Paper 5

A Level Physics

Planning, Analysis and Evaluation
Complete Solution

A.N. Chowhan

adorn advertising

Paper 5

A Level Physics

Planning, Analysis and Evaluation
Complete Solution

A.N. Chowhan

adorn advertising

PUBLISHED BY ADORN ADVERTISING LIMITED

335-B, Shad Bagh, Lahore, Pakistan
Phone: 0333 4030389; 0321 4452188

http://www.adornadvertising.co.uk

contactus@adornadvertising.co.uk

335-B, Shad Bagh, Lahore, Pakistan

Phone: 0333 4030389; 0321 4452188

contactus@adornadvertising.co.uk

Printed in Pakistan by

Crystal Printers

Islamabad

051-2807225

First published 2016

To all those people who are not afraid of doing things no one has ever done before.

CONTENTS

INTRODUCTION

Paper 5 consists of two questions (each carrying 15 marks) and the time duration of this paper is 1 hour and 15 minutes.

The examination paper does not require laboratory facilities.

The first question is the planning question, in which candidates are required to design an experimental investigation of a given problem, and answer the question with a labelled diagram and an extended piece of writing.

The second question is the analysis, conclusions and evaluation question, in which candidates are given an equation and some experimental data. From these they are required to find the values for different constants. They are also required to estimate the uncertainties in their answers.

Some questions on this paper may be set in areas of Physics that are difficult to investigate experimentally in school laboratories, but no question requires prior knowledge of theory or equipment that is beyond the syllabus: candidates are given all the information that they need.

Note: Average score in this paper to secure A grade is **21** (out of 30).

QUESTION 1: PLANNING

Generic Mark Scheme

(Before October/November 2015)

Breakdown of skills	Mark allocation
Defining the problem	3 marks
Methods of data collection	5 marks
Method of analysis	2 marks
Safety considerations	1 mark
Additional detail	4 marks

(After October/November 2015)

Breakdown of skills	Mark allocation
Defining the problem	2 marks
Methods of data collection	4 marks
Method of analysis	3 marks
Additional detail including safety considerations	6 marks

Note:

In the mark scheme of question 1:

- P denotes problem-defining mark
- M denotes method-of-data-collection mark
- A denotes method-of-analysis mark
- S denotes safety-consideration mark
- D denotes additional-detail mark

In order to understand the following rules better, first go through sample question 1.1 and its solution (on page 6).

1.1 Rules for Defining the Problem (P-marks)

1 The independent variable should be the one that can be varied easily, and the dependant variable should be the one that varies by itself as the independent variable is varied (i.e. it does not need to be varied separately).

2 The independent and dependent variables should both be there in the relationship given in the question.

3 All those variables (physical quantities) upon which the dependent and/or independent variables depend, directly or indirectly, should be kept constant, because: when these variables vary, the dependent and/or independent variables also vary with them. These variables may or may not be there in the given relationship.

Note: Sometimes, any one of the two quantities in the given relationship may be chosen as the independent variable, and the other quantity, as the dependent variable.

1.2 Rules for Method of Data Collection (M-marks)

1 A clear labelled diagram, illustrating the **assembled** experimental setup, should be drawn in the space provided.

Note: Sometimes (e.g. in the experiments of electricity), a separate circuit diagram containing conventional symbols of the circuit components should also be drawn.

2 Method of varying the independent variable should be described if appropriate.

3 Methods of determining the dependent and independent variables should be described, and the names of the measuring instruments to be used should also be stated explicitly.

Note: The measuring instrument chosen should be appropriate; that is, it should be able to measure the required physical quantity with appropriate accuracy (i.e. with reasonably small percentage uncertainty).

4 Method of minimising the environmental effect (e.g. background reading) on the readings to be taken should be described if appropriate.

5 Methods of keeping other variables constant should be described if appropriate.

For full marks to be scored in this section, the overall arrangement should be workable; that is, it should be possible to collect the required data without undue difficulty if the apparatus is assembled as described.

1.3 Rules for Describing Method of Analysis (A-marks)

1 From the equation given in the question, another equation should be written (either by simply rearranging the given equation or by using logarithmic identities) so that a straight-line graph may be obtained between (the functions of) dependent and independent variables.

2 The functions of dependent and independent variables, to be taken along the y- and x-axes respectively, should be identified.

3 The expressions for the gradient and y-intercept of the graph should be identified.

4 If the experiment is designed to test a relationship, then a statement of the following form should be given:

"If the graph turns out to be straight-line and passes/does not pass through the origin, then the suggested relationship is correct".

Note: Sometimes a statement like: "If the graph turns out to be straight-line, then the suggested relationship is correct" may also serve the purpose.

5 If the experiment is designed to determine a value for some constant, then the constant **must** be made the subject of the equation (from the expression of gradient or y-intercept).

1.4 Rule for Safety Considerations (S-mark)

Both, the risk of the experiment and the safety precaution to be taken to minimize the risk, should be stated.

1.5 Additional Detail Marks (D-marks)

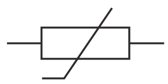
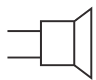
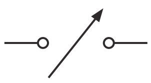
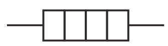
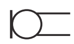
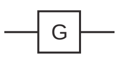
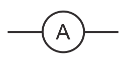
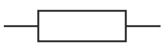
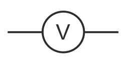
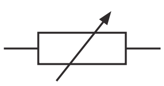
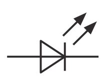
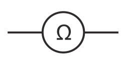
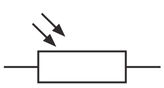
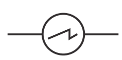
These marks may be awarded for:

- identifying which additional variable is to be kept constant;
- describing method how additional variable is to be kept constant;
- describing method to reduce random and/or systematic errors in the measurements to be taken (i.e. to increase the precision and/or accuracy in the results);
- drawing a separate diagram of a circuit needed to make a particular measurement;
- identifying an additional risk of the experiment and stating a safety precaution to minimise it.

Note: A candidate can score only **four** D-marks at the most.

1.6 Some Important Electrical Components and Their Circuit Symbols

The table below shows some electrical components and their circuit symbols that are important from the examination point of view.

Component	Symbol	Component	Symbol	Component	Symbol
power supply		thermistor		loudspeaker	
variable power supply		heater		microphone	
a.c. power supply		Inductor (or coil)		motor	
signal generator		transformer		galvanometer	
junction of conductors		lamp		ammeter	
fixed resistor		diode		voltmeter	
variable resistor (or rheostat)		light-emitting diode (LED)		ohmmeter	
light-dependant resistor (LDR)		electric bell		oscilloscope (c.r.o.)	

Advantage of Variable D.C. Power Supply over Simple D.C. Power Supply

- The output voltage of variable power supply, and therefore the current in the circuit, can be controlled by adjusting its voltage knob; hence no need for a separate variable resistor (or rheostat) in the circuit to control current.

Advantages of Signal Generator over A.C. Power Supply

- The frequency of output voltage of signal generator can be increased or decreased to produce noticeable effects (e.g. in the experiments involving electromagnetic induction).
- The output (peak or rms) voltage of signal generator, and therefore the current in the circuit, can be controlled by adjusting its voltage knob; hence no need for a separate variable resistor (or rheostat) in the circuit to control current.

Advantage of Storage C.R.O. over Voltmeter

- A storage c.r.o. can record a rapidly changing input voltage signal, and then display it on its screen as a still trace (i.e. voltage vs. time graph).

Note: If a component is not represented by its conventional symbol in the circuit diagram, then it must be labelled.

Sample Question 1.1 *(P05/M/J/07)*

It is useful to know how the speed of an object is affected by its size when it moves through liquid in a confined space. In a laboratory this can be modelled by dropping small steel balls through oil. It is suggested that the terminal velocity v is related to the radius r of a steel ball by the equation:

$$v = kr^2$$

where k is a constant. Design a laboratory experiment to investigate whether v is related to r as indicated in the above equation. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) how the radius of the steel ball would be measured,

(c) how the terminal velocity of the steel ball in oil would be measured,

(d) the control of variables,

(e) how the data would be analysed,

(f) any safety precautions that you would take. [15]

Conventions within the Account

BRACKETS

Where brackets are shown in the account, **not** in the diagram, the candidate is not required to give the bracketed information in order to earn the available marks. Text written inside the brackets makes only the part of explanation not required.

BLUE TEXT

In the account, blue text makes the part of information that has already been indicated in the diagram; so the candidate is not required to give the blue-text information again in order to earn the available marks.

UNDERLINING

In the account, underlining indicates information that is essential for marks to be awarded.

Solution

In this experiment, I will:

- vary r and determine v (for each value of r). [P + P]

  (i.e. r is the independent variable, and v is the dependent variable.)

- keep temperature (of the oil) <u>constant</u>. [P]

  (so that the density of the oil upon which the drag force depends remains constant.)

To collect and analyse the data, I will take the following steps:

1 Build the experimental setup as shown in Fig. 1.1.1. In the experimental setup:

  - the purpose of using the long tube of oil, having two marks on it, is to measure the time taken for the ball to fall from one mark to the other when dropped through the oil. [M]

  - the purpose of using the clear oil is to view the ball, moving through the oil, with ease. [D]

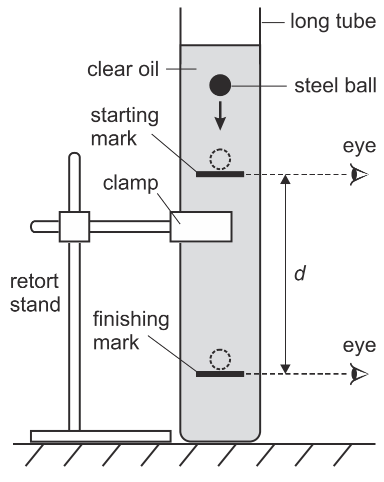


Figure 1.1.1

  - the purpose of using the retort stand and clamp arrangement is to hold the long tube in the upright position. [D]

When building the experimental setup, I will:

- draw the starting mark well below the oil surface to make sure that the ball has attained terminal velocity before it reaches the mark. [M]
- keep starting and finishing marks as far apart as possible so that the time *t* taken for the ball to fall through the distance *d* is (reasonably) large, and hence the percentage uncertainty in its measurement is (reasonably) small. [D + D]
- use a spirit level to make sure that the long tube is vertical. [D]

2 Measure distance *d* between the starting and finishing marks with a metre rule.

3 Take steel balls of different diameters.

4 Wash and dry them. [D]

5 Measure the diameter of a steel ball with a micrometer screw gauge. [M]

When measuring the diameter, I will take multiple readings in different directions and find the average value. [D]

6 Determine the radius *r* of the ball by dividing its average diameter by 2.

7 Drop the ball near the oil surface.

8 With a stopwatch, measure the time *t* taken for the ball to fall from the starting mark to the finishing mark. [M]

When measuring the time *t*, I will avoid parallax error by keeping the eye at right level as shown in Fig. 1.1.1. [D]

9 Retrieve the ball using a magnet. [D]

10 Repeat steps **7** and **8** for the same ball and find the average value of *t*. [D]

11 Determine the terminal velocity *v* of the ball using the formula:

$$v = \frac{d}{t}$$ [M]

12 Take another steel ball of different diameter.

13 Repeat the procedure from step **5** to **11**, and thus obtain about 6 sets of results.

14 From the equation given in the question:

$$v = kr^2$$

it follows that the gradient of v vs. r^2 graph is equal to k. [D]

15 Plot a graph of v against r^2. [A]

16 If the graph turns out to be straight-line and passes through the origin, then the suggested relationship is correct. [A]

Safety Precautions:

- To avoid splashing, I will drop the ball near the oil surface. [S]
- To prevent falling and rolling of the steel balls on the floor, I will keep them in a tray. [D]

Further additional-detail points might include:

- Allow oil to stand so that air bubbles escape/ball may trap air bubbles.

Note: A candidate can score only **four** D-marks at the most. However, as there is no negative marking in this paper, candidates are advised to provide as much additional detail in their accounts as they can think of.

Sample Question 1.2 *(P52/M/J/11)*

A student wishes to investigate projectile motion. A small ball is rolled with velocity v along a horizontal surface. When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface. The vertical displacement of the ball is p and the horizontal displacement of the ball is q, as shown in Fig. 1.2.1.

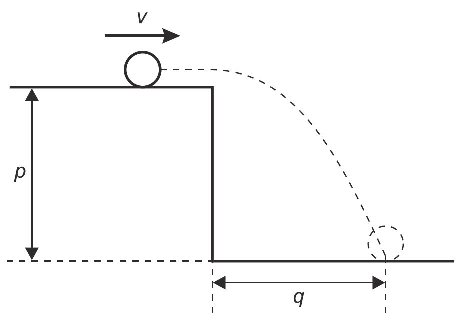


Figure 1.2.1

It is suggested that:

$$gq^2 = 2pv^2$$

where g is the acceleration of free fall. Design a laboratory experiment to investigate how q is related to p and how v may be determined from the results. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken. [15]

Solution

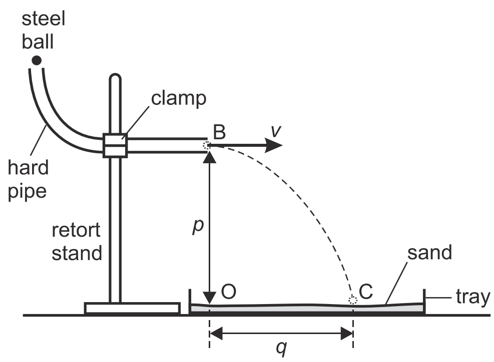


Figure 1.2.2

In this experiment, I will:

- vary p and measure q (for each value of p). [P + P]

  (i.e. p is the independent variable, and q is the dependent variable.)

- keep (horizontal) velocity v constant. [P]

To collect and analyse the data, I will take the following steps:

1 Build the experimental setup as shown in Fig. 1.2.2. In the experimental setup:

- the purpose of using the arrangement of retort stand, clamp and hard pipe is to vary p. [M]
- the purpose of using the tray of sand is to determine the position of the ball as it lands on the sand surface. [M]
- the purpose of using the hard pipe, which is half curved and half straight, is to make sure that the velocity of the ball, as it leaves the pipe, has horizontal component only. [D]

When building the experimental setup, I will:

- use a spirit level to make sure that the straight part of the pipe is horizontal.
- use a plumb line to draw, on the sand surface, a small mark O right below the end B of the pipe. [D]

2 Measure distance p between end B and mark O with a metre rule. [M]

3 Take a steel ball to minimise the effect of air resistance. [D]

4 Release the ball from the top end A of the pipe. The ball will roll, fall and land on the sand surface producing a crater at point C.

5 Measure the distance q between point C and mark O with a metre rule. [D]

6 Repeat steps **4** and **5** for same p and find the average value of q. [D]

7 Change the height of the clamp so that the end B remains right above the mark O.

8 Repeat the procedure from step **4** to **6**, and thus obtain about 6 sets of results. When repeating the procedure to collect the data, I will:

- always use the spirit level to make sure that the straight part of the pipe is horizontal. [M]
- always release the ball from the top end A of the pipe (to make sure that the velocity v remains constant). [M]

9 The equation given in the question can be rearranged as:

$$q^2 = \left(\frac{2v^2}{g}\right)p$$

From the above equation, it follows that the gradient of q^2 vs. p graph is equal to the expression: $\dfrac{2v^2}{g}$.

10 Plot a graph of q^2 against p. [A]

11 If the graph turns out to be straight-line and passes through the origin, then the suggested relationship is correct. [D]

12 Find the gradient of the graph, and determine v using the equation:

$$v = \sqrt{\frac{g \times \text{gradient}}{2}}$$ [A]

Safety Precaution:

To prevent injury from the rolling ball, I will use safety screen. [S]

Further additional-detail points might include:

- Detail on method of determining position of ball; e.g. slow motion playback including scale.

Sample Question 1.3 *(P51/M/J/10)*

A hammer is often used to force a nail into wood. The faster the hammer moves, the deeper the nail moves into the wood. This can be represented in a laboratory by a mass falling vertically onto a nail. It is suggested that the depth d of the nail in the wood (see Fig. 1.3.1) is related to the velocity v of the mass at the instant it hits the nail by the equation:

$$d = kv^n$$

where k and n are constants.

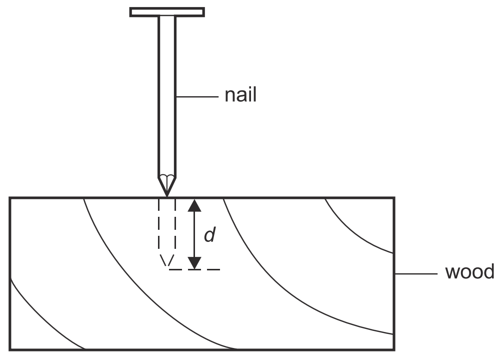


Figure 1.3.1

Design a laboratory experiment to investigate the relationship between v and d so as to determine a value for n. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken. [15]

Solution

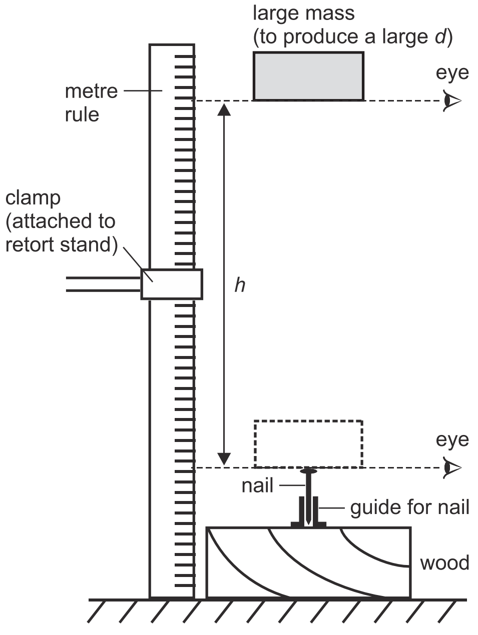


Figure 1.3.2

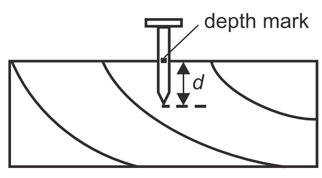


Figure 1.3.3 (enlarged view)

In this experiment, I will:

- vary v and measure d (for each value of v). [P]
  (i.e. v is the independent variable, and d is the dependent variable.)
- keep the mass (falling onto the nail) constant. [P]
- also keep the wood constant. [P]
  (i.e. use the same wood type.)

To collect and analyse the data, I will take the following steps:

1 Build the experimental setup as shown in Fig. 1.3.2. In the experimental setup:
- the mass is positioned above the nail so that it falls onto the centre of the nail when dropped. [M]
- the purpose of using the vertical guide, the internal diameter of which is only slightly greater than the diameter of the nail, is to make sure that the nail goes straight into the wood when hit by the falling mass. [D]
- the purpose of using the large mass is to produce a large depth d, and thus reduce the percentage uncertainty in its measurement. [D + D]

When building the experimental setup, I will use a set square to make sure that the nail is vertical. [D]

2 Hold the mass at a height h above the head of the nail.

3 Measure h with a metre rule. [M]

When measuring h, I will avoid parallax error by keeping the eye at right level as shown in Fig. 1.3.2. [D]

4 Drop the mass from height h. The mass will fall, hit and force the nail into the wood to depth d.

5 Determine the velocity v of the mass with which it hits the nail using the equation:

$$v^2 - u^2 = 2gh$$

where $u = 0$ and $g = 9.81 \text{ m s}^{-2}$. [M]

6 Mark the nail (with a thin hacksaw blade) at a point up to which it goes into the wood, as shown in Fig. 1.3.3, (and then pull it out). [M]

7 Measure the depth d with vernier calipers. [D]

8 Repeat steps **4, 6,** and **7** for same h and find the average value of d. [D]

When repeating the steps **4, 6** and **7**, I will use different part of the wood every time. [D]

9 Change the height of the falling mass (to vary v). [M]

10 Repeat the procedure from step **3** to **8**, and thus obtain about 6 sets of results.

11 From the equation given in the question, it can be shown that:

$$\lg d = n \lg v + \lg k$$ [D]

From the above equation, it follows that the gradient and y-intercept of $\lg d$ vs. $\lg v$ graph are equal to n and $\lg k$ respectively.

12 Plot a graph of $\lg d$ against $\lg v$. [A]

13 If the graph turns out to be straight-line, then the suggested relationship is correct. [D]

(**Note:** The graph line might or might not pass through the origin; it all depends upon the value of k. For example: if $k = 1$, then the graph will pass through the origin, as $\lg 1 = 0$; otherwise not.)

14 Determine the value of n by finding the gradient of the graph, as:

$$n = \text{gradient}$$ [A]

Safety Precaution:

To prevent injury from the falling mass, I will keep my hands and feet well away from it. [S]

Further additional-detail points might include:

- Use of microscope when measuring d.

Sample Question 1.4 *(P51/M/J/13)*

A student is investigating the flow of water through a horizontal tube. The rate Q (volume per unit time) at which water flows through a tube depends on the pressure difference per unit length across the tube. The student has the use of a metal can with two holes. A narrow horizontal tube goes through the hole in the side of the can. The can is continuously supplied with water from a tap. The level of water in the can is kept constant by the position of a wide vertical tube which passes through the hole in the bottom of the can as shown in Fig. 1.4.1. Both tubes may be moved along the holes.

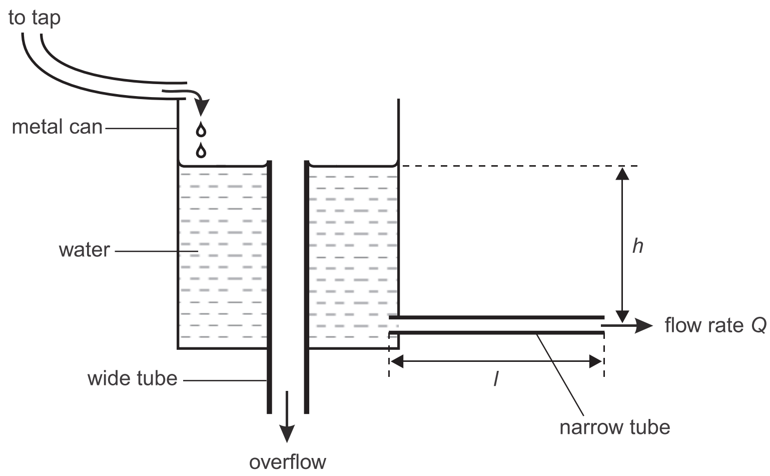


Figure 1.4.1

It is suggested that the relationship between the flow rate Q of water through the narrow horizontal tube and the vertical height h is:

$$Q = \frac{2\pi\rho g h d^4}{\eta l}$$

where ρ is the density of water, g is the acceleration of free fall, d is the internal diameter of the tube, l is the length of the tube and η is a constant. Design a laboratory experiment to test the relationship between Q and h and determine a value for η. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken. [15]

Solution

In this experiment, I will:

- vary h and determine Q (for each value of h). [P + P]
- keep l <u>constant</u>. [P]
- also keep the <u>temperature of water constant</u>. [D]

  (so that the density ρ of water remains constant.)

To collect and analyse the data, I will take the following steps:

1. Take some water in a measuring cylinder and record its volume V_w.
2. Measure the combined mass m_{cw} of the cylinder and water with a digital balance.
3. Empty the cylinder and measure its mass m_c with the digital balance.

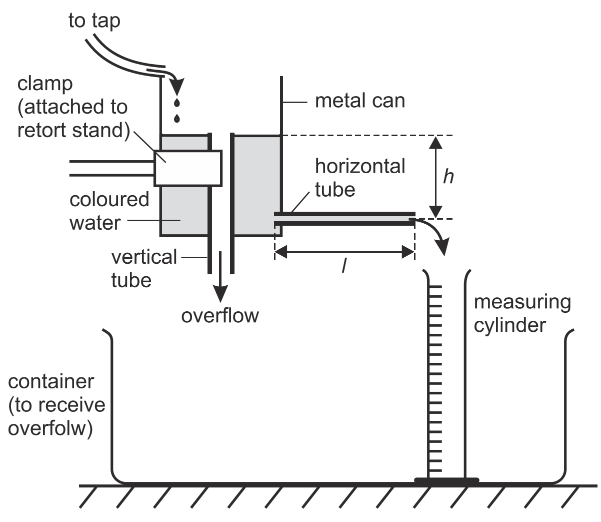


Figure 1.4.2

4 Find the mass m_w of the water using the equation:

$$m_w = m_{cw} - m_c$$

5 Determine the density ρ of water using the formula:

$$\rho = \frac{m_w}{V_w}$$ [D]

(**Note:** All steps, from **1** to **5**, are required to score this mark.)

6 Measure the internal diameter *d* of the narrow tube with vernier calipers. [M]

When measuring *d*, I will take multiple readings in different directions and find the average value. [D]

7 Measure the length *l* of the narrow tube with a rule.

8 Build the experimental setup as shown in Fig. 1.4.2. In the experimental setup:

- the purpose of using the measuring cylinder is to receive and measure the volume of water flowing out of the narrow tube. [M]
- the purpose of using the coloured water is to take the reading of volume of water with ease. [D]
- the purpose of using the large container is to receive the overflow. [D]
- the purpose of using the retort stand and clamp arrangement is to hold the steel can in position above the container. [D]

When building the experimental setup, I will use a spirit level to make sure that the narrow tube is horizontal. [D]

9 Measure the vertical height *h* of the wide tube with the rule. [M]

10 Note the capacity *V* of the measuring cylinder.

11 With a stopwatch, measure the time *t* taken for the water flowing out of the horizontal tube to fill the empty measuring cylinder. [M]

12 Repeat step **11** for same *h* and find the average value of *t*. [D]

13 Determine the flow rate *Q* of water through the horizontal tube using the formula:

$$Q = \frac{V}{t}$$

14 Change the position of the vertical tube (to vary *h*). [M]

15 Repeat the procedure from step **9** to **13**, and thus obtain about 6 sets of results.

16 From the equation given in the question:

$$Q = \left(\frac{2\pi\rho g d^4}{\eta l}\right)h$$

it follows that the gradient of *Q* vs. *h* graph is equal to the expression: $\frac{2\pi\rho g d^4}{\eta l}$.

17 Plot a graph of *Q* against *h*. [A]

18 If the graph turns out to be straight-line and passes through the origin, then the suggested relationship is correct. [D]

19 Find the gradient of the graph, and determine the value of η using the equation:

$$\eta = \frac{2\pi\rho g d^4}{l \times \text{gradient}}$$ [A]

Safety Precaution:

To prevent injury when adjusting the metal tubes, I will wear (protective) gloves. [S]

Further additional-detail points might include:

- Use a large measuring cylinder to reduce percentage uncertainty in the measurement of time *t* / flow rate *Q*.
- Detail on measuring *h* to the centre of the horizontal tube; e.g. add radius to tube.

Sample Question 1.5 *(P05/M/J/09)*

A student wishes to determine the Young modulus E of wood from the period of oscillation of a loaded wooden rule, as shown in Fig. 1.5.1.

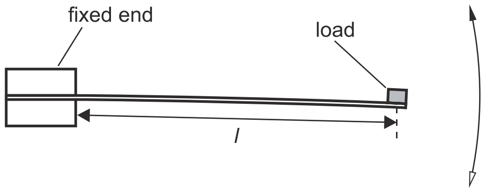


Figure 1.5.1

An equation relating the period of oscillation T to the overhanging length l of the rule is:

$$T^2 = \frac{kl^3}{E}$$

The constant k is given by:

$$k = \frac{16\pi^2 M}{wd^3}$$

where M is the mass of the load, w is the width of the rule and d is the thickness of the rule. Design a laboratory experiment to determine the Young modulus of wood. You should draw a diagram showing the arrangement of your equipment. In your account, you should pay particular attention to:

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) how to analyse the data,

(e) how to determine E,

(f) the safety precautions to be taken. [15]

Solution

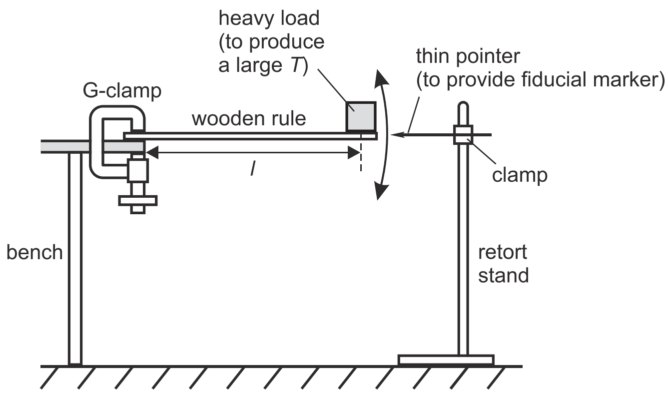


Figure 1.5.2

In this experiment, I will:

- vary l and determine T (for each value of l). [P + P]
- keep M constant. [P]
- also keep w and d constant. [D]

  (i.e. use the rule having uniform w and d along the length.)

To collect and analyse the data, I will take the following steps:

1 Take a load of a large mass *M* to produce a measurable period of oscillation *T*. [D]

2 Measure the mass *M* of the load with a digital balance. [M]

3 Take a half-metre wooden rule.

4 Measure the width *w* and thickness *d* of the rule with vernier calipers. [M]

When measuring *w* and *d*, I will take multiple readings <u>at different points along the rule and</u> find the average values. [D]

5 Build the experimental setup as shown in Fig. 1.5.2. In the experimental setup:

- the purpose of using the bench and G-clamp arrangement is to fix one end of the rule firmly in position. [M]
- the purpose of using the thin pointer, positioned close to the equilibrium position of the load, is to provide fiducial marker; so that the oscillations may be timed with ease. [D]

When building the experimental setup, I will secure the load to the rule with tape. [D]

6 Record the overhanging length *l* of the rule. [M]

7 Set the rule into oscillation, while keeping the amplitude of oscillation (reasonably) small (to ensure that the equation relating *T* and *l* holds good.) [D]

8 Wait until the oscillations have settled. [D]

9 With a stopwatch, time at least 10 oscillations, so that the time *t* taken for 10 oscillations is (reasonably) large and hence the percentage uncertainty in its measurement is (reasonably) small. [D]

10 Repeat step **9** <u>and</u> find the average value of *t*. [M]

11 Determine the period of oscillation *T* using the formula:

$$T = \frac{t}{10}$$

12 Change the position of the load on the rule (to vary *l*).

13 Repeat the procedure from step **6** to **11**, and thus obtain about 6 sets of results.

14 From the two equations given in the question, it can be shown that:

$$T^2 = \left(\frac{16\pi^2 M}{wd^3 E}\right) l^3$$

From the above equation it follows that the gradient of T^2 vs. l^3 graph is equal to the expression: $\frac{16\pi^2 M}{wd^3 E}$.

15 Plot a graph of T^2 against l^3. [A]

16 <u>If no mistake</u> is made up to this point, then the <u>graph will be straight-line and pass through the origin</u>. [D]

17 Find the gradient of the graph, and determine the Young modulus *E* of wood using the equation:

$$E = \frac{16\pi^2 M}{wd^3 \times \text{gradient}}$$ [A]

Safety Precaution:

To prevent injury from the <u>load</u>, which may detach from the rule during oscillation, I will keep my feet well away from it. [S]

Further additional-detail points might include:

- <u>Discussion</u> of use of motion sensor, e.g. orientation, or light gates with detail.

Sample Question 1.8 *(P53/O/N/13)*

A student is investigating how the resistance R of nichrome in the form of a wire varies with temperature θ. It is suggested that:

$$R = R_0(1 + \alpha\theta)$$

where R_0 is the resistance at 0 °C, α is a constant and θ is the temperature measured in °C. Design a laboratory experiment to test the relationship between θ and R and determine the value of α. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken. [15]

Solution

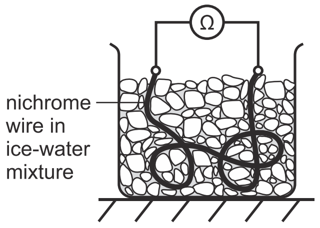


Figure 1.8.1

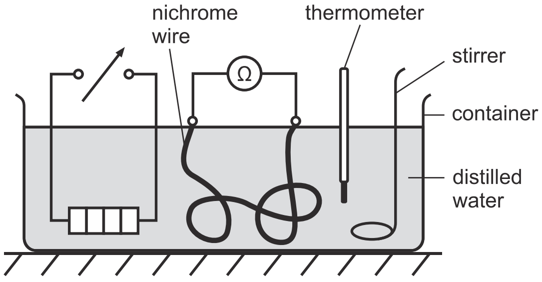


Figure 1.8.2

In this experiment, I will:

- vary θ and determine R (for each value of θ). [P + P]
- keep length of the wire <u>constant</u>. [P]

To collect and analyse the data, I will take the following steps:

1 Take a long nichrome wire to obtain a large value for its resistance and hence a small percentage uncertainty in the measurement of resistance. [D + D]

2 Immerse it in the <u>ice-water mixture</u> as shown in Fig. 1.8.1. [M]

(The temperature of melting ice is always 0 °C)

3 Wait for its temperature to become 0 °C. [D]

4 Record its resistance R_0 from the ohmmeter. [M]

5 Take the wire out of the ice-water mixture and build the experimental setup as shown in Fig. 1.8.2. In the experimental setup:

- the purpose of using the heater is to supply heat to the nichrome wire through water. [M]
- the purpose of using the stirrer is to make sure that the heat is distributed uniformly. [D]
- the purpose of using the thermometer is to measure the temperature of the wire. [M]
- the purpose of using the ohmmeter is to measure the resistance of the wire. [M]

6 Switch on the variable power supply connected to the heater. The temperature of the water (and everything immersed in it) will start rising.

7 Wait for the reading of the thermometer (i.e. temperature of the water and wire) to stabilise.

8 Record the temperature θ of the wire from the thermometer.

9 Record the resistance R of the nichrome wire from the ohmmeter.

10 Turn up the heater a bit. The temperature of the water will start rising again.

11 Repeat the procedure from step **7** to **9**, and thus obtain about 6 sets of results.

12 The equation given in the question can be rearranged as:

$$R = (R_0\alpha)\theta + R_0$$

From the above equation, it follows that the gradient and y-intercept of R vs. θ graph are equal to '$R_0\alpha$', and R_0 respectively.

13 Plot a graph of R against θ. [A]

14 <u>If the graph turns out to be straight-line and does not pass through the origin, then the suggested relationship is correct</u>. [D + D]

15 Find the gradient of the graph, and determine the value of α using the equation:

$$\alpha = \frac{\text{(gradient)}}{R_0}$$ [A]

Safety Precaution:

To prevent burns from <u>hot nichrome wire</u>, I will wear gloves. [S]

Further additional-detail points might include:

- Use insulated wire.
- Use a protective resistor to minimise heating effect (if power supply, ammeter and voltmeter circuit is used to determine the resistance).

Sample Question 1.10 *(P05/O/N/08)*

A student wishes to investigate how the resistance R of a light-dependent resistor varies with the distance d from an intense light source. It is believed that the relationship between R and d is:

$$R = kd^n$$

where k and n are constants. Design a laboratory experiment to test the above relationship. The light-dependent resistor has a resistance of 100 Ω when it is in bright light and a resistance of 500 kΩ when no light falls on it. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) the measurements that would be taken,

(c) the control of variables,

(d) how the data would be analysed,

(e) any safety precautions that you would take. [15]

Solution

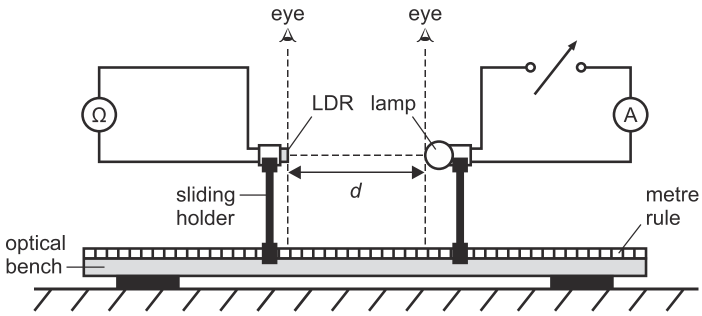


Figure 1.10.1

In this experiment, I will:

- vary d and measure R (for each value of d). [P + P]
- keep current through the <u>light source</u> (lamp) <u>constant</u>; [P]

  (so that its brightness, or the intensity of light emitted, remains constant)
- also keep temperature of the light-dependent resistor (LDR) <u>constant</u>. [D]
- also keep the orientation of the LDR, with respect to the lamp, <u>constant</u>. [D]

To collect and analyse the data, I will take the following steps:

1 Choose a dark room to perform the experiment so that there is no source of light other than that used on purpose (i.e. lamp), as the resistance of LDR changes with intensity of light falling on it. [M + D]

2 Build the experimental setup as shown in Fig. 1.10.1. In the experimental setup:

- the purpose of using the independent lamp is to shine light on the LDR connected into a separate circuit. [M]
- the purpose of using the metre rule fixed to the optical bench is to measure the distance d between the lamp and LDR. [M]
- the purpose of using ohmmeter is to measure the resistance R of the LDR. [M]
- the purpose of using the ammeter is to check if the current through the lamp remains constant. [D]
- the purpose of using the variable power supply is to keep the current through the lamp constant. [D]
- the purpose of using the optical bench and sliding holders is to keep the orientation of the LDR, with respect to the lamp, constant. [D]

3 Note the readings, on the metre rule, of the positions of the lamp and the LDR by looking from above, and determine *d* by calculating the difference between the readings. [D]

When measuring *d*, I will avoid parallax error by keeping the eye in the right position as shown in Fig. 1.10.1. [D]

4 Record the resistance *R* of the LDR from the ohmmeter. [M]

5 Change *d* by sliding the holder holding LDR.

6 Repeat the procedure from step **3** to **4**, and thus obtain about 6 sets of results.

7 From the equation given in the question, it can be shown that:

$$\lg R = n \lg d + \lg k \quad [D]$$

From the above equation, it follows that the gradient and *y*-intercept of lg *R* vs. lg *d* graph are equal to '*n*' and 'lg *k*' respectively.

8 Plot a graph of lg *R* against lg *d*. [A]

9 <u>If the graph turns out to be straight-line, then the given relationship is correct</u>. [A]

Safety Precaution:

To prevent burns from the <u>hot lamp</u>, I will wear gloves. [S]

Further additional-detail points might include:

- Determination of a typical current using value of resistance given.
- Likely meter range of ohmmeter or ammeter with reasoning.

Question 2: Analysis, Conclusions and Evaluation

Generic Mark Scheme

(Before October/November 2015)

Breakdown of skills	**Mark allocation**
Approach to data analysis	1 mark
Table of results	2 marks
Graph	3 marks
Conclusion	4 marks
Treatment of uncertainties	5 marks

(After October/November 2015)

Breakdown of skills	**Minimum mark allocation***
Approach to data analysis	1 mark
Table of results	1 marks
Graph	2 marks
Conclusion	3 marks
Treatment of uncertainties	3 marks

*The remaining 5 marks are allocated across the skills in this grid and their allocation may vary from paper to paper.

In order to get an idea of the structure of question 2, first go through the complete questions given in the exercise section.

2.1 Determining Expressions of Gradient and *Y*-Intercept from a Linear Equation

If a y vs. x graph is drawn from an equation of the form:

$$y = mx + c$$

then:

gradient of the graph = m

y-intercept = c

Sample Question 2.1 *(P52/M/J/12)*

A student investigates how the resonant length L of a loaded wire varies with frequency f. It is suggested that f and L are related by the equation:

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

where T is the tension in the wire and μ is a constant. A graph is plotted of f on the y-axis against $1/L$ on the x-axis. Determine an expression for the gradient in terms of T and μ. [1]

Solution

gradient = $\frac{1}{2}\sqrt{\frac{T}{\mu}}$

Note: In this section (i.e. question-2 section), instead of complete past-paper questions, only their respective components have been solved after explaining the required rules and methods. So, the sample question 2.1 solved above is not an example of complete question 2 that came in paper 52 of May/June 2012; rather, it is just a component of the actual question.

Sample Question 2.2 *(P53/O/N/11)*

A student is investigating how a mass m attached to a trolley by a string affects its velocity v. It is suggested that v and m are related by the equation:

$$mg = (m + M)\frac{v^2}{2h}$$

where M is the mass of the trolley, h is the height from which the mass m is released and g is the acceleration of free fall. A graph is plotted of v^2 on the y-axis against $\frac{m}{m+M}$ on the x-axis. Express the gradient in terms of g and h. [1]

Solution

gradient = $2gh$

Working

Sample Question 2.1

$$f = \frac{1}{2}\sqrt{\frac{T}{\mu}} \cdot \frac{1}{L}$$

Sample Question 2.2

$$v^2 = 2gh\left(\frac{m}{m+M}\right)$$

Sample Question 2.3 *(P53/O/N/12)*

A student investigates how the maximum speed v of a trolley varies with its total mass M. It is suggested that v and M are related by the equation:

$$v = A\sqrt{\frac{k}{M}}$$

where A is the length of the card attached to the trolley and k is the spring constant of the springs attached to it. A graph is plotted of v^2 on the y-axis against $1/M$ on the x-axis. Determine an expression for the gradient in terms of A and k. [1]

Solution

gradient = A^2k

Sample Question 2.4 *(P51/O/N/12)*

A student investigates how the minimum potential difference V required to cause an LED to emit light varies with its characteristic wavelength λ. It is suggested that V and λ are related by the equation:

$$\frac{hc}{\lambda} = B + eV$$

where c is the speed of light in a vacuum, e is the elementary charge, h is the Planck constant and B is a constant. A graph is plotted of V on the y-axis against $1/\lambda$ on the x-axis. Determine expressions for the gradient and y-intercept in terms of B, c, e and h. [1]

Solution

gradient = $\frac{hc}{e}$

y-intercept = $\frac{-B}{e}$

Sample Question 2.5 *(P51/M/J/14)*

A student investigates how the reading V on a voltmeter varies with the resistance Q of a resistor connected into a circuit. It is suggested that V and Q are related by the equation:

$$V = -ER\left(\frac{1}{P} + \frac{1}{Q}\right)$$

where E is the e.m.f. of the cell, and P and R are the resistances of other resistors connected into the circuit. A graph is plotted of V/E on the y-axis against $1/Q$ on the x-axis. Determine expressions for the gradient and the y-intercept in terms of P and R. [1]

Solution

gradient = – R

y-intercept = $\frac{-R}{P}$

Working

Sample Question 2.3

$v^2 = A^2k \cdot \frac{1}{M}$

Sample Question 2.4

$$eV = \frac{hc}{\lambda} - B$$

$$\Rightarrow \quad V = \frac{hc}{e\lambda} - \frac{B}{e}$$

$$\Rightarrow \quad V = \frac{hc}{e} \cdot \frac{1}{\lambda} + \left(\frac{-B}{e}\right)$$

Sample Question 2.5

$$\frac{V}{E} = -\frac{R}{Q} - \frac{R}{P}$$

$$\Rightarrow \quad \frac{V}{E} = (-R)\frac{1}{Q} + \left(\frac{-R}{P}\right)$$

2.2 Logarithmic Identities

1 lg (mn) = lg m + lg n

2 $\lg\left(\frac{m}{n}\right) = \lg m - \lg n$

3 lg m^n = n lg m

4 lg 10 = 1

5 ln e = 1

(where 'ln' is the symbol of natural logarithm, and e = 2.718)

6 ln e^x = x ln e

= x

7 If:

lg m = n

then:

$m = 10^n$

8 If:

ln m = n

then:

$m = e^n$

9 If:

lg m = n

then:

$\lg\left(\frac{1}{m}\right) = -n$

Note: All above-stated identities hold true for natural logarithm as well.

Sample Question 2.6

(P51/O/N/10)

A student investigates how the period T of a simple pendulum depends on its length l. It is suggested that T and l are related by the equation:

$$T = al^b$$

where a and b are constants. A graph is plotted of lg T on the y-axis against lg l on the x-axis. Determine expressions for the gradient and y-intercept in terms of a and b. [1]

Solution

gradient = b

y-intercept = lg a

Working

Sample Question 2.6

$\lg T = \lg a + \lg l^b$

$\Rightarrow \lg T = \lg a + b \lg l$

$\Rightarrow \lg T = b \lg l + \lg a$

Sample Question 2.7 *(P51/O/N/11)*

A scientist investigates how the period T of an orbit about the planet Jupiter varies with its radius r. It is suggested that T and r are related by the equation:

$$T^2 = kr^3$$

where k is a constant. A graph is plotted of lg T on the y-axis against lg r on the x-axis. Determine the value of the gradient and express the y-intercept in terms of k. [1]

Solution

gradient = $\dfrac{3}{2}$

y-intercept = $\dfrac{\lg k}{2}$

Sample Question 2.8 *(P05/M/J/08)*

A student investigates how the count rate R registered by a Geiger-Muller tube varies with the thickness x of a lead absorber placed between a radioactive source and the tube. It is suggested that R and x are related by the equation:

$$R = R_0 e^{-\rho\eta x}$$

where R_0 is the count rate with no absorbers, ρ is the density of lead and η is a constant. If a graph of ln R against x were plotted, what quantities in the above equation would the gradient and y-intercept represent? [1]

Solution

gradient = $-\rho\eta$

y-intercept = $\ln R_0$

Working

Sample Question 2.7

$\lg T^2 = \lg k + \lg r^3$

$\Rightarrow \quad 2 \lg T = \lg k + 3 \lg r$

$\Rightarrow \quad \lg T = \dfrac{\lg k}{2} + \dfrac{3}{2} \lg r$

$\Rightarrow \quad \lg T = \dfrac{3}{2} \lg r + \dfrac{\lg k}{2}$

Sample Question 2.8

$\ln R = \ln R_0 + \ln e^{-\rho\eta x}$

$\Rightarrow \quad \ln R = \ln R_0 + (-\rho\eta x)$

$\Rightarrow \quad \ln R = (-\rho\eta)x + \ln R_0$

2.3 Rules for Writing Column Heading

Examples

(a) The column heading for a quantity 'v^2', to be expressed in the units 'm^2/s^2', should be:

$$v^2 \,/\, m^2\, s^{-2}$$

(b) The column heading for a quantity $1/\lambda$, to be expressed in the units '10^6 m^{-1}', should be:

$$(1/\lambda) \,/\, 10^6\, m^{-1}$$

(c) The column heading for 'lg v^2', where v^2 is to be expressed in the units 'm^2/s^2', should be:

$$\lg\,(v^2 \,/\, m^2\, s^{-2})$$

(d) The column heading for 'lg $(1/\lambda)$', where '$1/\lambda$' is to be expressed in the units '10^6 m^{-1}', should be:

$$\lg\,[(1/\lambda) \,/\, 10^6\, m^{-1}]$$

Rules

1 In the column heading, the symbol of the quantity and its measuring unit should be separated by the distinguishing mark '/'.

2 Where logarithms are required, unit should be shown with the quantity whose logarithm is to be taken.

Note: The logarithm itself does not have a unit.

2.4 Rules for Determining the Number of Significant Figures (s.f.) and Decimal Places (d.p.)

Example

❖ If:

$r = 422 \times 10^6$ m

then:

no. of s.f. in $r = 3$

Rule 1

no. of s.f. in a quantity (r) = no. of digits in the <u>number part</u> of its value (<u>422</u> $\times 10^6$ m)

Examples

(a) If:

$V = 1.80 \pm 0.05$ V

then:

no. of s.f. in $V = 3$

(b) If:

$T = 24 \pm 4$ s

then:

no. of s.f. in $T = 2$

(c) If:

$T = 1420 \pm 15$ s

then:

no. of s.f. in $T = 3$ (if it is a calculated quantity)

Rules

2 In a quantity, stated with its absolute uncertainty (also known as the actual uncertainty), last s.f. is the one that occupies the same decimal place (d.p.) as the first non-zero digit in its absolute uncertainty.

3 By definition of significant figures, the absolute uncertainty has only 1 s.f. (and it is always the first non-zero digit from the left). So, when stating the absolute uncertainty of a calculated quantity, it is always a good practice to round off it to the first non-zero digit (just to avoid confusion). For example, in the above example **(c)**, the absolute uncertainty in T could have been stated as ± 20 s, instead of ± 15 s. Although ± 15 s is also acceptable, but ± 20 s is just more appropriate.

Note: The absolute uncertainty is preferably stated to 1 s.f. only. The percentage uncertainty should, however, preferably be stated to 2 s.f., especially when the second digit is not zero (or does not remain as zero when the value is rounded off to the first two digits). For example, if the percentage uncertainty is calculated to be $\pm 1.09\%$, then it should preferably be stated to 2 s.f. as $\pm 1.1\%$.

Examples (of multiplication and division)

(a) If:

$\lambda = 950 \times 10^{-9}$ m

then:

$1/\lambda = 1.05263 \times 10^6 = 1.05 \times 10^6$ m^{-1}

(b) If:

$M = 1.25$ kg

then:

$1/M = 0.8 = 0.800$ kg^{-1}

(c) If:

$$d = 0.050 \text{ m},\ t = 0.0581 \text{ s, and } v^2 = \frac{d^2}{t^2}$$

then:

$$v^2 = \frac{d^2}{t^2} = \frac{(0.050)^2}{(0.0581)^2} = 0.740607 = 0.74 \text{ m}^2 \text{ s}^{-2}$$

Rule 4

no. of s.f. retained in the calculated quantity = least no. of s.f. in the raw data

Note: This rule is a bit flexible. The number of s.f. to be retained in the calculated quantity may be either equal to or 'one more' than the least number of s.f. in the raw data, but it is usually preferable to keep the number of s.f. in the calculated quantity the same as the least number of s.f in the raw data. For example:

(i) if the calculated quantity may be stated to 3 or 4 s.f., then it is preferable to use 3 s.f.;

(ii) if the calculated quantity may be stated to 2 or 3 s.f., then it is preferable to use 2 s.f.;

(iii) **but** if the calculated quantity may be stated to 1 or 2 s.f., then it is preferable to use 2 s.f.

Examples (of addition and subtraction)

(a) If:

$x = 2.3$ m and $y = 1.946$ m

then:

$x + y = 2.3 + 1.946 = 4.246 = 4.2$ m

(b) If:

$x = 2.3$ m and $y = 1.956$ m

then:

$x - y = 2.3 - 1.956 = 0.344 = 0.3$ m

Rule 5

no. of d.p. retained in the calculated quantity = least no. of d.p. in the raw data

Example (of logarithm)

❖ If:

$x = 422 \times 10^6$ m

then:

$\lg x = \lg (422 \times 10^6) = 8.62531 = 8.625$

Rule 6

no. of d.p. in the calculated value of lg x = no. of s.f. in x

Note: This rule is also a bit flexible. The number of d.p. to be retained in the calculated value of lg x may be either equal to or 'one more' than the number of s.f. in x, but it is usually preferable to keep the number of d.p. in the calculated value of lg x the same as the number of s.f. in x.

Example (of antilogarithm)

❖ If:

$x = 4.15$ m

then:

$10^x = 10^{4.15} = 1.4125 \times 10^4 = 1.4 \times 10^4$

Rule 7

no. of s.f. in the calculated value of 10^x = no. of d.p. in x

Note: This rule is also a bit flexible. The number of s.f. to be retained in the calculated value of 10^x may be either equal to or 'one more' than the number of d.p. in x, but it is usually preferable to keep the number of s.f. in the calculated value of 10^x the same as the number of d.p. in x.

2.5 Rules for Rounding off the Calculated Quantities

Examples (of decimal-point values)

(a) 4.23189 m, when rounded off to the 2nd d.p., becomes 4.23 m

(b) 4.23589 m, when rounded off to the 2nd d.p., becomes 4.24 m

(c) 4.23689 m, when rounded off to the 2nd d.p., becomes 4.24 m

Rules

1 The last digit to be retained in the value remains unchanged if the very next digit (to its right) is less than 5.

2 The last digit to be retained in the value is increased by 1 if the very next digit (to its right) is 5 or greater than 5.

Examples (of whole-number values)

(a) 42318 m, when rounded off to 3 s.f., becomes 42300 m

(b) 42358 m, when rounded off to 3 s.f., becomes 42400 m

(c) 42368 m, when rounded off to 3 s.f., becomes 42400 m

Rules

3 The last digit to be retained in the value remains unchanged if the very next digit (to its right) is less than 5; whereas all the digits to be dropped are replaced with zeros.

4 The last digit to be retained in the value is increased by 1 if the very next digit (to its right) is 5 or greater than 5; whereas all the digits to be dropped are replaced with zeros.

Sample Question 2.9 *(P53/O/N/12)*

Values of M and t are given in Fig. 2.9.1.

M / kg	t / s	$(1/M)$ / kg^{-1}	v^2 / m^2 s^{-2}
0.75	0.046 ± 0.002		
1.25	0.058 ± 0.002		
1.75	0.068 ± 0.002		
2.25	0.078 ± 0.002		
2.75	0.086 ± 0.002		
3.25	0.092 ± 0.002		

Figure 2.9.1

Calculate and record values of $(1/M)$ / kg^{-1} and v^2 / m^2 s^{-2} in Fig. 2.9.1.

(where: $v = \dfrac{d}{t}$, and $d = 5.0 \pm 0.1$ cm) [2]

Solution

M / kg	t / s	$(1/M)$ / kg^{-1}	v^2 / $m^2\ s^{-2}$
0.75	0.046 ± 0.002	1.3	1.2
1.25	0.058 ± 0.002	0.800	0.74
1.75	0.068 ± 0.002	0.571	0.54
2.25	0.078 ± 0.002	0.444	0.41
2.75	0.086 ± 0.002	0.364	0.34
3.25	0.092 ± 0.002	0.308	0.30

Sample Question 2.10 *(P52/M/J/12)*

Values of f and L are given in Fig. 2.10.1.

f / Hz	L / 10^{-2} m	
256	54.5 ± 0.5	
294	48.0 ± 0.5	
330	42.5 ± 0.5	
350	40.0 ± 0.5	
396	35.5 ± 0.5	
440	32.0 ± 0.5	

Figure 2.10.1

Calculate and record values of $(1/L)$ / m^{-1} in Fig. 2.10.1. [2]

Solution

f / Hz	L / 10^{-2} m	$(1/L)$ / m^{-1}
256	54.5 ± 0.5	1.83
294	48.0 ± 0.5	2.08
330	42.5 ± 0.5	2.35
350	40.0 ± 0.5	2.50
396	35.5 ± 0.5	2.82
440	32.0 ± 0.5	3.13

Working

Sample Question 2.9

$$v^2 = \frac{d^2}{t^2} = \frac{(0.050\ \text{m})^2}{(0.046\ \text{s})^2} = 1.18\ \text{m}^2\ \text{s}^{-2} = 1.2\ \text{m}^2\ \text{s}^{-2}$$

Sample Question 2.10

$$\frac{1}{L} = \frac{1}{54.5 \times 10^{-2}\ \text{m}} = 1.83486\ \text{m}^{-1} = 1.83\ \text{m}^{-1}$$

Sample Question 2.11 *(P52/M/J/11)*

Values of R and V are given in Fig. 2.11.1.

R / Ω	V / V	$(1 / R) / 10^{-3}\ \Omega^{-1}$
150	14.4 ± 0.1	
220	10.4 ± 0.1	
330	7.4 ± 0.1	
470	5.6 ± 0.1	
680	4.4 ± 0.1	
860	3.8 ± 0.1	

Figure 2.11.1

Calculate and record values of $(1 / R) / 10^{-3}\ \Omega^{-1}$ in Fig. 2.11.1. [1]

Solution

R / Ω	V / V	$(1 / R) / 10^{-3}\ \Omega^{-1}$
150	14.4 ± 0.1	6.7
220	10.4 ± 0.1	4.5
330	7.4 ± 0.1	3.0
470	5.6 ± 0.1	2.1
680	4.4 ± 0.1	1.5
860	3.8 ± 0.1	1.2

Working

Sample Question 2.11

$$\frac{1}{R} = \frac{1}{150\ \Omega}$$

$$= 6.6666 \times 10^{-3}\ \Omega^{-1}$$

$$= 6.7 \times 10^{-3}\ \Omega^{-1}$$

Note: All values of R are whole-number values with '0' in the end; this implies that these zeros are not significant. So, all values of R have 2 significant figures, not 3.

Sample Question 2.12 *(P51/O/N/12)*

Values of λ and V are given in Fig. 2.12.1.

$\lambda / 10^{-9}$ m	V / V	
950	0.60 ± 0.05	
875	0.70 ± 0.05	
655	1.20 ± 0.05	
560	1.55 ± 0.05	
505	1.80 ± 0.05	
430	2.25 ± 0.05	

Figure 2.12.1

Calculate and record values of $(1/\lambda) / 10^{6}\ \text{m}^{-1}$ in Fig. 2.12.1. [2]

Sample Question 2.12

$$\frac{1}{\lambda} = \frac{1}{950 \times 10^{-9}\ \text{m}}$$

$$= 1.0526 \times 10^{6}\ \text{m}^{-1}$$

$$= 1.05 \times 10^{6}\ \text{m}^{-1}$$

Solution

λ / 10^{-9} m	V / V	$(1/\lambda)$ / 10^{6} m^{-1}
950	0.60 ± 0.05	1.05
875	0.70 ± 0.05	1.14
655	1.20 ± 0.05	1.53
560	1.55 ± 0.05	1.79
505	1.80 ± 0.05	1.98
430	2.25 ± 0.05	2.33

Sample Question 2.13 *(P51/O/N/10)*

Values of *l* and *t* are given in Fig. 2.13.1.

l / cm	*t* / s	*T* / s	lg (*l* / cm)	lg (*T* / s)
95.0	19.6 ± 0.2			
85.0	18.4 ± 0.2			
75.0	17.4 ± 0.2			
65.0	16.2 ± 0.2			
55.0	14.8 ± 0.2			
45.0	13.4 ± 0.2			

Figure 2.13.1

Calculate and record values of *T* / s, lg (*l* / cm) and lg (*T* / s) in Fig. 2.13.1.

(where: $T = \dfrac{t}{10}$) [2]

Solution

l / cm	*t* / s	*T* / s	lg (*l* / cm)	lg (*T* / s)
95.0	19.6 ± 0.2	1.96	1.978	0.292
85.0	18.4 ± 0.2	1.84	1.929	0.265
75.0	17.4 ± 0.2	1.74	1.875	0.241
65.0	16.2 ± 0.2	1.62	1.813	0.210
55.0	14.8 ± 0.2	1.48	1.740	0.170
45.0	13.4 ± 0.2	1.34	1.653	0.127

Sample Question 2.14 *(P51/O/N/11)*

Values of *r* and *T* are given in Fig. 2.14.1.

r / 10^6 m	T / 10^3 s	lg (r / m)	lg (T / s)
129	24 ± 4		
181	42 ± 4		
422	154 ± 8		
671	304 ± 8		
1070	590 ± 15		
1880	1420 ± 15		

Figure 2.14.1

Calculate and record values of lg (r / m) and lg (T / s) in Fig. 2.14.1. [2]

Solution

r / 10^6 m	T / 10^3 s	lg (r / m)	lg (T / s)
129	24 ± 4	8.111	4.38
181	42 ± 4	8.258	4.62
422	154 ± 8	8.625	5.188
671	304 ± 8	8.827	5.483
1070	590 ± 15	9.0294	5.771
1880	1420 ± 15	9.2742	6.152

Working

$$\lg (r / \text{m}) = \lg (129 \times 10^6)$$
$$= 8.11058971$$
$$= 8.111$$

Endorsed by:

Mr. Muhammad Rafique has been teaching A-Level Physics for last **25 years**. He started his teaching career at **City School Capital Campus, Islamabad**, where he taught from 1991 to 1998. In the past, he has also taught A-Level Physics at **Headstart School, Islamabad**. Currently, he is teaching A-Level Physics at **Beaconhouse Margalla Campus, Roots I-9/3 Campus and Islamabad College of Arts & Sciences (ICAS).**

Mr. Muhammad Javed Solehri has been teaching A-Level Physics for last **24 years**. He started his teaching career at **Garrison Academy, Lahore**. His former institutions also include **City School, Lahore** and **Westminister College, Lahore**. Currently, he is teaching A-Level Physics at **Lahore Grammar School, Beaconhouse DHA Campus, Lahore** and **Salamat International Campus for Advanced Studies (SICAS), Lahore**.

Mr. Nadeem Islam has been involved in the field of academics for nearly **20 years**. His teaching career began with teaching O-Level Physics in 1996-97 at **Bay View High School, Karachi**. Along the way, he has taught A-Level Physics at **Karachi Grammar School**, **Convent of Jesus & Mary**, **Bay View Academy** and **Southshore School, Karachi**. In 2006, he assumed full-time responsibilities at **Bay View High School** firstly, as the Vice Principal for the O/A Level Campus and subsequently, as the Head of A Levels at **Bay View College** until November 2015. At present, he is teaching A-Level Physics at **Cedar College, Karachi**.