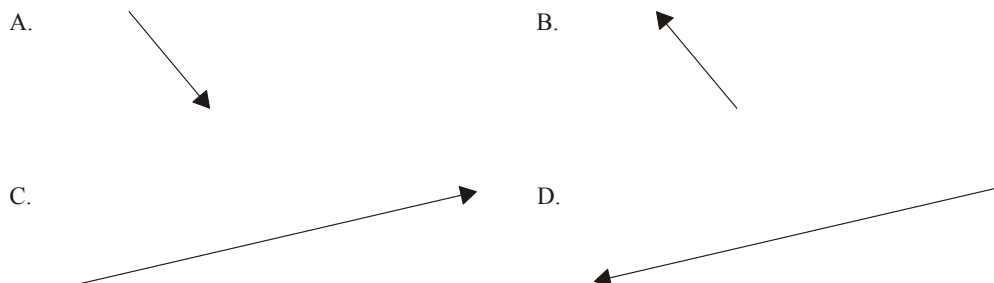
27. Which **one** of the following includes three vector quantities?

A.	velocity	weight	field strength
B.	weight	mass	field strength
C.	velocity	energy	weight
D.	mass	energy	field strength

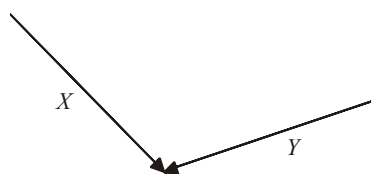
28. The diagram below shows two vectors,  $x$  and  $y$ .



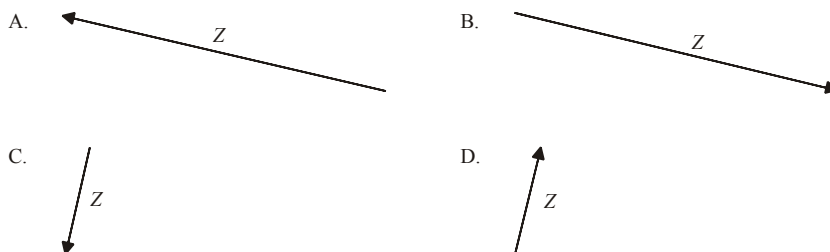
Which of the vectors below best represents the vector  $c$  that would satisfy the relation  $c = x + y$ ?



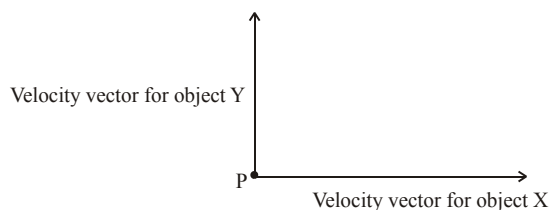
29. The diagram below shows two vectors  $X$  and  $Y$ .



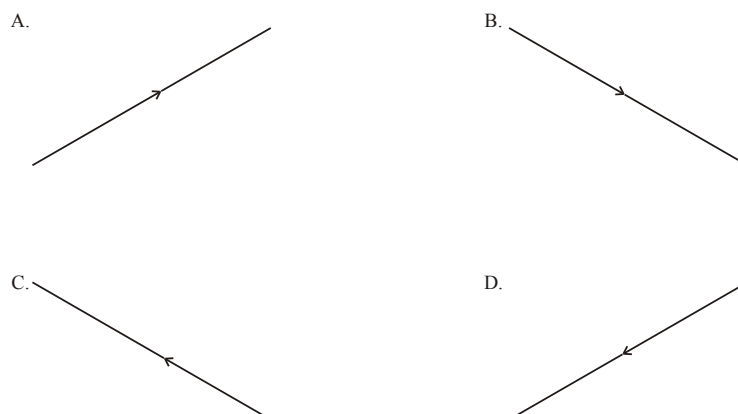
Which of the following best represents the vector  $Z = X - Y$ .



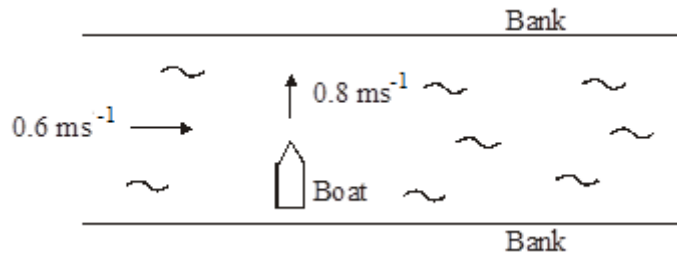
30. Two objects X and Y are moving away from the point P. The diagram below shows the velocity vectors of the two objects.



Which of the following velocity vectors best represents the velocity of object X relative to object Y?



31. The diagram below shows a boat that is about to cross a river in a direction perpendicular to the bank at a speed of  $0.8 \text{ m s}^{-1}$ . The current flows at  $0.6 \text{ m s}^{-1}$  in the direction shown.

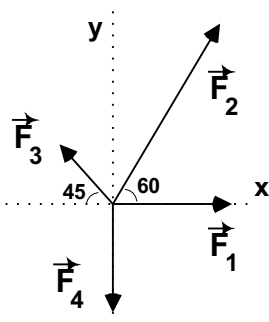


The magnitude of the displacement of the boat 5 seconds after leaving the bank is

- A. 3 m.  
B. 4 m.  
C. 5 m.  
D. 7 m.
32. Two forces of magnitudes 7 N and 5 N act at a point. Which **one** of the following is **not** a possible value for the magnitude of the resultant force?
- A. 1 N  
B. 3 N  
C. 5 N  
D. 7 N

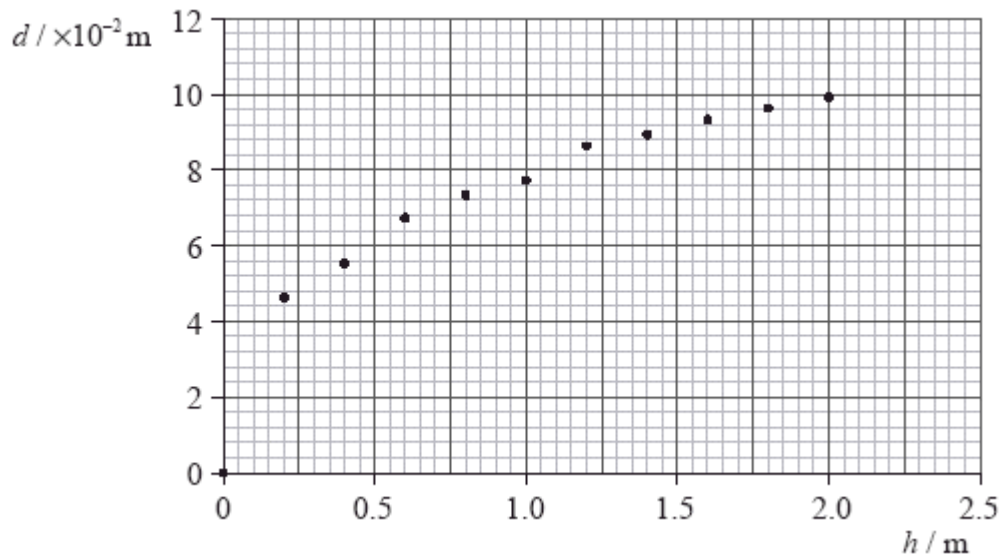
### Short answer questions

1. Find the resultant force of the following set of forces graphically and algebraically: 1) 200 N to the right; 2) 300 N @  $60^\circ$  above the horizontal to the right. 3) 100 N @  $45^\circ$  above the horizontal to the left; 4) 200 N vertically downward.



## 2. Data analysis question.

Gillian carried out an experiment to investigate the craters formed when steel balls are dropped into sand. To try and find the relationship between the diameter of the crater and the energy of impact of steel balls of the same diameter, she dropped a steel ball from different heights  $h$  into sand and measured the resulting diameter  $d$  of the crater. The data are shown plotted below.



- (a) The uncertainty in the measurement of  $d$  is  $\pm 0.40$  cm; the uncertainty in  $h$  is too small to be shown. Draw error bars for the data point (0.2, 0.047) and the data point (2.0, 0.10).

(2)

- (b) Draw a best-fit line for the data points.

(2)

- (c) The original hypothesis, made by Gillian, was that the diameter of the crater is directly proportional to the energy of impact of the steel balls. Explain why the data does not support this hypothesis.

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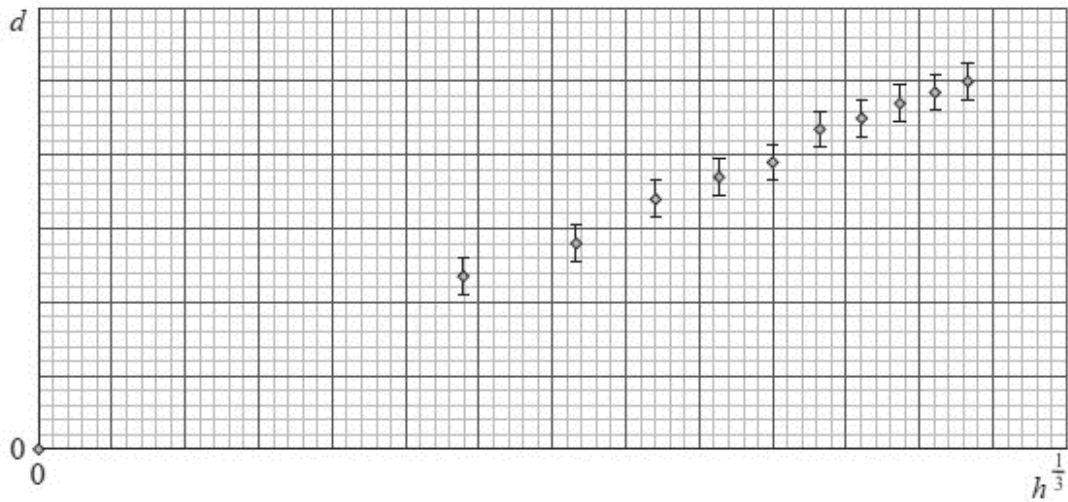
(3)

- (d) Since Gillian's data did not support her hypothesis, she researched to find alternative hypotheses. She found that there are two theories used to predict a relationship between  $d$  and  $h$ . In order to find which theory is best supported by the data, she processed the data in two separate ways. The processed data are shown below.



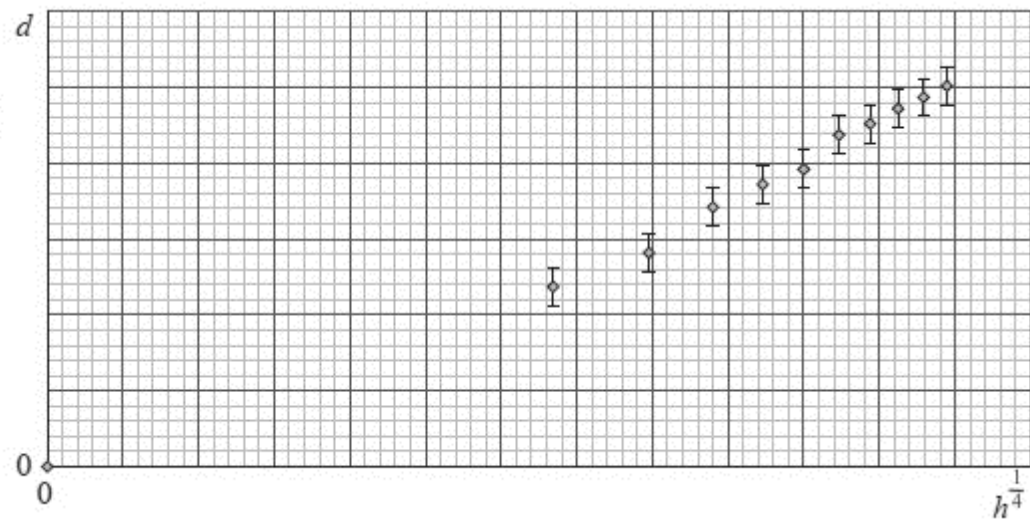
**Theory 1**

Predicts that  
 $d = \text{const}(h)^{\frac{1}{3}}$



**Theory 2**

Predicts that  
 $d = \text{const}(h)^{\frac{1}{4}}$



- (i) Draw a line of best-fit on each graph.

(2)

- (ii) State and explain which theory is best supported by the student's data.

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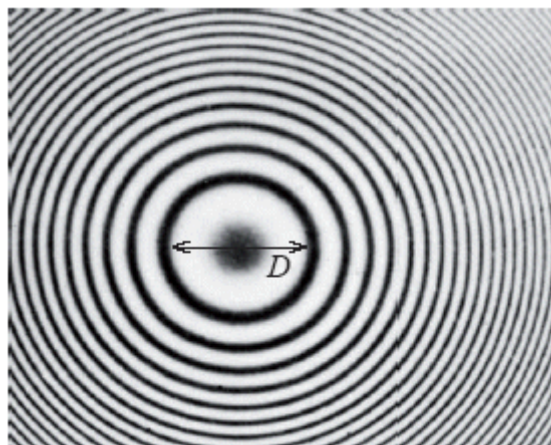
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(2)

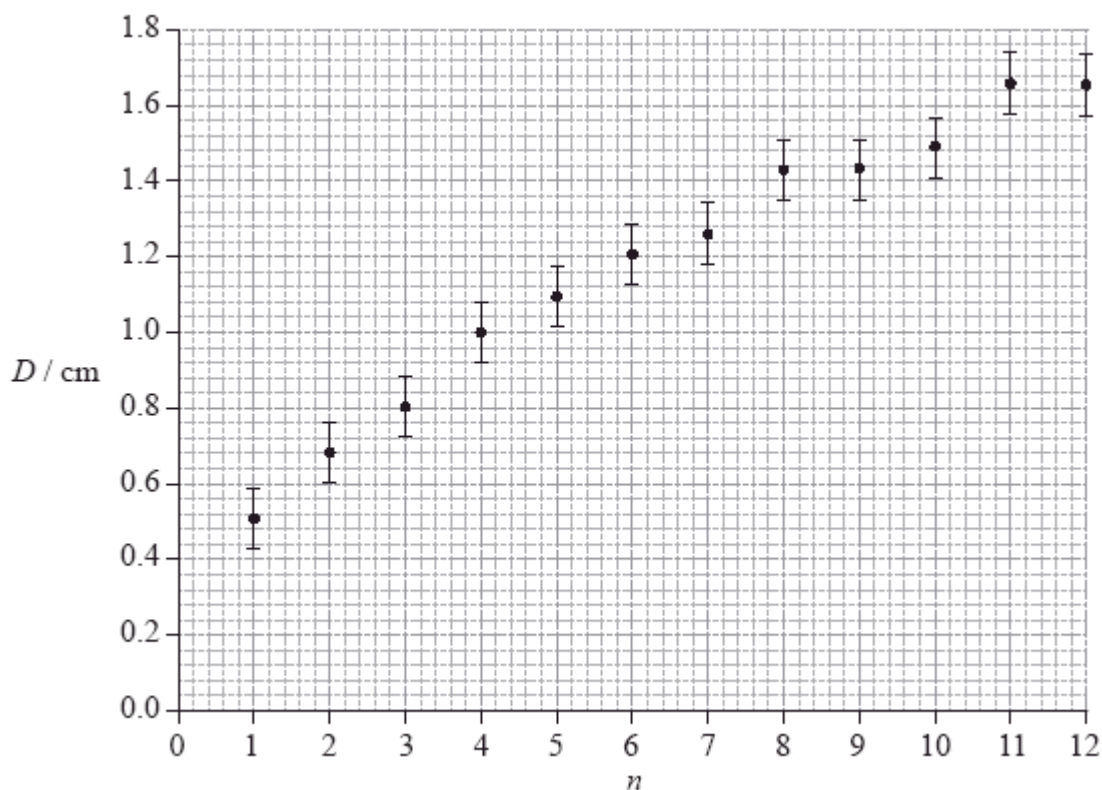
(Total 11 marks)

### 3. 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.



- (a) State **one** piece of evidence that shows that  $D$  is not proportional to  $n$ .

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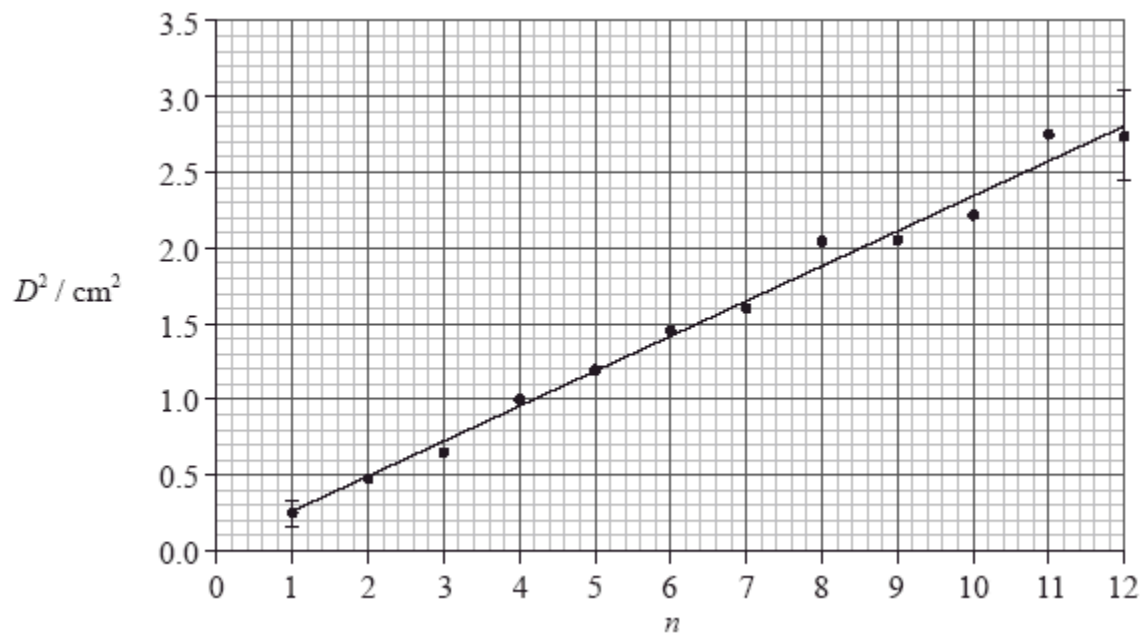
(1)

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

(2)

- (c) Theory suggests that  $D^2 = kn$ .

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 first graph, calculate the percentage uncertainty in  $D^2$ , of the ring  $n = 7$ .

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(2)

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

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(1)

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

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(4)

- (iv) State the unit for the constant  $k$ .

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(1)

(Total 11 marks)