

Cambridge International Advanced Subsidiary (AS) Level Physics 9702 – P3

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Paper 3 Advanced Practical Skills

Paper 3 is a timetabled, laboratory-based practical paper focusing on the experimental skills of

- Manipulation, measurement and observation
- Presentation of data and observations
- Analysis, conclusions and evaluation.

Paper 3

Advanced Practical Skills

2 hours

40 marks

Practical work and structured questions

Questions are based on the experimental skills in the Practical assessment section of the syllabus.

The context of the questions may be outside the syllabus content.

Externally assessed

23% of the AS Level

11.5% of the A Level

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P3 - Advanced Practical Skills

Paper format:

There are **two questions** in each paper. **Each question should take one hour** as **both questions are of 20 marks**.

Question number 1:

- It requires candidate to **collect data**, **plot a graph** and **draw simple conclusions**.

Question number 2:

- No graph will be required**. It will require candidates to follow an **inaccurate method**, take several readings and then evaluate the results.
- It requires candidates to **identify the problems faced** in experiment and **suggest improvements** that can be made.

Note:

- The two questions will be set in different areas of physics.**
- No prior knowledge of the theory will be required.**

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Assessment

In Paper 3, you have to perform experiments in the lab, by focusing on

- Manipulation, measurement and observation
- Presentation of data and observations
- Analysis, conclusions and evaluation.

Question 1

Skill	Breakdown of skills	Minimum mark allocation*
Manipulation, measurement and observation	Successful collection of data	7 marks
	Quality of data	
Presentation of data and observations	Table of results	6 marks
	Recording of data, observations and calculations	
	Graph	
Analysis, conclusions and evaluation	Interpretation of graph	4 marks
	Drawing conclusions	

*The remaining 3 marks will be allocated across the skills in this grid and their allocation may vary from paper to paper.

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Assessment

Question 2

Skill	Breakdown of skills	Minimum mark allocation*
Manipulation, measurement and observation	Successful collection of data	5 marks
	Quality of data	
Presentation of data and observations	Recording of data, observations and calculations	2 marks
Analysis, conclusions and evaluation	Drawing conclusions	10 marks
	Estimating uncertainties	
	Identifying limitations	
	Suggesting improvements	

*The remaining 3 marks will be allocated across the skills in this grid and their allocation may vary from paper to paper.

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General Rule for Rounding Numbers

- if the *last digit dropped is greater than 5*, Then the *last digit retained is increased by 1*.

Example: If only two decimals are to be kept, then

- 1.346 becomes 1.35
- 6.4872 becomes 6.49
- 6.997 becomes 7.00

- If the *last digit dropped is less than 5*, then the *last digit retained remains as it is*.

Example:

- If only two decimals are to be kept, then
1.343 becomes 1.34
- If only one decimal is to be kept, then
6.422 becomes 6.4

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General Rule for Rounding Numbers

- If the last **digit dropped is equal to 5**, and all the digit following the 5 are **zero** or if there are no digit after the 5, then the last **digit retained should be increased by 1 if that last digit is odd**.

Example: If only two decimals are to be kept, then

6.755000 becomes 6.76

1.345 becomes 1.34

1.355 becomes 1.36

8.995 becomes 9.00

- If the last **digit dropped is equal to 5**, and there are **any non-zero digit** following the 5, then the last **digit retained should be increased by 1**.

Example:

- If only one decimals are to be kept, then

6.6501 becomes 6.7

- If only two decimals are to be kept, then

7.4852007 becomes 7.49

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Treatment of significant figures (s.f.)

- Definition: A significant figure is a reliably known digit.**
- You should be familiar with treatment of **significant figures** and **uncertainties**
- Magnitudes of physical quantities are often quoted in terms of significant number.

- Can you tell how many sig. fig. in these numbers?**

103, 100.0 , 0.030, 0.4004, 200

- If you multiply 2.3 and 1.45, how many s.f. should you quote?**

3.3, 3.335 , 3.34

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The rules for identifying significant figures

The rules for identifying significant figures when writing or interpreting numbers are as follows:-

- **All non-zero digits are considered significant.**

For example, 91 has two significant figures (9 and 1), while 123.45 has five significant figures (1, 2, 3, 4 and 5).

- **Zeros appearing anywhere between two non-zero digits are significant.**

Example: 101.1203 has seven significant figures: 1, 0, 1, 1, 2, 0 and 3.

- **Leading zeros are not significant.**

For example, 0.00052 has two significant figures: 5 and 2.

- **Trailing zeros in a number containing a decimal point are significant.**

For example

a. 12.2300 has six significant figures: 1, 2, 2, 3, 0 and 0.

b. 200 has only one significant figure: 2.

- **Exact numbers and Constants have an infinite number of significant figures**

For example, No. of people in a room are 15.

The rules for identifying significant figures

Examples

1. The number 0.000122300 still has only *six significant figures* (the zeros before the 1 are not significant)
2. 120.00 has *five significant figures* since it has three trailing zeros.
3. 500 has only *one significant figure* since it does not contain any decimal point.
4. 5.0×10^2 has *two significant figures*
5. 5.00×10^2 has *three significant figures*

Treatment of significant figures

Rule for Multiplication and Division:

When multiplying several quantities, the number of **significant figures in the final answer** is the same as the number of significant figures in the quantity having **the smallest number of significant figures**.

The same rule applies to division.

Example: Area of the rectangle of length 2.3 m and width 1.45 m.

Solution:

$$\text{Area} = \text{Length} \times \text{Width}$$

$$\text{Area} = 2.3 \times 1.45$$

$$\text{Area} = 3.3 \text{ m}^2$$

- **Calculator may give -----** 3.335 m²

You might be tempted to report the result as 3.34 m²

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Treatment of significant figures

For addition and subtraction, you must consider the **number of decimal places (d.p.)** when you are determining how many significant figures to report:

- **Rules for Addition:**

*When numbers are added or subtracted, the number of decimal places in the result should equal **the smallest number of decimal places of any term in the sum or difference**.*

Examples:

1. Consider the sum: $23.2 + 5.1745 = 28.4$
We do not report the answer as 28.374
2. Consider the sum: $1.0001 + 0.0003 = 1.0004$
3. Consider the difference: $1.002 - 0.9985 = 0.004$
4. Consider the multiplication: $1.0001 \times 3 = 3$
5. Consider the division: $\frac{4.125}{2.3} = 1.8$

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Treatment significant figures

For Trigonometric functions, the number of significant figures should be same as in the value of angle.

Example:

If $\theta = (30 \pm 1)^\circ$ (2 s.f.), Then

$$\cos 30^\circ = 0.866025403$$

$$\cos 31^\circ = 0.8571673$$

$$\cos 29^\circ = 0.874619707$$

- The rule is that the values should differ only in one digit.
- To 2 digits after the decimal place, the values become

$$\cos 30^\circ = 0.87$$

$$\cos 31^\circ = 0.86$$

$$\cos 29^\circ = 0.87$$

- These differ only in the second digit after the decimal place, so the cosine of the **measured** angle 30° has two significant figures.
- The cosine of the **mathematical** (exact) angle 30° has an infinite number of significant figures.

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Measurements and Uncertainty

Physical Quantity: *A physical quantity is one that can be measured.*

Every physical quantity has a numerical value (magnitude) and a unit.

Numerical values + Units

Physical Quantity Measurement:

We use instrument to measure the physical quantity.

Measuring instruments are not exact!

To indicate this to the reader of the experiment report, the results of measurements should be written as

$$a = (a \pm \Delta a) \text{ Units}$$

Where Δa is the absolute uncertainty.

Importance of uncertainty knowledge:

"Any measurement that you make without the knowledge of its uncertainty is completely meaningless." (Professor Walter Lewin, MIT)

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Uncertainty

- Rule For Stating Uncertainties**

Experimental uncertainties should be stated to 1-significant figure.

Example:

$$v = 31.25 \pm 0.034953 \text{ m s}^{-1} \text{ (Incorrect)}$$

$$v = 31.25 \pm 0.03 \text{ m s}^{-1} \text{ (Correct)}$$

The uncertainty is just an estimate and thus it cannot be more precise (more significant figures) than the best estimate of the measured value.

- Rule For Stating Answers** – The last significant figure in any answer should be in the same place as the uncertainty.

Example:

$$a = 1261.29 \pm 200 \text{ cm s}^{-2} \text{ (Incorrect)}$$

$$a = 1300 \pm 200 \text{ cm s}^{-2} \text{ (correct)}$$

- Since the uncertainty is stated to the hundreds place, we also state the answer to the hundreds place. Note that the uncertainty determines the number of significant figures in the answer.

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Scientific Notation

Large and small quantities are usually expressed in scientific notation (Alternative writing method)

“A method of expressing very large or very small numbers as the product of a decimal less than 10 and multiplied by a power of 10.”

Using standard form of scientific notation

$$a \times 10^n$$

where $1 \leq a < 10$ and n is an integer can be positive or negative

The diagram shows the expression $a \times 10^n$ with labels and arrows indicating its parts:

- A red arrow points from the word "Coefficient" to the variable a .
- A red arrow points from the inequality $1 \leq a < 10$ to the variable a .
- A blue arrow points from the word "integer" to the superscript n .
- A green arrow points from the text "A base of 10." to the base 10.

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Measurements and Uncertainty

Analogue Instruments

- Meter Rule
- Vernier Caliper
- Micrometer Screw Gauge
- Prorector
- Newton Meter
- Measuring Cylinder

Digital Instruments

- Stop watch
- Voltmeter
- Ammeter
- Top pan balance

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Least count of a measuring instrument

Least Count:

The smallest value that can be measured by the measuring instrument is called its least count.

- Measured values are good only up to this value.
- The least count error is the error associated with the resolution of the instrument.

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Measurements and Uncertainty

Least Counts of different Instruments

#	Instrument	Least Count	Presentation of Raw Data
1	Meter Rule	1 mm	Report data without decimal place in “mm” unit
		0.1 cm	Report data in one decimal place in “cm” unit
		0.001 m	Report data in three decimal place in “m” unit
2	Vernier Caliper	0.05 mm	Report data in two decimal place in “mm” unit
		0.005 cm	Report data in three decimal place in “cm” unit
		Note: Always measure the data in mm, then use conversion factor and scientific notation to represent in cm or m.	
3	Screw Gauge	0.01 mm	Report data in two decimal place in “mm” unit
		0.001 cm	Report data in three decimal place in “cm” unit
		Note: Always measure the data in mm, then use conversion and scientific notation to represent in cm or m.	
4	Protractor	1°	Report data without decimal place in “°” unit
5	Thermometer	1 °C	Report temperature data in one decimal place in °C unit. And temperature difference without decimal place in °C
6	Digital Stopwatch	0.01 s	Time should report up to 1 decimal place due to presence of Human reaction time which is 0.2-0.5 s. ¹⁹

Measurements and Uncertainty

For analogue Instruments

Single point measurement. Uncertainty in a Scale Measuring Device is equal to the smallest increment divided by 2.

$$\Delta a = \text{half a Least count of the Instrument}$$

$$a = \text{Reading} \pm \text{half a Least count of the Instrument}$$

Examples: Temperature, (Mass, current, voltage) using analogue meter.

For two point measurements (e.g. Length measurement) Uncertainty in a Scale Measuring Device is equal to the smallest increment.

$$a = \text{Reading} \pm \text{Least count of the Instrument Used}$$

Examples: Length or displacement: using Meter rule, Vernier calipers, and Micrometer screw gauge.

$$\Delta a = \text{Least count of the Instrument Used}$$

For Digital Instrument:

Uncertainty in Digital Measuring Device a is equal to the smallest increment.

$$\Delta a = \text{Smallest increment}$$

For repeated measurements:

If measurements are repeated (a_1 , a_2 and a_3) using either analogue or digital instrument, then the uncertainty

$$\Delta a = \text{Half of the range of data}$$

$$\Delta a = \frac{a_{\max} - a_{\min}}{2}$$

Repeated Readings

In some cases, you have to measure something and judging by the space provided you have to *show the evidence that you have taken repeated readings and averaged them out*.

Example: You have to measure the diameter of a sample of wire, so using the micrometer screw gauge take 3 readings in three different parts along the length of the wire and show:

d_1, d_2, d_3 (with correct precision or decimal places and Unit) and report the average value calculated

$$d = \frac{d_1 + d_2 + d_3}{3}$$

The uncertainty in d is

$$\Delta d = \frac{d_{\max} - d_{\min}}{2}$$

Also remember to add appropriate units along with the individual readings you measure.

$$d = (d \pm \Delta d) \text{ mm}$$

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Repeated Measurements

Example: Some values for diameter of a wire measured using screw gauge.

Repeat	Diameter /mm	Average Diameter /mm
1	0.35	$d_{\text{avg}} = \frac{0.35 + 0.37 + 0.36 + 0.34}{4}$ $d_{\text{avg}} = 0.36$
2	0.37	
3	0.36	
4	0.34	

Range

$$R = d_{\max} - d_{\min}$$

$$R = 0.37 - 0.34 = 0.03 \text{ mm}$$

Uncertainty in the measurement (Δd)

$$\Delta d = \frac{R}{2} = \frac{0.03}{2} = 0.015 \text{ mm} = 0.02 \text{ mm}$$

Therefore, the reading is

$$d = (0.36 \pm 0.02) \text{ mm}$$

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Measurement of Length

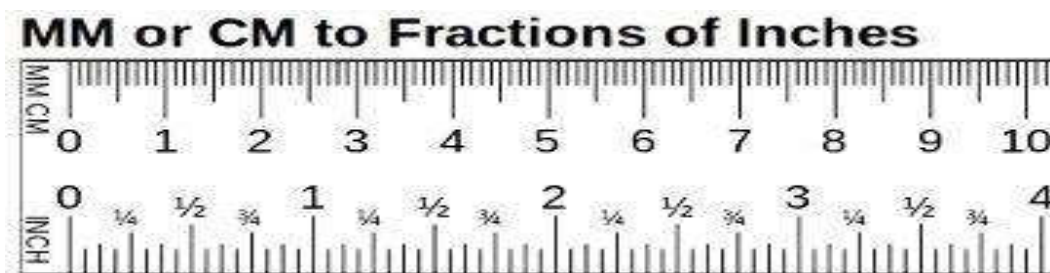
Length

- **Measuring tape** is used to measure relatively long lengths
- For shorter length, a **metre rule** or a **shorter rule** will be more accurate.
- For shortest length, a **Vernier caliper** or a **micrometer** will be more accurate



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Methods of measuring length (Meter Rule)



The metre rule

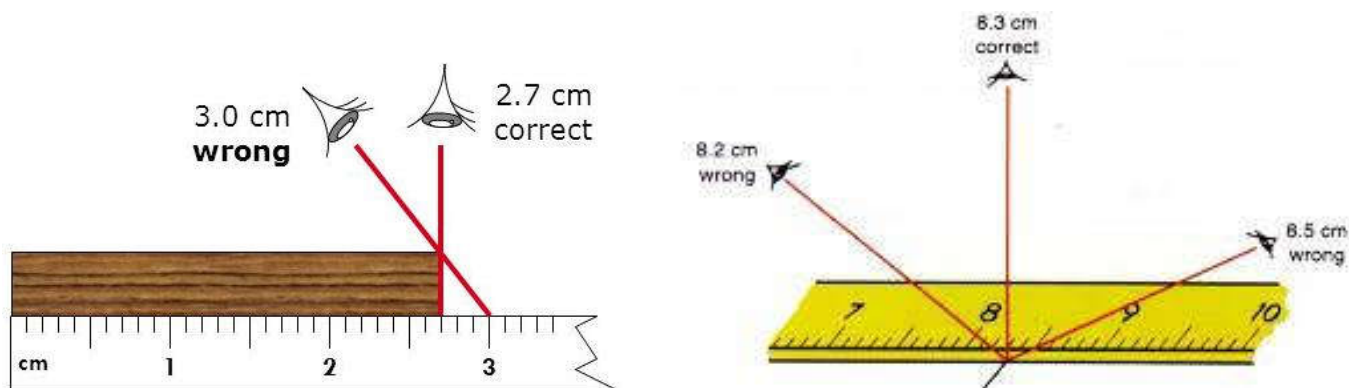
- Simplest length-measuring instrument is the metre or half metre rule (i.e. 100 cm or 50 cm or 30 cm)
- **Smallest division** on the metre rule is **1 mm** (Least count)
- Should be able to take a reading with an **uncertainty of 0.5 mm**

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Parallax error

What is parallax error?

It is the error which arises due to incorrect positioning of the eye.



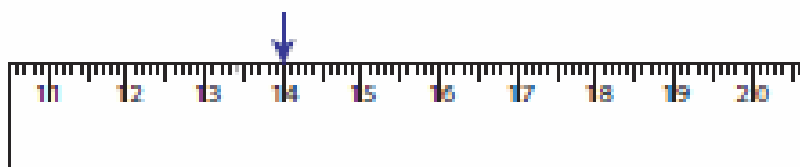
- Look from the correct position to avoid the parallax error.

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Write the reading shown by the pointer in each problem.

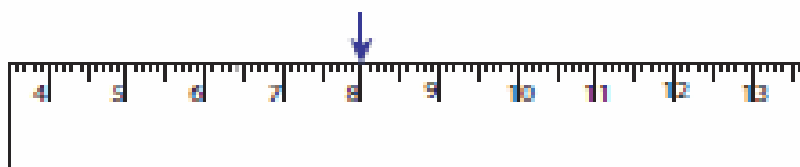
Position measurement
It's a single point measurement

1)



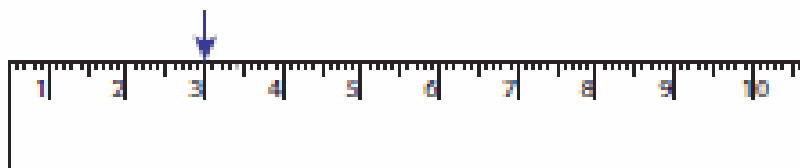
14.0 ± 0.05 cm

2)



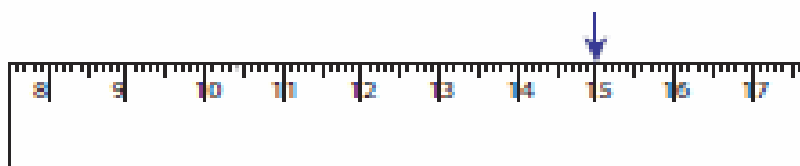
8.0 ± 0.05 cm

3)



3.0 ± 0.05 cm

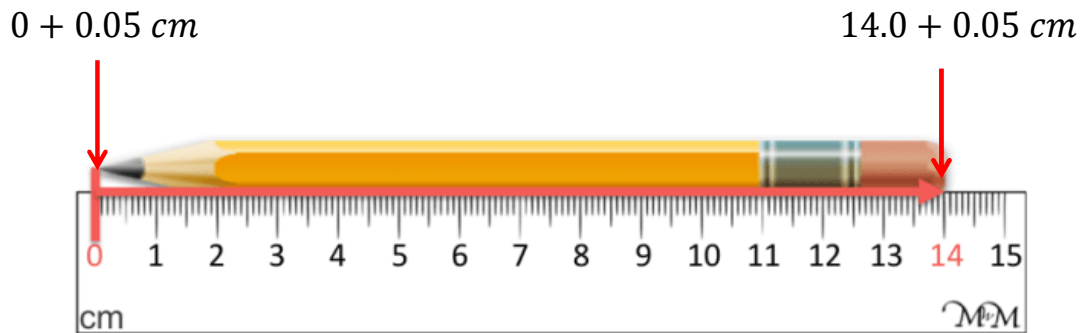
4)



15.0 ± 0.05 cm

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Measure the length of the pencil?



Two point measurement

Right end position: $l_1 = 0.0 \pm 0.05 \text{ cm}$

Left end position: $l_2 = 14.0 \pm 0.05 \text{ cm}$

Final Reading:

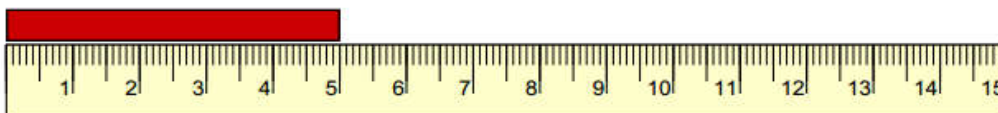
$$l = l_2 - l_1$$

$$l = (14.0 \pm 0.1) \text{ cm}$$

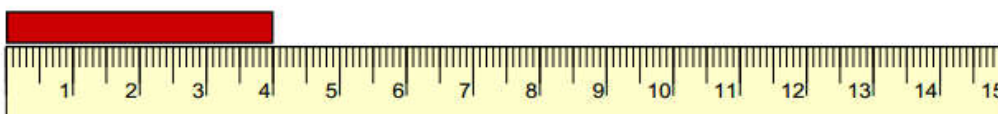
27

How long is the red bar in cm

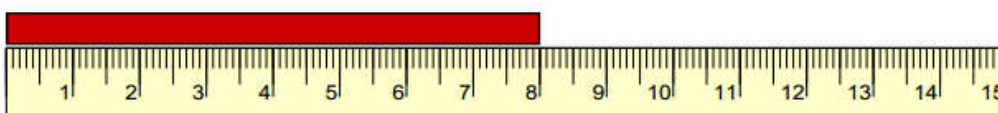
How many Centimeters ?



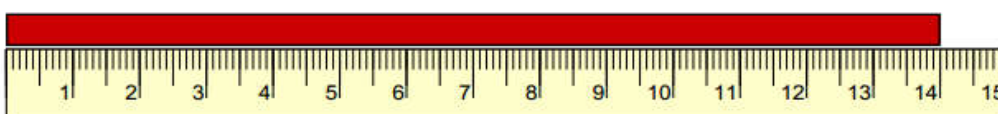
$$a = (5.0 \pm 0.1) \text{ cm}$$



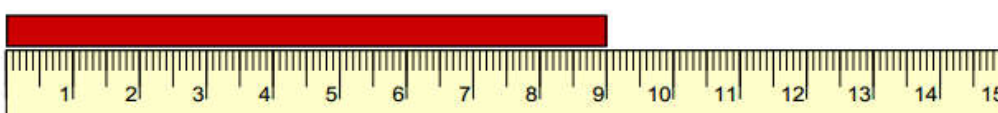
$$a = (4.0 \pm 0.1) \text{ cm}$$



$$a = (8.0 \pm 0.1) \text{ cm}$$



$$a = 14.0 \pm 0.1 \text{ cm}$$



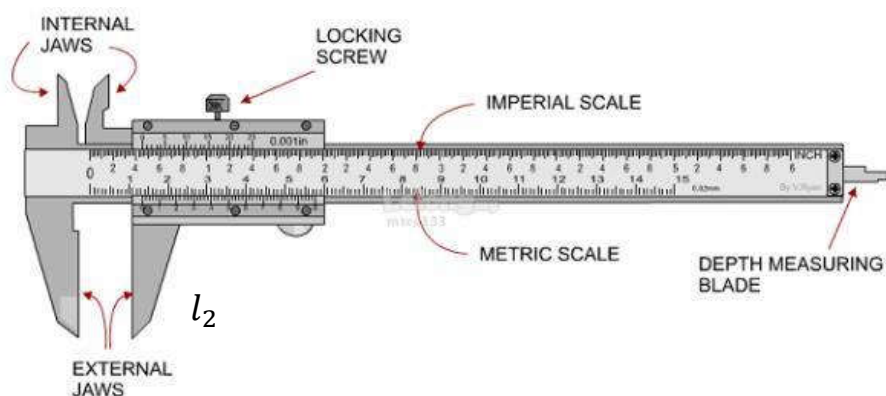
$$a = 9.0 \pm 0.1 \text{ cm}$$

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Vernier Calipers

- Versatile instrument for measuring the dimensions of an object.
- The length of the an object
- The outer diameter
- The inner diameter of the hole
- The depth of a hole.

Its range is up to 20 cm



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Vernier Calipers

Measuring Small Distances: The Vernier Scale

Least count of Vernier Calipers

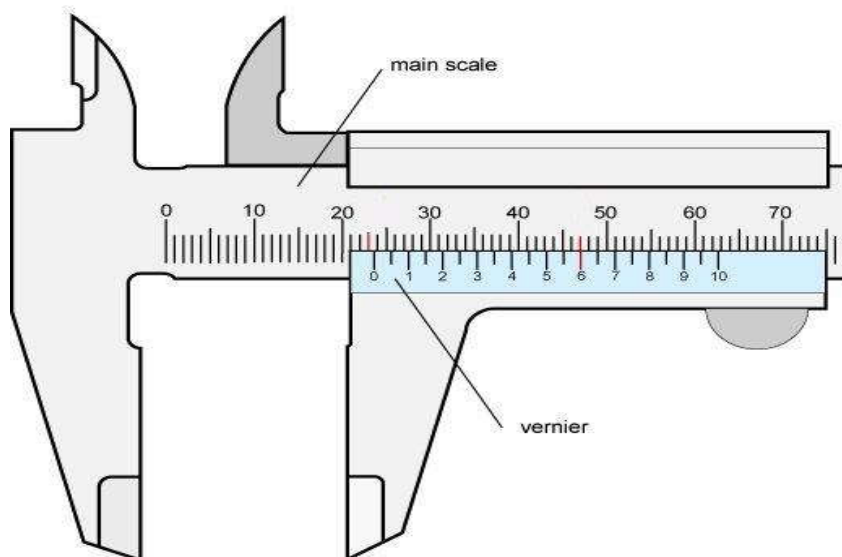
$$\text{Least Count} = \frac{\text{Smallest reading on the Main scale}}{\text{Total \# of division on Vernier scale}}$$

Smallest reading on the Main scale = 1 mm

of division of V.S. = 20

$$\text{Least Count} = \frac{1 \text{ mm}}{20}$$

$$\text{Least Count} = 0.05 \text{ mm}$$



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Vernier caliper zero error

When the jaws of Vernier calipers are brought into contact, the zero of the Vernier must coincide with the zero of the main scale (**No zero error**).

Otherwise, the instrument has an error *called zero error*.

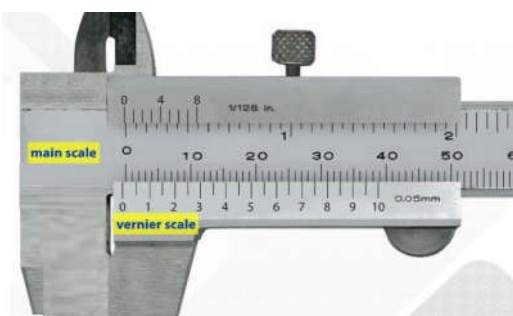
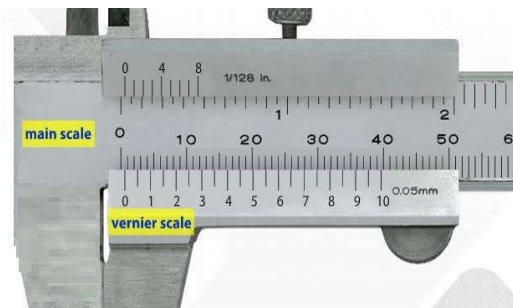
Zero error can be negative or positive.

Positive zero error

If the zero of the Vernier scale is to the *right of the zero of the main scale* then the *error is positive*.

Negative Zero Error

If the zero of the Vernier scale is to the *left of the zero of the main scale* then the *error is negative*.



Vernier caliper zero error

$$\text{Final Reading} = \text{Observed value} - ZE$$

Positive zero error

$$ZE = n \times LC$$

Since the zero error is positive, the *zero correction (ZC) will be negative*.

$$\text{Final Reading} = \text{Observed value} - ZE$$

$$\text{Final Reading} = \text{Observed value} - (n \times LC)$$

Negative Zero Error reading

For negative zero error, we read from the right to left.

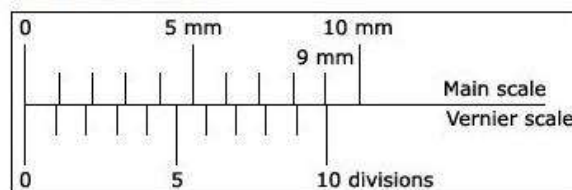
$$ZE = -n \times LC$$

Since the zero error is negative, the *zero correction (ZC) will be positive*.

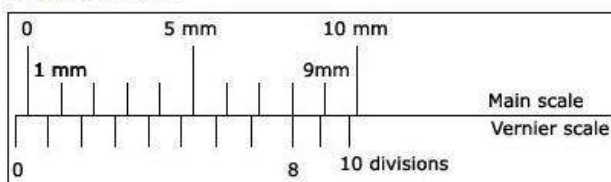
$$\text{Final Reading} = \text{Observed value} - ZE$$

$$\text{Final Reading} = \text{Observed value} + (n \times LC)$$

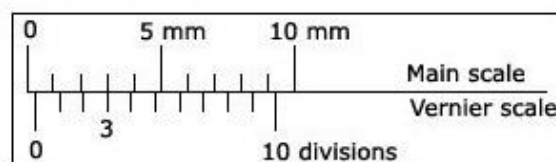
No Zero Error



Negative Error



Positive Error



How to read a Vernier caliper?

- Find the **least count (LC)**. Close the jaws to check the Zero error and calculate the **zero error if any** $ZE = n \times LC$
- Hold the object between the two jaws of the Vernier caliper. Tighten the jaws gently.
- Note the main scale division which is either coinciding or is on the left of Vernier scale zero line.
- Record this value as the **main scale reading (MSR)**.
- Note the **Vernier division (line number n)** which exactly coincides with any one division of the main scale.
- Multiply this "**n**" with least count and calculate the value of fraction (**VSR**) which is to be added in the main scale reading.

$$VSR = n \times LC$$

- Add the values 'M.S.R ' and 'V.S.R ' to observed value Y .

$$Y = MSR + VSR$$

or

$$Y = MSR + (n \times LC)$$

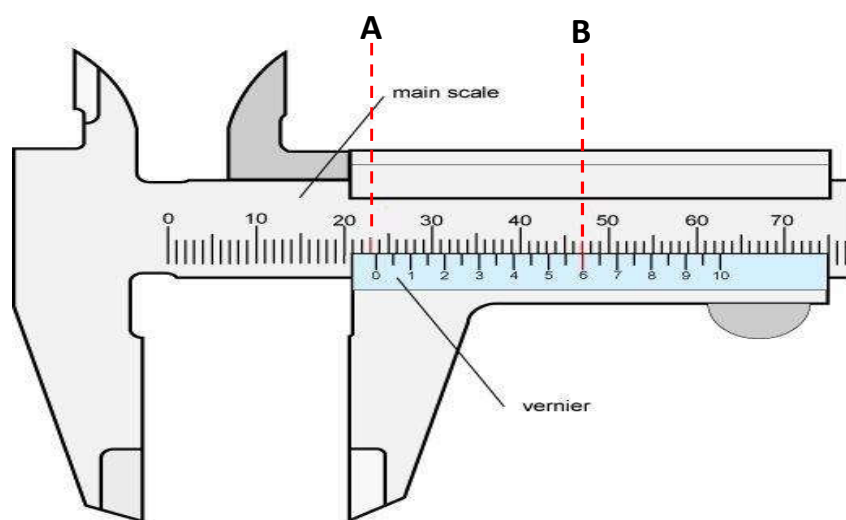
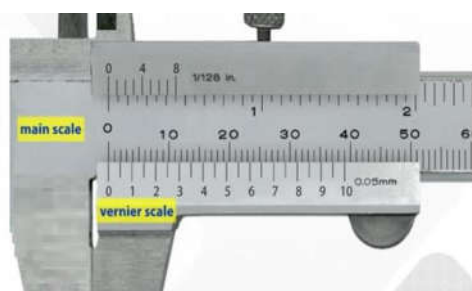
- Apply zero correction to Y if needed, to obtain final reading.

$$Final\ Reading = Y \pm ZE$$

- Repeat the experiment at least three times by gripping the wire at different places to obtain its average diameter.

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Measurement Using Vernier Calipers



Zero Error $ZE = 0$

A: $MSR = 23\text{ mm}$

B: line number n on vernier scale

$$n = 12$$

Therefore, $VSR = n \times LC$

$$VSR = 12 \times 0.05 = 0.60\text{ mm}$$

$$Reading = MSR + VSR$$

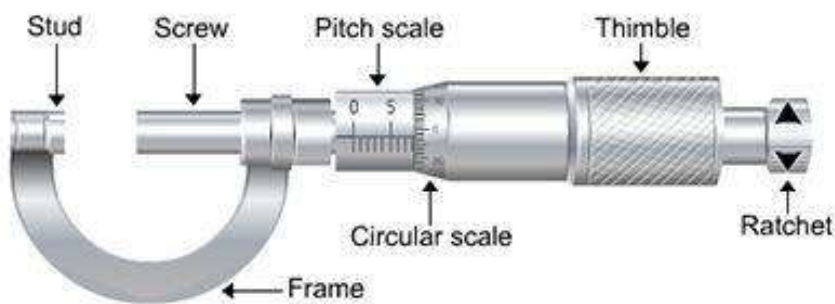
$$Reading = 23 + 0.60$$

$$Reading = (23.60 \pm 0.05)\text{mm}$$

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Micrometer or Screw Gauge

- To measure diameter of fine wires, thickness of paper and small lengths, a micrometer screw gauge is used
- The micrometer has two scales:
 - Main/Pitch scale on the sleeve
 - Circular scale on the thimble
- There are 50 divisions on the thimble /circular scale
- One complete turn of the thimble moves the spindle by 0.50 mm



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Micrometer or Screw Gauge

Least count of Micrometer

$$\text{Least Count} = \frac{\text{Pitch of screw gauge}}{\text{Total \# of division on circular scale}}$$

Smallest reading on the main scale = 0.5 mm

Total \# of division on circular scale = 50

$$\text{Least Count} = \frac{0.5 \text{ mm}}{50} = 0.01 \text{ mm}$$

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Precautions when using a micrometer

1. Never tighten thimble too much.
2. Use Ratchet to tighten the object in the anvil and spindle, stop when ratchet start noising.
3. Clean the ends of the anvil and spindle before making a measurement.
 - Any dirt on either of surfaces could affect the reading
4. Check for zero error by closing the micrometer when there is nothing between the anvil and spindle
 - The reading should be zero, but it is common to find a small zero error
 - Correct zero error by adjusting the final measurement

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How to use screw gauge?

- Find the **least count (LC)**. Close the jaws to check the Zero error and calculate the **zero correction (ZC)**.
- Fix the given object between the stud and spindle by turning the ratchet in the clockwise direction.
- Note the **main scale reading (MSR)** (up to complete division visible on the horizontal line just beyond the circular scale).
- Note the circular scale division says '**n**' which is exactly in front of the **index line** or **reference line**.
- Multiply '**n**' with the least count (LC) to get a fraction of the circular scale reading (CSR)

$$CSR = n \times LC$$
- Add the values 'MSR' and 'CSR' to find the value of reading Y.

$$Y = MSR + CSR$$

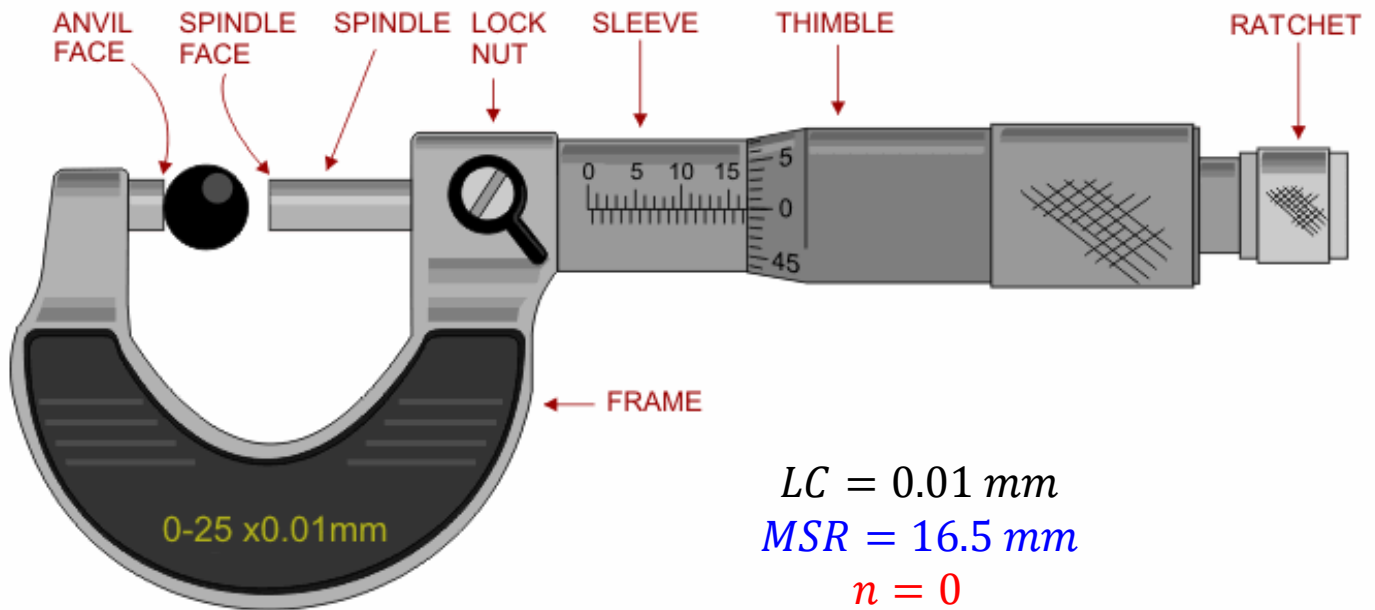
or

$$Y = MSR + (n \times LC)$$
- Apply zero correction to Y if needed, to obtain final reading.

$$\text{Final Reading} = Y \pm ZC$$
- Repeat the experiment at least three times by gipping the wire at different places to obtain its average diameter.

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Micrometer



$$\text{Reading} = MSR + (n \times LC)$$

$$\text{Reading} = 16.5 + (0 \times 0.01)$$

$$\text{Reading} = 16.50 \text{ mm}$$

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How to read a micrometer



$$LC = 0.01 \text{ mm}$$

$$ZE = 0$$

Diameter of the wire

$$MSR = 0 \text{ mm}$$

$$n = 24$$

$$\text{Reading} = MSR + (n \times LC)$$

$$\text{Reading} = 0 + (24 \times 0.01)$$

$$\text{Reading} = 0.24 \text{ mm}$$

$$\text{Reading} = (0.24 \pm 0.01) \text{ mm}$$

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How to read a micrometer



$LC = 0.01 \text{ mm}$

$ZE = 0$

Thickness of the wire

$MSR = 1.0 \text{ mm}$

$n = 39$

$Reading = MSR + (n \times LC)$

$Reading = 1.0 + (29 \times 0.01)$

$Reading = 1.39 \text{ mm}$

$Reading = (1.39 \pm 0.01) \text{ mm}$

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Zero Error

Positive zero error

- Positive zero error refers to the case when the jaws of the screw gauge are just closed and the reading is a positive reading away from the actual reading of 0.00 mm on circular scale.

Negative zero error

- Negative zero error refers to the case when the jaws of the screw gauge are just closed and the reading is a negative reading away from the actual reading of 0.00 mm.

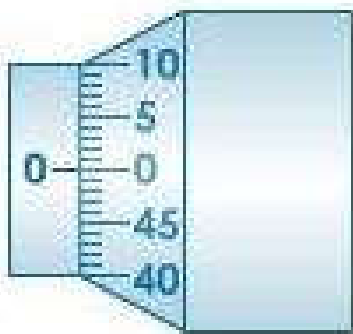
$$\text{Zero error (ZE)} = \pm n \times \text{least count (LC)}$$

Correction

$$\text{Actual Reading} = \text{Observed Reading} - \text{Zero Error}$$

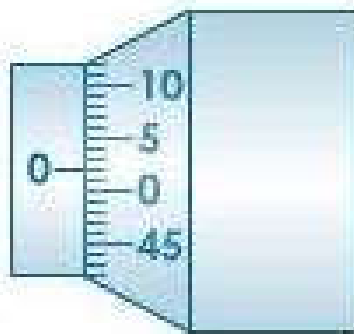
42

Zero Correction in Micrometer



(a)

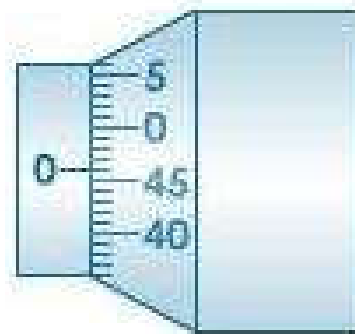
No zero error



(b)

Positive zero error

$$\text{Zero Error} = 2 \times 0.01 = +0.02$$



(c)

Negative zero error

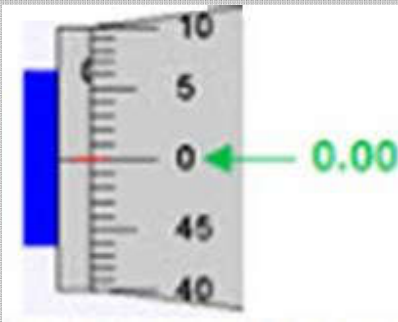
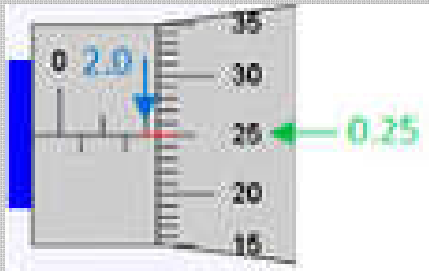
$$\text{Zero Error} = -4 \times 0.01 = -0.04$$

$$\text{Final Reading} = \text{Observed value} - \text{ZE}$$

$$\text{Final Reading} = \text{Observed value} - \text{ZE}$$

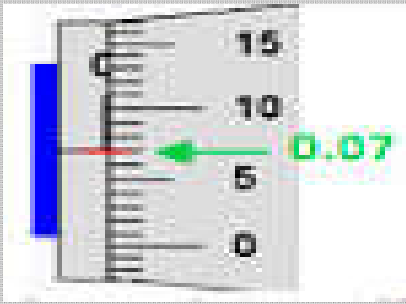
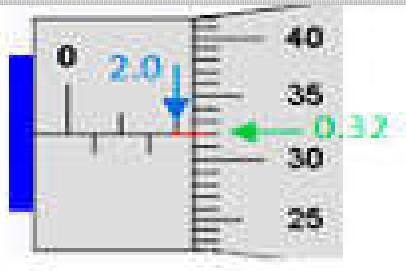
43

Micrometer

Checking for Zero Correction Error	Observed Reading	Actual Reading = Observed Reading – Zero Error
		Actual Reading = 2.25 – 0 Actual Reading = 2.25 mm
Zero Mark on the circular scale coincides with the datum line on the main scale and reading on main scale is zero ⇒ No Zero error	Reading = 2.0 + (0.01)(25) Reading = 2.25 mm	No zero Error correction required

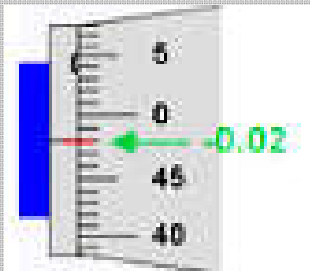
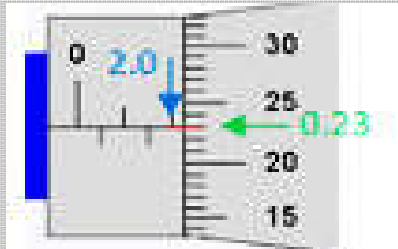
44

Micrometer

Checking for Zero Correction Error	Observed Reading	Actual Reading = Observed Reading – Zero Error
		Actual Reading = 2.32 – 0.07
Zero Mark on the datum line can be seen. $\Rightarrow$ Positive Zero error Reading = $0.01 \times 7 = 0.07\text{mm}$ (count from 0)	Reading = $2.0 + (0.01)(32)$ Reading = 2.32 mm	Actual Reading = 2.25 mm

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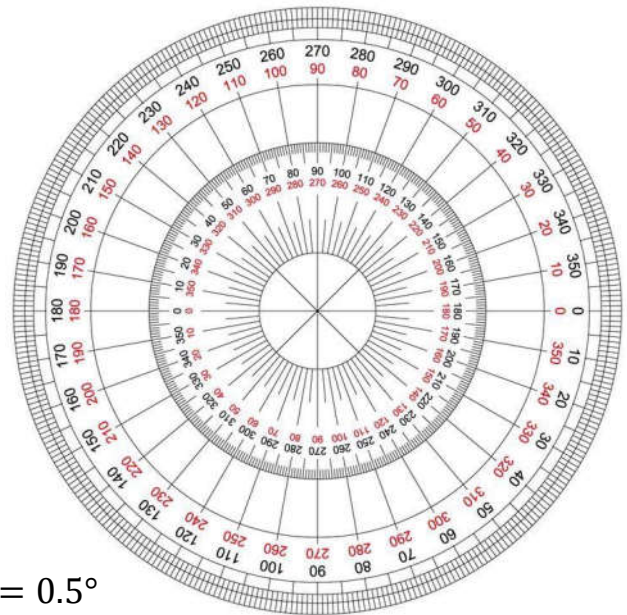
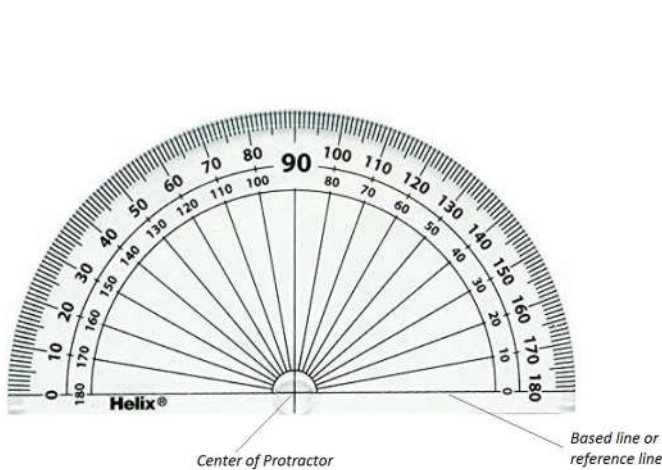
Micrometer

Checking for Zero Correction Error	Observed Reading	Actual Reading = Observed Reading – Zero Error
		Actual Reading $= 2.23 - (-0.02)$ $= 2.23 + 0.02$
Zero Mark on the datum line cannot be seen. $\Rightarrow$ Negative Zero error Reading = $0.01 \times (-2)$ Reading = – 0.02mm (Count down from 0)	Reading = $2.0 + (0.01)(23)$ Reading = 2.23 mm	Actual Reading = 2.25 mm

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Measurement an Angle

- A protractor is a handy tool used to measure and draw angles. Generally, semi-circular in shape, protractors are also available in full-circle, 360-degree versions.



Least Count of protractor = 1°

Uncertainty in single point measurement = 0.5°

Remember angle measurement is a two point measurement.

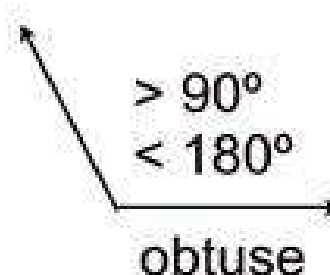
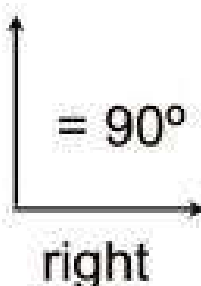
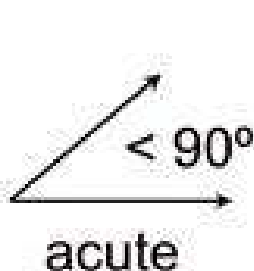
47

Measurement of an Angle

Approximate the measure of your angle.

- Angles can be classified in three ways: acute, obtuse, and right.
- Acute angles** are narrow (less than 90 degrees)
- Obtuse angles** are wide (greater than 90 degrees) and
- Right angles** are exactly 90 degrees (two lines perpendicular to each other).
- You can easily identify by eye, the category of angle you are trying to measure. Doing this step first helps you identify which scale to use on the protractor.

At a glance, we can tell this angle is acute because it is less than 90 degrees.

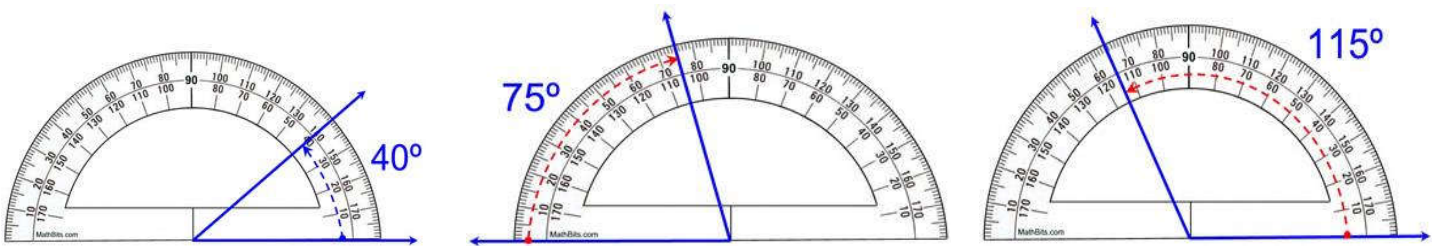


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How to use a Protractor?

To measure an angle:

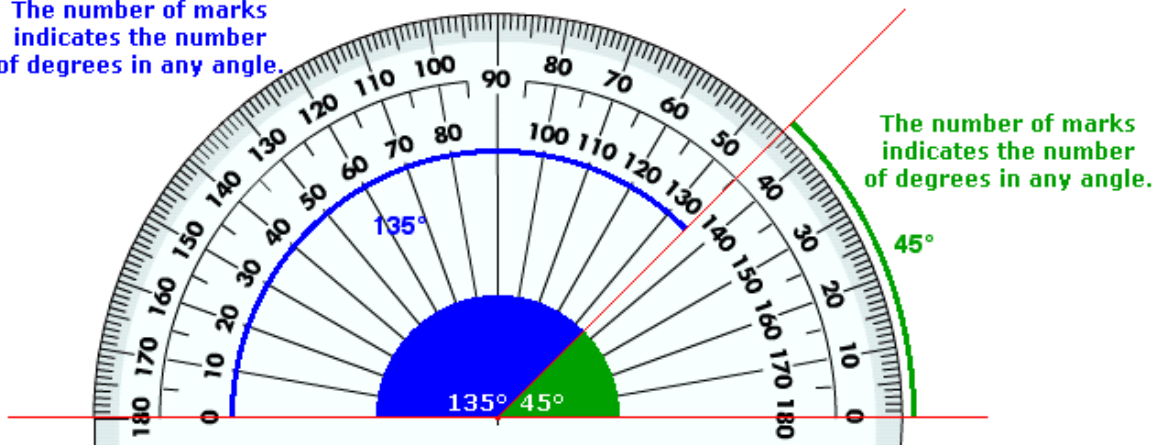
- Place protractor's center at a vertex of the angle (where two lines meet).
- Line up one ray (side) of the angle with the zero degree mark of the protractor. On this protractor, the zero mark is the bottom edge of the protractor.
- If the line does not pass through the protractor's arc, extend the angle's line until it does. Alternatively, you can align the edge of a piece of paper with the angle's leg to pass beyond the edge of the protractor, continuing the line of the angle.
- Read the degrees where the other ray of the angle crosses the protractor.
- The number the line passes through is the angle's measurement in degrees.



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Protractor

The number of marks indicates the number of degrees in any angle.



Least Count of protractor = 1°

Green:

$$\theta = 45^\circ$$

Therefore

$$\theta = 45^\circ \pm 1^\circ$$

Blue:

$$\theta = 135^\circ$$

Therefore

$$\theta = 135^\circ \pm 1^\circ$$

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Newton Meter

Spring balance measures directly both in force units i.e. Newton and also in grams.

To measure the force using the newton meter:

- First check the zero error in the newton meter.
- The least count of the Newton meter is 0.1N.
- Read the value of the force from the pointer position on the Newton (N) scale.
- Newton meter can also be used as spring balance to measure the mass on the scale in gram g scale.



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Newton Meter Reading



$$F = 1.8 \text{ N}$$



$$F = 3.5 \text{ N}$$



$$F = 4.0 \text{ N}$$

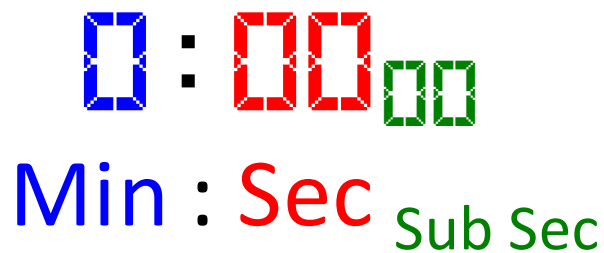
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Stopwatch

To measure short intervals of time we use the digital stop in lab.

- **Digital stopwatch** it can measure time in intervals of 0.01 seconds.
- Since we start and stop the stopwatch by observing the event, so human reaction error present in the time measurement.
- The human reaction time range is 0.2 to 0.5 s.
- So in the presence of human reaction error, the least count error become insignificant. Therefore we report the time value up to one decimal place.

Digital Stop watch Display



 Min : Sec Sub Sec



Stopwatch Reading

- Use the start/stop button to run and stop the stopwatch (button on the top right).
- Reset the stop watch using the reset button (left button on the top)
- Note the time value up to one decimal place applying the round of rule.
- For example: To note down the value on stopwatches in figure below, we report the time as



$t = 16.4 \text{ s}$



$t = 17.0 \text{ s}$



$t = 8.6 \text{ s}$

Measurement of Time

Period or Time Period measurement:

- The oscillation of a simple pendulum is an example of a regularly repeating motion.
- The time for 1 complete oscillation is referred to as the period of the oscillation.

How to measure the period of oscillation?

- Measure the time t for multiple oscillations e.g. for 10 oscillations t
- Repeat this measurement (time for 10 oscillations) 3 times and note down t_1 , t_2 and t_3 .
- Calculate the average time for 10 Oscillations

$$t_a = \frac{t_1 + t_2 + t_3}{3}$$

- The uncertainty in t_a

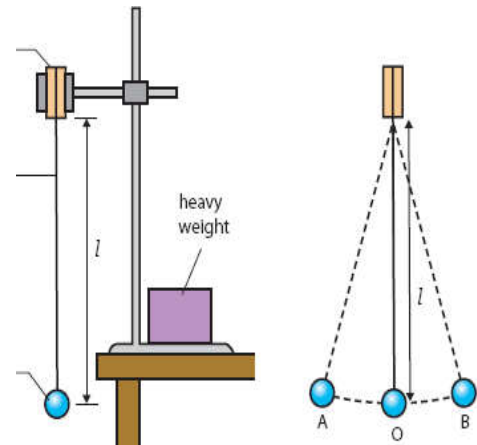
$$\Delta t_a = \frac{t_{\max} - t_{\min}}{2}$$

$$t = t_a \pm \Delta t_a$$

- Calculate the period (Time for one oscillation using

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

$$T = \frac{t_a \pm \Delta t_a}{10}$$



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Thermometer

Liquid in a glass thermometers are based on the thermal expansion of a liquid.

A liquid-in-glass thermometer is a thermometer which provides temperature readings through the expansion and contraction of liquid inside a calibrated tube.

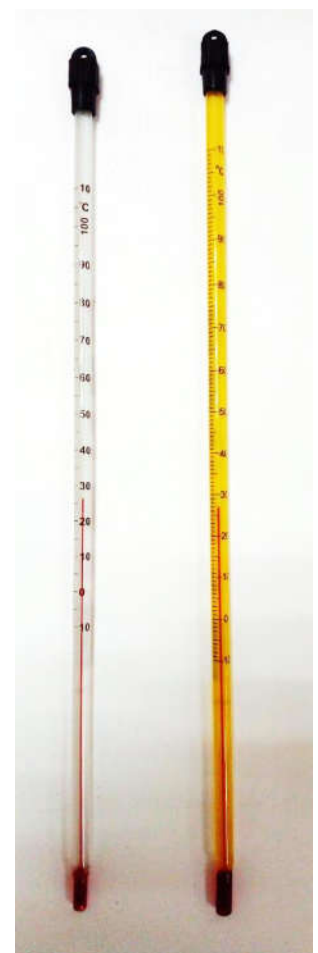
Least count of a Thermometer = 1°C

Mercury thermometer range: -10°C to 110°C

Temperature is a single point measurement.

The reading on thermometer in the figure can be reported as

$$\theta = (27.0 \pm 0.5)^\circ\text{C}$$



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Multimeter

- A multimeter is a device used to measure **voltage**, **resistance** and **current** in electronics & electrical equipment
- It is also used to **test continuity between 2 points** to verify if there is any breaks in circuit or line
- There are two types of multimeter **Analog** & **Digital**
 - Analog has a **needle style gauge**
 - Digital has a **LCD display**
- There are 2 styles of multimeters
 - **Switched Manually**: Switch between ranges to get most accurate reading.
 - **Auto Range**: Switches between ranges automatically for best reading.

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Symbols found on multimeter

These symbols are often found on multimeter and schematics are shown.

~	AC Voltage		Ground
—	DC Voltage		Capacitor
Hz	Hertz	μF	MicroFarad
+	Positive	μ	Micro
—	Negative	m	Milli
Ω	Ohms	M	Mega
	Diode	k	Kilo
•)))	Audible Continuity	OL	Overload

They are designed to symbolize components and reference values

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Ohmmeter:
Different Ranges of
DC Resistance
measurement

Voltmeter:
Different Ranges of DC
voltage measurement

Voltmeter:
Different Ranges of AC
voltage measurement

Ammeter:
Different Ranges of DC
current measurement



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Multimeter



For normal use

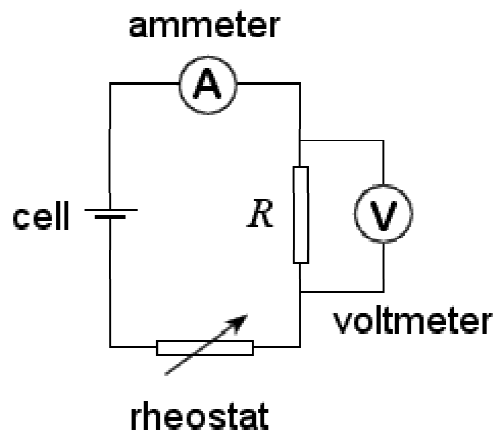


For High Current measurement up to 10 A

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Voltmeter

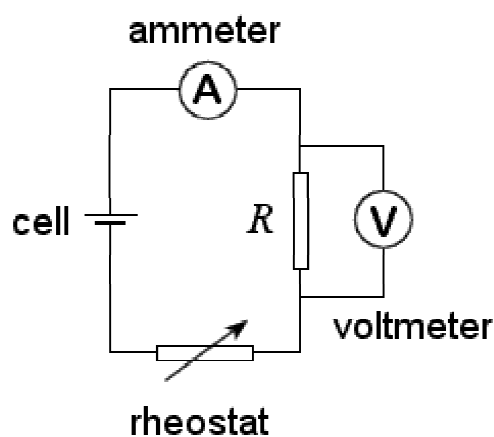
1. A voltmeter is a device or instrument that measures the amount of voltage throughout a circuit.
2. Voltmeter is connected parallel with the circuit to measure its voltage.
3. We know, in a parallel connection, the potential drop is the same in all the branches.
4. So, we connect the voltmeter in parallel with the device whose voltage has to be measured.
5. Here, in the figure, the voltmeter is connected in parallel with resistance, to measure the potential drop across it.
6. Since, in parallel combination, the potential drop is the same, the voltage drop across the voltmeter will be the same as the potential drop across the resistor.



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Ammeter

1. An ammeter is a device or instrument that measures the amount of current passing through a circuit.
2. An Ammeter is connected in series with the circuit to measure its current.
3. We know, flow of current will be the same in a series combination, but in case of parallel combination, current is divided into branches.
4. So, we connect ammeter in series with the device whose current has to be measured.
5. Here, in the figure, the ammeter is connected in series with the bulb, to measure the current flowing through it.
6. Since, in a series combination, the current flow is the same, the current flowing through the ammeter will be the same as the current flowing through the bulb.



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Multimeter as a Voltmeter



Range selection:

In AS:

- Voltmeter range selection is 20 V (DC voltage)

Readings

- In this range, the voltmeter shows the reading with two decimal places in units of V.
- Note down all the digit in the display.
- The last digit place tell us about the uncertainty in the measurement.



Note:

- Connect in Parallel to the component across which you want to measure the voltage.
- When connecting in the circuit, always connect the positive terminal of voltmeter (red) lead toward the positive terminal of battery and negative terminal of voltmeter (Black lead) to the positive terminal of battery.

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Multimeter as an ammeter



Range selection:

In AS:

- Ammeter range selection is 200 mA (DC current)

Readings

- In this range, the ammeter shows the reading with one decimal places in mA units
- Note down all the digit in the display.
- The last digit place tell us about the uncertainty in the measurement.



Note:

- Connect in Parallel to the component across which you want to measure the voltage.
- When connecting in the circuit, always connect the positive terminal of voltmeter (red) lead toward the positive terminal of battery and negative terminal of voltmeter (Black lead) to the positive terminal of battery.

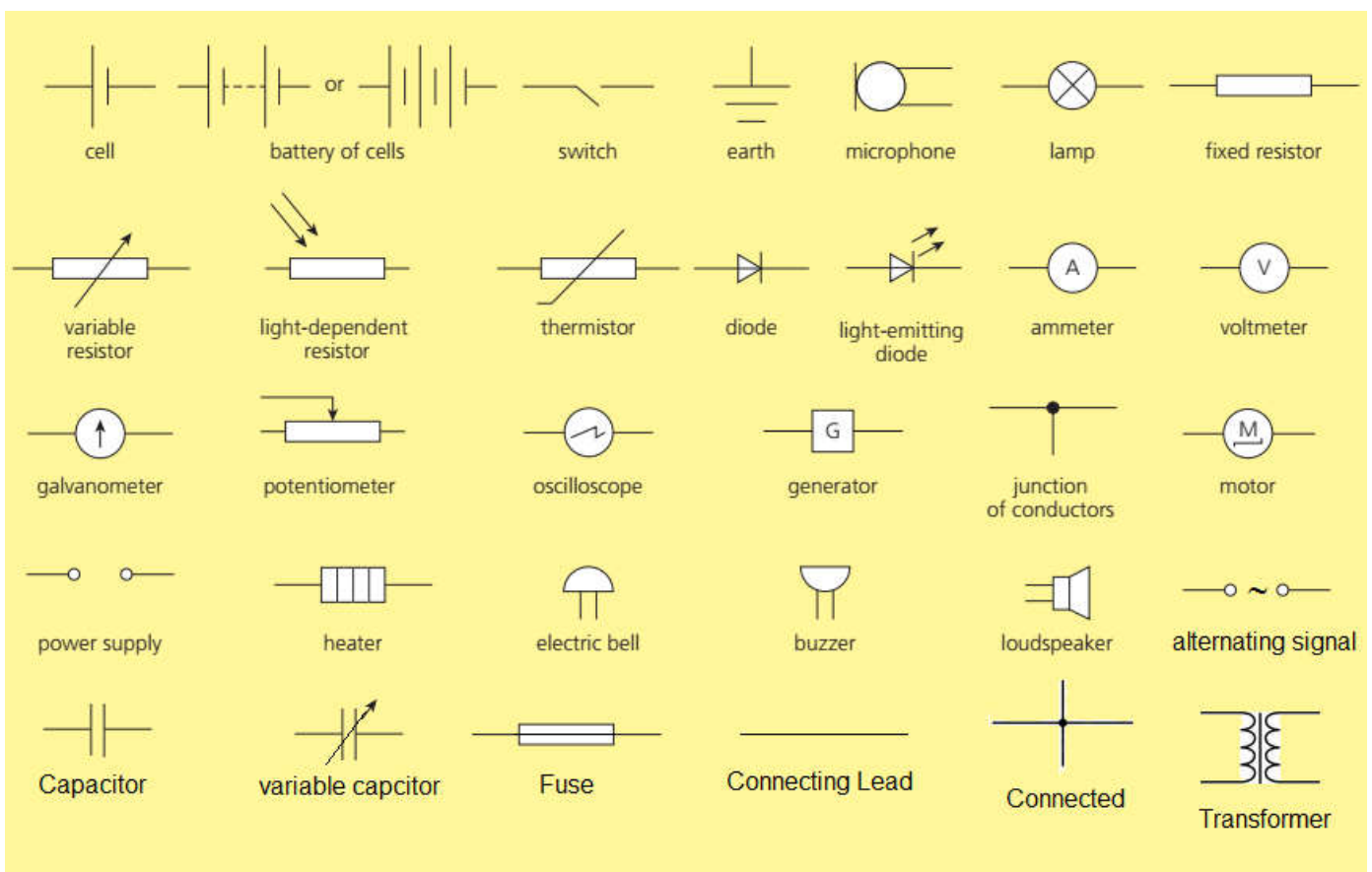
64

Making Circuits (General Guide line)

- Read care fully the circuit diagram.
- Identify all the components provided.
- First arrange all the component on the table according to circuit diagram.
- Start connecting these components form any one terminal of battery to using connecting wires.
- When connecting ammeter, make sure the positive terminal of ammeter is toward the positive terminal of battery.
- Always connect voltmeter at the end in parallel to the component with either positive terminal towards the positive terminal of battery if not stated, or as stated in the circuit.
- Always connect the positive terminal of Capacitor or diode to the positive terminal of battery or power supply.
- The labeled positive terminal of given component must be connected to the positive terminal of battery or power supply.

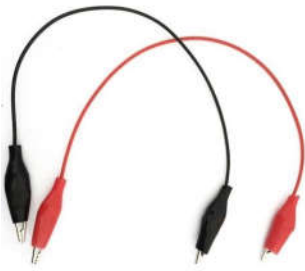
65

Circuit symbols and diagrams



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Electronics Components



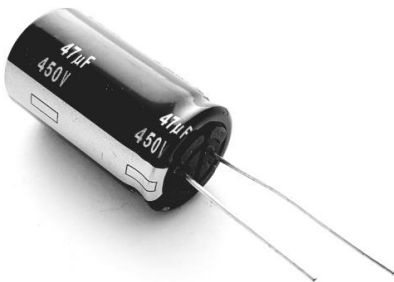
Connecting Wires



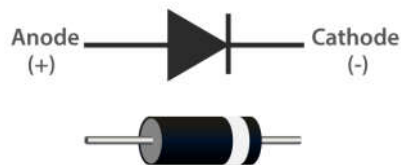
Resistors



Rheostat or Variable Resistor



Capacitor



Diode



LED

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Electronics Components



Switch



Component Holder



1.5 V



3.0 V



4.5 V

D.C. Battery Pack

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Electronics Components



d.c. power supply

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Range and distribution

Largest possible range is required.

Point distribution should be equally spaced

- It means that for example if you have to measure length (L) from 0-100 cm, so we must take highest range while **keeping the difference constant** and getting **6 set of readings**.
- The difference you can take here is 15, so the readings of L you'll take will be: 15 cm, 30 cm, 45 cm, 60 cm, 75 cm, 90 cm. These values of L you have cover almost the whole range of values possible from minimum to maximum.
- Same applies if you have set of resistors and you are asked to make different combinations of resistors to yield different values of resistances
 - Minimum number of resistors to Maximum number of resistors if varying the number of resistors between the points.
 - The values of resistance must cover the whole possible range, like from minimum to maximum value possible (here keeping the difference between individual values of resistance for different combinations common is not necessary!)

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Quality of data

In a nutshell this one mark is for how close your readings are to the readings of supervisor.

- Do your readings have the points which make them look *actual readings instead of made-up readings* such as:
 - i. Scatter of points about the graph, due to random error the points will never lie on a straight line
 - ii. The trend (in the data or graph) is correct like dependent variable increasing with increasing independent variable and so on.
- You will get accuracy marks if you actually write the values which are there on the equipment instead of making your own and if you did the experiment as accurately as supervisor.

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Table of results

You should be able to:

- Present numerical data and values in a single table of results record all data in the table
- Draw up the table in advance of taking readings so that they do not have to copy up their results
- Include in the table of results columns for raw data and for values calculated from them
- Use column headings that include both the quantity and the unit and that conform to accepted scientific conventions
- In next few slide will explain how to draw a table

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Table

Recording results:

It is important that you develop the skill of recording results in a clear and concise manner.

Generally, numerical results will be recorded in a table.

The table should be neatly drawn using a ruler and each heading in the table should include both the quantity being measured and the unit it is measured in.

Layout:

You will draw one single table with headings.

Each heading will have the symbol of quantity with its standard units after slash (**Symbol / Units**) such as "L / m".

Writing "L m" is not accepted.

#	L/cm	I/A	$\frac{1}{I}/A^{-1}$
1	10.3	0.628	1.47
2	19.0	0.350	2.86

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Table

Raw data:

Data you record from the instrument is called Raw data

The data must be reported up to, "to the same precision".

- All the raw data readings of a particular quantity should be recorded to the *same number of decimal places* which should in turn be *consistent with the precision of the measuring instrument (least count)*.
- "*Decimal places* should be same through out the raw data column".

Calculated Data:

Data you asked to calculate using the raw data

- Significant Figure in the calculated data should be in accordance with the rules of treatment of significant figures.
- You may used 1 more significant figure to make number of significant figure same through out the calculated data column
- If only one quantity involve in the calculation, then Significant Figure in the calculated data should be same as in the RAW data (or one more not one less).

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Example

In an experiment, a student investigated how the extension of a rubber cord varied with the diameter of the cord. The length of each cord was 80.0 cm. A mass of 500 g was attached to each cord. The student measured and recorded the diameter d of each cord using a caliper and determined the extension e of each cord using a metre rule. The student then calculated values of $\frac{1}{d^2}$ and completed a table of results, as shown in table.

The caliper measured d to the nearest 0.1 mm.

d/mm	$\frac{1}{d^2}/\text{mm}^{-2}$	e/cm
1.0	1.0	4.2
1.2	0.69	2.9
1.4	0.51	2.1
1.6	0.39	1.6
1.8	0.31	1.3
2.0	0.25	1.0

Since e was measured using a metre rule, all values are given to the nearest millimetre. 1 cm or 1.00 cm would be incorrect.

Values of $\frac{1}{d^2}$ were calculated. Since d was recorded to 2 significant figures, $\frac{1}{d^2}$ should also be calculated to 2 (or 3) significant figures. For the first row, 1.00 would also be acceptable, but not 1.

Note the unit for $\frac{1}{d^2}$.

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Example: 9702/33/O/N/10-Q1

In this experiment, you will investigate how the motion of a pendulum bob is affected by the height of the bob above the bench.

- (a) (i) Set up the apparatus as shown in Fig. 1.1.

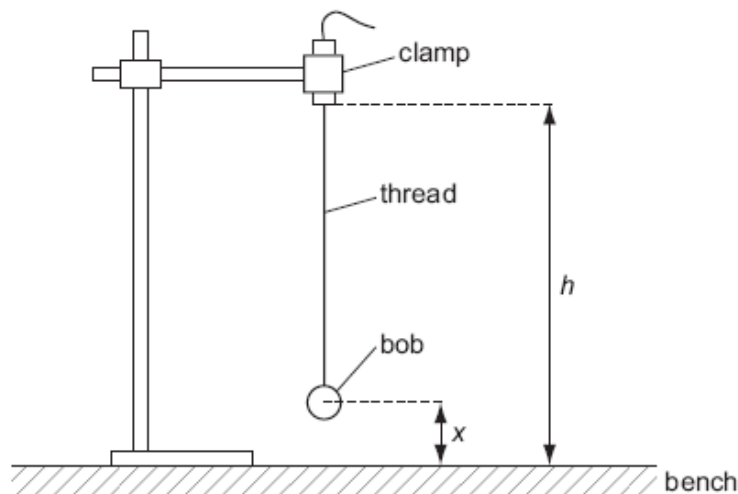


Fig. 1.1

The distance h from the point of suspension to the bench should be as large as possible.

The distance x between the centre of the bob and the bench should be approximately 5 cm.

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Example: 9702/33/O/N/10-Q1

- (ii) Measure and record distance h .

Throughout this experiment, do not change the distance h .

$$h = \dots (76.0 \pm 0.1) \text{ cm}$$

- (iii) Measure and record distance x .

$$x = \dots (5.0 \pm 0.1) \text{ cm}$$

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- (b) Displace the bob a small distance to the left. Release the bob and watch the movement.

The time the bob takes for each complete swing, first to the right and then back to the left, as shown in Fig. 1.2, is T .

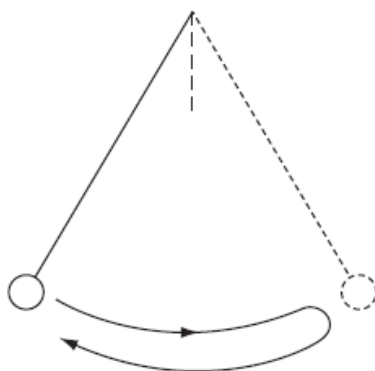


Fig. 1.2

By timing several of these complete swings, determine an accurate value of T .

Time for 10 oscillations

$$t_1 = 16.8 \text{ s}$$

$$t_2 = 16.9 \text{ s}$$

$$t_3 = 17.0 \text{ s}$$

$$t_{\text{avg}} = \frac{16.8 + 16.9 + 17.0}{3} = 16.9 \text{ s}$$

$$\Delta t_{\text{avg}} = \frac{17.0 - 16.8}{2} = 0.1 \text{ s}$$

$$t = (16.9 \pm 0.1) \text{ s}$$

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

$$T = \frac{(16.9 \pm 0.1) \text{ s}}{10}$$

$$T = \frac{16.9}{10} \pm \frac{0.1}{10}$$

$$T = \dots (1.69 \pm 0.01) \text{ s}$$

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Example: 9702/33/O/N/10-Q1

- (c) Keeping h constant, change x and repeat (a)(iii) and (b) until you have six sets of values for x and T . Include values for T^2 in your table of results.

x / cm	Time for 10 Oscillations				T/s	T^2/s^2
	t_1/s	t_2/s	t_3/s	t_{avg}/s		

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Example: 9702/33/O/N/10-Q1

Raw Data					Calculated Data	
x / cm	Time for 10 Oscillations				T/s	T^2/s^2
	t_1/s	t_2/s	t_3/s	t_a/s		
5.0	16.8	16.9	17.0	16.9	1.69	2.85
15.0	15.6	15.6	15.8	15.7	1.57	2.46
25.0	14.3	14.3	14.6	14.4	1.44	2.07
35.0	12.8	12.6	12.8	12.7	1.27	1.61
50.0	10.1	10.2	10.3	10.2	1.02	1.04
65.0	6.9	6.9	6.9	6.90	0.690	0.470
<i>Same number of decimal places</i> in a column					Significant Figure same as in the RAW data or 1 more significant figure. Same number of significant figure in a column (e.g. <i>The "0" in red are one plus S.F in calculated data in the last row</i>)	

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Analysing Results

When you have obtained your results the next thing to do is to analyse them.

Graph:

Very often this will be done by plotting a graph. You may be asked to plot a graph in a particular.

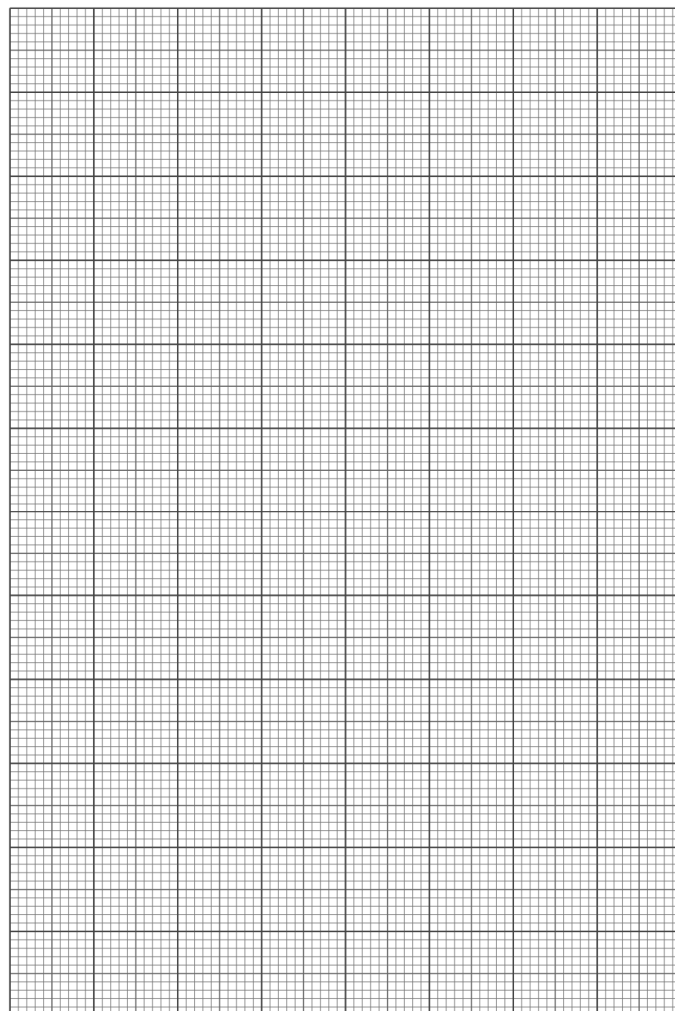
The general rule is that the variable you control (the independent variable) is plotted on the x-axis and the variable which that changes as a result (the dependent variable) is plotted on the y-axis.

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Graph

Choice of Scale

- Scales should be chosen in such a way that data are easy to plot and easy to read.
- Grid provided in 12×8
- Choose such a scale that cover 80% (or at least more than 50%) of the grid on both axes.
- On coordinate paper, every 10th line is slightly heavier than every 5th which is slightly heavier than other lines; *called the major division*.
- *Such a major division-line should always represent a multiple or decimal multiple of 1, 2, or 5 (e.g., 0.1, 0.2, 0.5, 10, 20, 500, etc.).*



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Graph

Choice of Scale:

To find out the suitable scale, note down the range of data that you want to plot on both x and y axes.

Procedure

- Note down the maximum x_{max} (round off to higher side) and minimum x_{min} (round off and choose lower value) value of variable plotting on x-axis

- Take the difference

$$R = x_{max} - x_{min}$$

- Divide this with number of boxes you want to cover. (maximum 8 boxes on x-axis)

$$x \text{ scale} = \frac{x_{max} - x_{min}}{8}$$

- Note down the maximum y_{max} (round off to higher side) and minimum y_{min} (round off and choose lower value) value of variable plotting on y-axis

- Take the difference

$$R = y_{max} - y_{min}$$

- Divide this with number of boxes you want to cover. (maximum 12 boxes on y-axis)

$$y \text{ scale} = \frac{y_{max} - y_{min}}{10}$$

Round off both the scale to multiple or submultiple of 1, 2 and 5.

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Graph

- To plot the data point on the graph, you can calculate the number of small boxes to locate the exact position on the graph grid.
- After choosing the scale, find the value of the smallest square box
- The for any data point to plot, find the number of boxes using the formula,

$$\# \text{ of small boxes} = \frac{\text{Data value} - \text{Fake Origin value}}{\text{Value of the smallest square box}}$$

If the fake origin is (x_o, y_o)

You want to plot the point (x, y)

$$\# \text{ of small boxes on } x \text{ axis} = \frac{x - x_o}{\left(\text{Value of the smallest square box on } x - \text{axis} \right)}$$

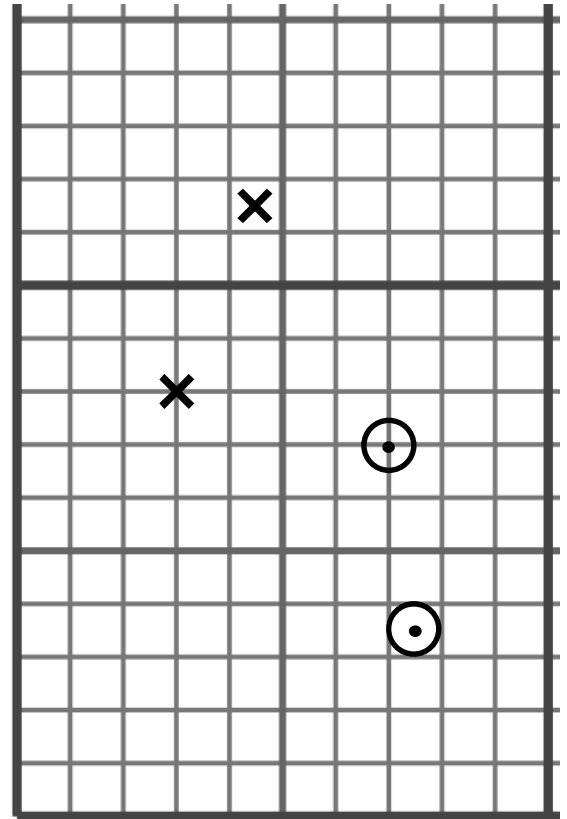
$$\# \text{ of small boxes on } y \text{ axis} = \frac{y - y_o}{\left(\text{Value of the smallest square box on } y - \text{axis} \right)}$$

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Graph

Plotting:

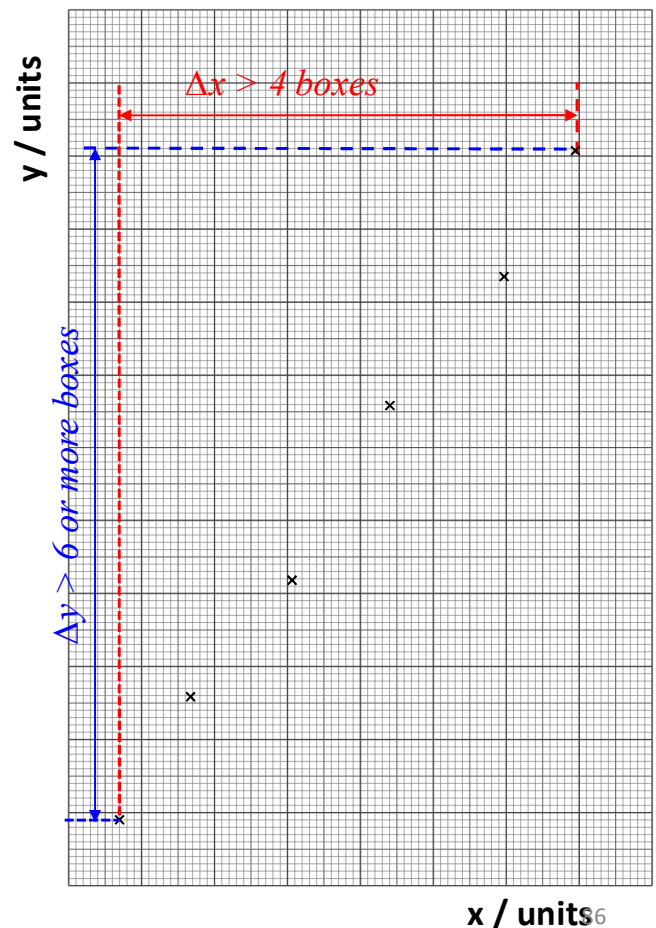
- All points must be **plotted accurately** so they are not more than 0.5 mm away from where they must be plotted (slight offsetting is pardoned).
- The point must be **plotted sharply**. If the points are not visible due to sharp lead **then cross them or encircle them**.
- Personally, I recommend **using small crosses instead of dots** (points), because blobs (points with diameter greater than 0.5 small square) are not accepted.
- Otherwise, if you find it easy to work with dots, use them, but make sure they are not blobs.



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Best Fit Line on Graph

- Choose such a scale on both the axes that cover at least more than 50% of the grid.
- Form left most point to right most point on x-axis, and bottom most point to top most point on y-axis. (See figure)
- My personal recommendation is to choose such a scale on both the axes that cover 80% of the grid on both axes.



Graph

Trend:

You should be able to:

- Draw straight lines of best fit or curves to show the trend of a graph
- draw tangents to curved trend lines.

Best Fit Line:

The graph is a straight line. But it is not possible that all points lie on the line.

“LINE PASSING, NEAREST TO MAXIMUM NUMBER OF POINTS”

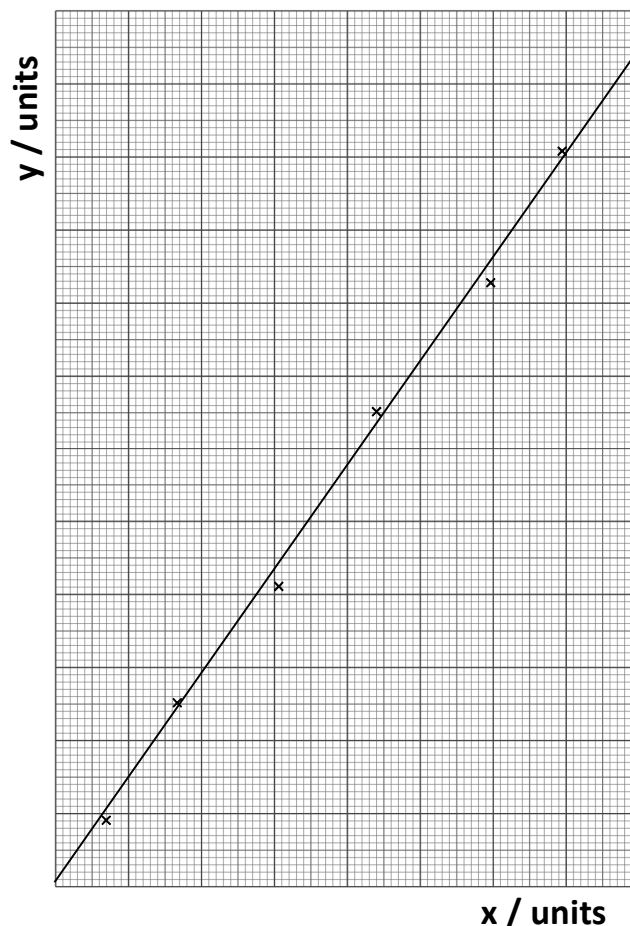
- A best-fit line has to be drawn. Most people don't get the idea of best-fit line. By best-fit we mean 'average of all points' line.
- There must be **even distribution of points above and below the line**. The scattering of points around the line is due to random errors.
- Best fit line **must have the balance of at least 5 points** which means you can ignore any one point which does not fit into a trend.
- There must be an even distribution of points either side of the line along the full length, as we can call the best fit line '**Insaaf Wali Line**' in Urdu, which means **line doing fair treatment to all the points**.
- So the vector displacement of the points from the line should cancel out to zero.

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Graph

Best fit line:

- Lines must not be kinked.
- Lines thicker than half a small square are not accepted so I recommend a **sharp lead pencil and a transparent ruler** for this job.
- **All points in the table (minimum 5) must be plotted** for this mark to be scored.
- When finding gradient from the line draw the triangle with the **hypotenuse at least 70% of the graph**. **Label the points with their coordinates.**

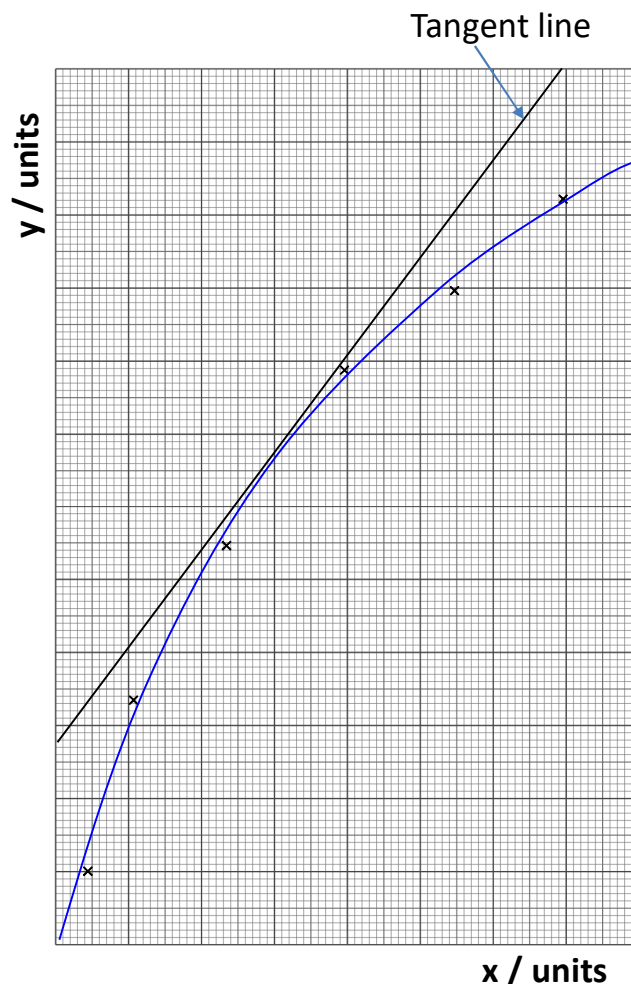


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Graph

Best fit Curve:

- Lines must not be kinked.
- Lines thicker than half a small square are not accepted so I recommend a *sharp lead pencil and a transparent ruler* for this job.
- All *points in the table* (minimum 5) *must be plotted* for this mark to be scored.
- When finding gradient from the tangent line draw the triangle with the *hypotenuse at least 70% of the graph*. *Label the points with their coordinates.*



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Graph

Summary

- The axes must be labeled with their appropriate **Symbol / units** (same as the headings of table).
- The scale must not be odd such as each 1 big box = 3 units or 7 units.
- Appropriate scales are 1,2 and 5 units = 1 box.
- Scale must be chosen to *give at least 50% of the graph in both of x- & y-directions*.
- On the graph grid provided, there are about **8 big boxes horizontally** & **12 big boxes vertically** (when the paper is viewed in portrait form). Therefore, the graph you draw **must cover ATLEAST 4 boxes horizontally and 6 boxes vertically** – appropriate scales must be chosen to ensure this.
- **False origin should be used** if the values start far away from the origin.
- *The numerical labels must be regularly spaced.*
- Scale markings should be no more than three large squares apart so **to be on the safe side label all big box marks**.
- The line drawn must be extended beyond the points to occupy full graph.

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Analysis Conclusion and Evaluation

Finding gradient and y-intercept:

Finding gradient

The linear line can be written in equation as:

$$y = mx + c$$

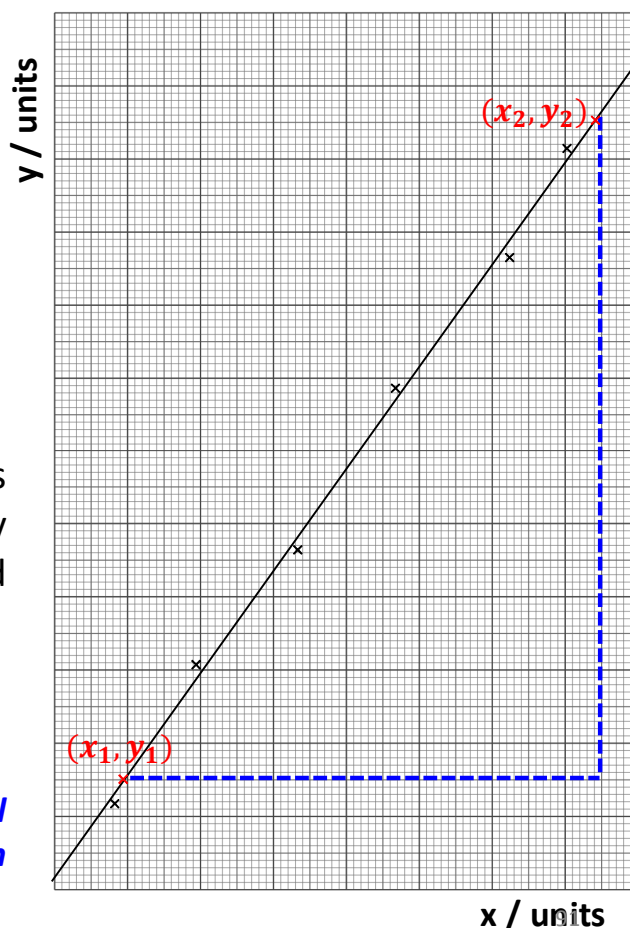
y is dependent variable, x independent variable, c is point where line touches y-axis at $x = 0$, (a constant), and m is gradient of graph.

- **To find gradient.** From your points $[(x_1, y_1)]$ and $[(x_2, y_2)]$ which you found by drawing triangle on the line, you can find gradient by this equation:

$$\text{Gradient} = \frac{(y_2 - y_1) \text{ Units}}{(x_2 - x_1) \text{ Units}}$$

Note:

Both read-offs must be accurate to half a small square and sensibly quoted on the graph and in the calculations as well.



Analysis Conclusion and Evaluation

Finding gradient and y-intercept:

Finding gradient

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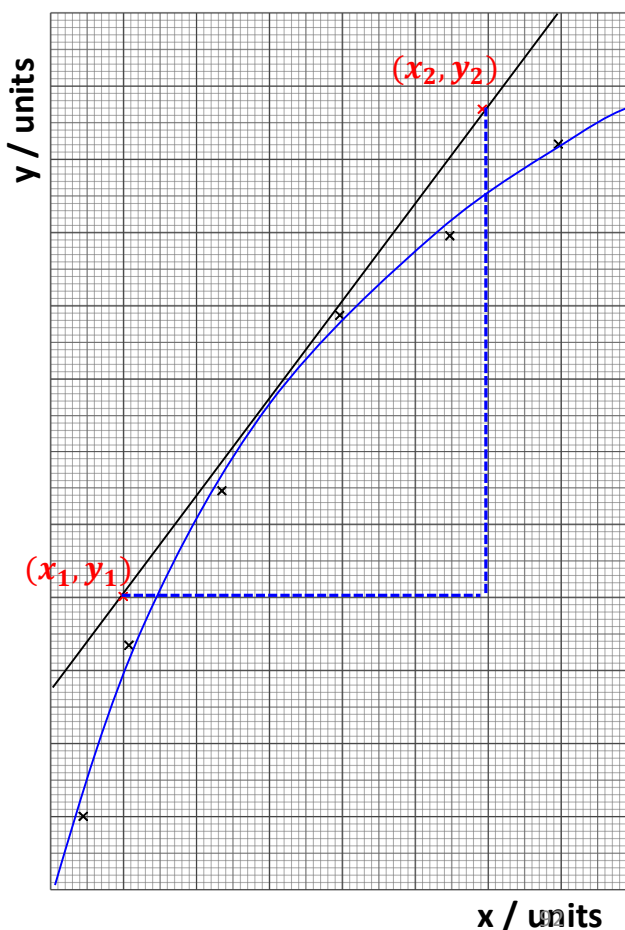
y is dependent variable, x independent variable, c is point where line touches y-axis at $x = 0$, (a constant), and m is gradient of graph.

- **To find gradient.** From your points $[(x_1, y_1)]$ and $[(x_2, y_2)]$ which you found by drawing triangle on the line, you can find gradient by this equation:

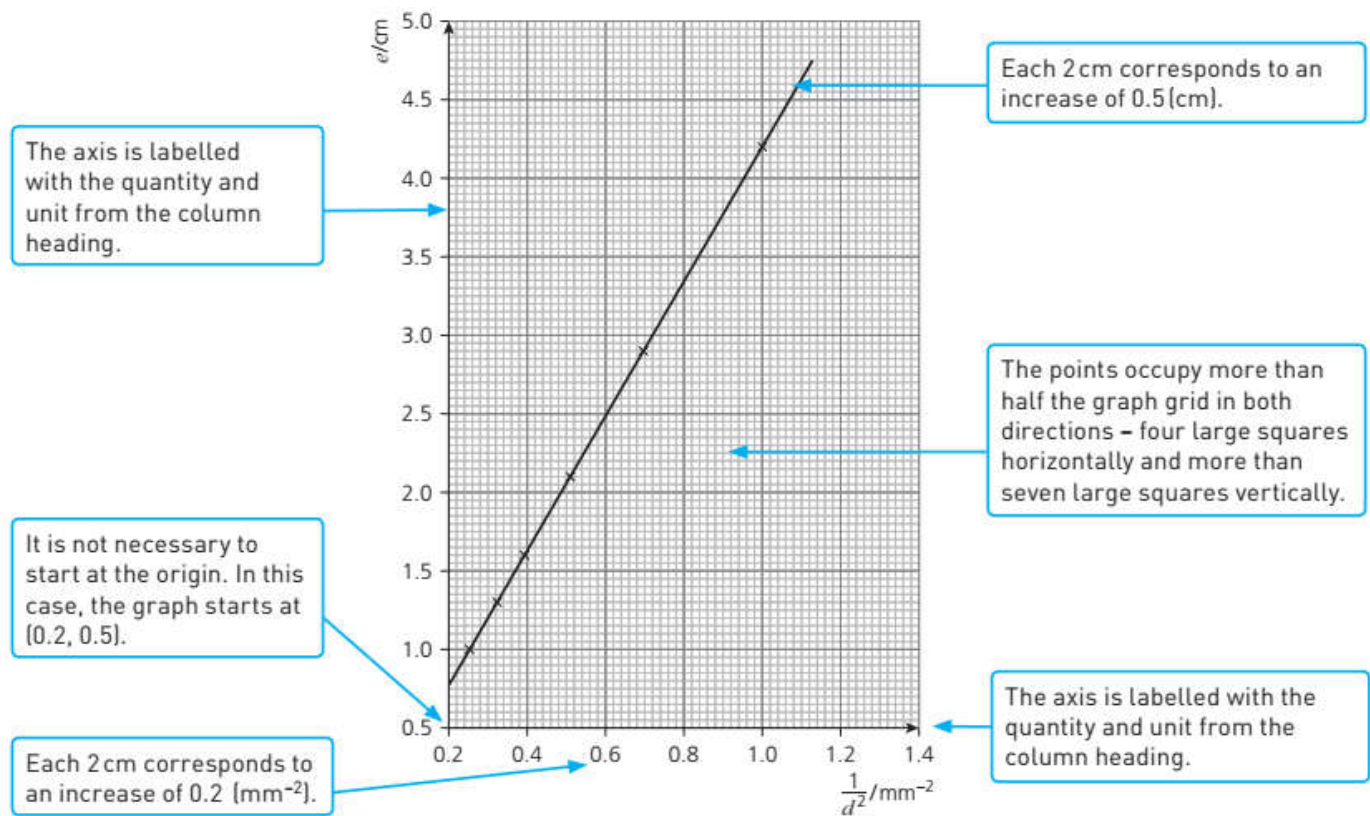
$$\text{Gradient} = \frac{(y_2 - y_1) \text{ Units}}{(x_2 - x_1) \text{ Units}}$$

Note:

Both read-offs must be accurate to half a small square and sensibly quoted on the graph and in the calculations as well.



Example (Graph of data on slide 73)



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Example: 9702/33/O/N/10-Q1

From best fit line

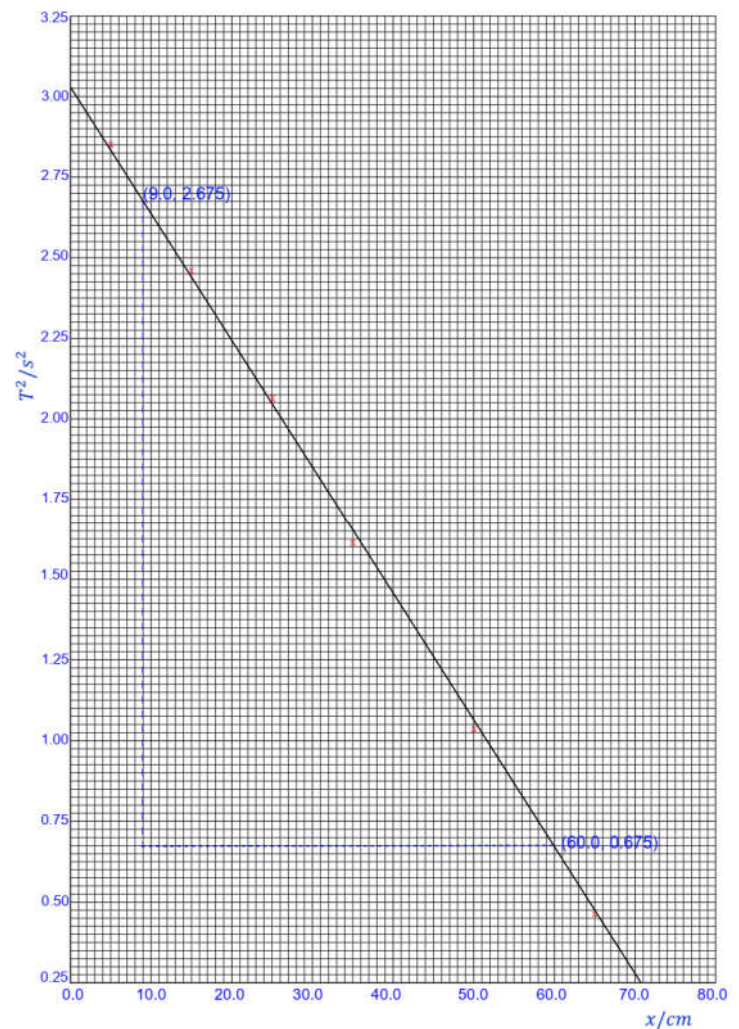
$$(x_1, y_1) = (9.0, 2.675) \text{ and}$$

$$(x_2, y_2) = (60.0, 0.675)$$

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\text{Gradient} = \frac{(0.675 - 2.675) \text{ s}^2}{(60.0 - 9.0) \text{ cm}}$$

$$\text{Gradient} = -0.0392 \text{ s}^2 \text{ cm}^{-1}$$



Analysis conclusion and evaluation

Finding the Intercept:

Either: Check correct read-off from a point (x,y) on the line, then a calculation follows which requires you to substitute the values obtained in previous calculation of gradient.

- Substitution into

$$c = y - mx$$

$$y \text{ intercept} = y - mx$$

Read-off must be accurate to half a small square.

Or: If **x-axis** is start from 0, correct read-off from a point on the line at x=0 gives the value of y-intercept.

- A method mark and a accuracy mark for the new calculated value.

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Example: 9702/33/O/N/10-Q1

From best fit line

$$(x, y) = (60.0, 0.675)$$

$$y \text{ intercept} = y - mx$$

$$y \text{ intercept} = 0.675 - (-0.0392 \times 60.0)$$

$$y \text{ intercept} = 3.03s^2$$

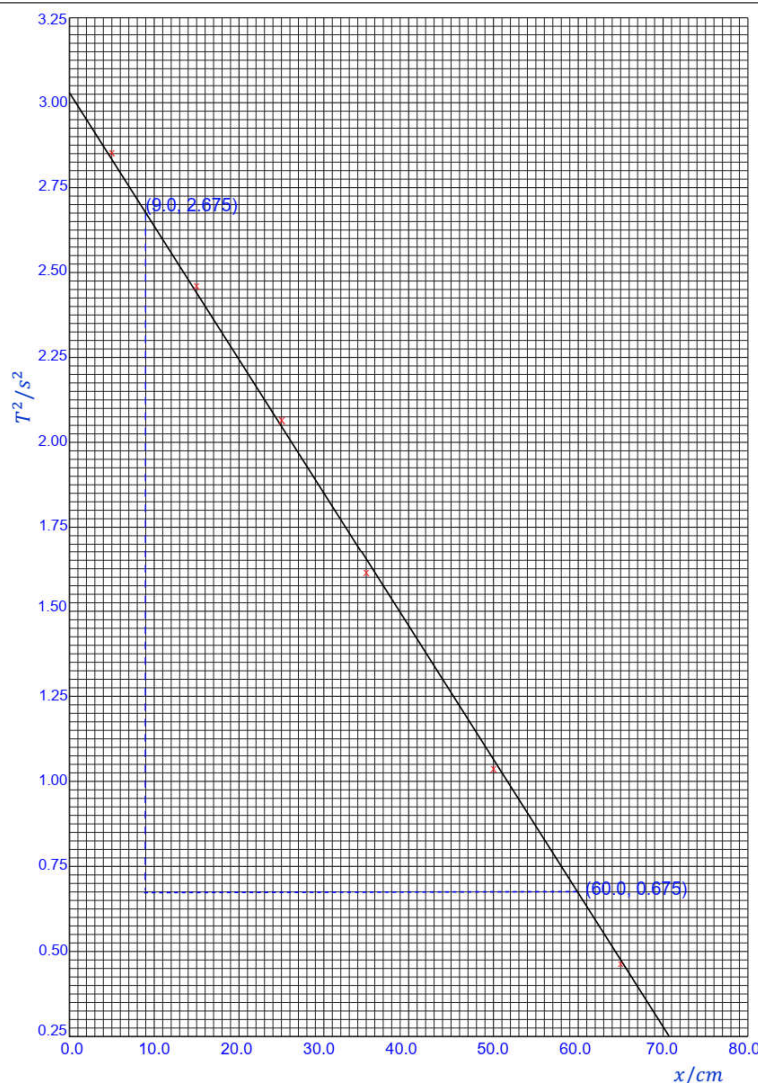
Or

Since x-axis is start from zero, we can directly read from graph the value of y-intercept,

$$y \text{ intercept} = 3.025 s^2$$

Note:

If x-axis start from zero, then read out the value of y intercept from graph if possible.



Analysis conclusion and evaluation

Conclusion:

In the last part of Question 1, an equation is provided, e.g.,

$$T^2 = A - Bx$$

This equation is the equation of straight line of best fit on graph of T^2 on the y-axis against x on the x-axis.

From the plotted graph, we know that, $y = T^2$ and $x = x$

Rearrange the given equation as,

$$T^2 = -Bx + A$$

Compare the given with the line Equation

$$y = mx + c$$

to find the *expression for gradient and y-intercept*.

$$\text{Gradient} = -B$$

$$y \text{ intercept} = A$$

“Find the values of A and B using the values of gradient and y-intercept” with appropriate units.

Calculate the quantities you ask to calculate using the value of A and B and other given data.

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Example: 9702/33/O/N/10-Q1

(e) The quantities T and x are related by the equation

$$T^2 = A - Bx$$

where A and B are constants.

Use your answers to (d)(iii) to determine the value of $\frac{A}{B}$.

Give an appropriate unit.

Re-arrange the given equation

$$T^2 = -Bx + A$$

Compare with

$$y = mx + c$$

This implies that

$$y = T^2 \text{ and } x = x$$

The equation for the gradient and y-intercepts are

$$\text{Gradient} = -B$$

$$\Rightarrow B = -\text{Gradient}$$

$$B = 0.0392 \text{ s}^2 \text{ cm}^{-1}$$

$$y \text{ intercept} = A = 3.03 \text{ s}^2$$

$$\frac{A}{B} = \frac{3.03 \text{ s}^2}{0.0392 \text{ s}^2 \text{ cm}^{-1}} = 77.2 \text{ cm}$$

$$\frac{A}{B} = \text{77.2 cm}$$

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Question 2

This question is more accurately described as an 'error-question' – meaning that this question depends on *how accurately you work*, and in case your *accuracy is compromised*, how can you *improve the experiment to avoid it*.

Throughout this question you should think:

- Why I am feeling that this is difficult?
- What is the problem with this experiment?
- How can I modify it to take better readings?

This critical thinking is very important to do the last part of this question, but the observations are made while doing experiment and setting up the apparatus.

Question 2

This question usually has something 'vulnerable' to error to be measured so in this case a repeated reading is required.

Repeated Measurement: Same as the method described in question 1, take several readings (2-3 readings) and take their average and find the absolute uncertainty (half of the range of the data)

$$x = \frac{x_1 + x_2 + x_3}{3}$$

After measurements follow the calculations for finding out the *uncertainty in the readings*. The uncertainty in x is

$$\Delta x = \frac{x_{\max} - x_{\min}}{2}$$

- Keep in mind! A **consistent unit** must be quoted with the measured value and absolute uncertainty.

Example - 9702/32/M/J/07-Q2

- 2 In this experiment you will investigate how the rebound height h of a table-tennis ball is related to the height d from which it is dropped.

If air resistance is ignored, then theory predicts that

$$e = \sqrt{\frac{h}{d}}$$

where e is a constant. Air resistance may be ignored if $d < 40$ cm.

- (a) (i) Mount a half-metre rule vertically using a stand, boss and clamp.
 (ii) Place the table-tennis ball next to the rule and record d . Release the ball and make measurements to determine the rebound height h , as shown in Fig. 2.1.

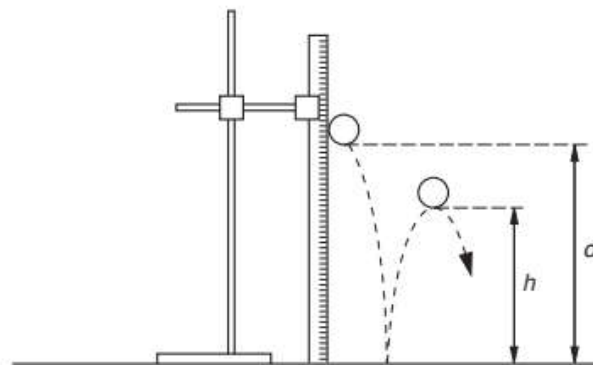


Fig. 2.1

$$h_1 = 26.0 \text{ cm}$$

$$h_2 = 26.5 \text{ cm}$$

$$h_3 = 27.0 \text{ cm}$$

$$h = \frac{26.0 + 26.5 + 27.0}{3} = 26.5 \text{ cm}$$

$$\Delta h = \frac{27.0 - 26.0}{2} = 0.5 \text{ cm}$$

$$h = (26.5 \pm 0.5) \text{ cm}$$

$$d = (35.0 \pm 0.1) \text{ cm}$$

$$h = (26.5 \pm 0.5) \text{ cm}$$

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When you have to repeat the measurement

1. If examiner is awarding 2 mark for single measurement, a clear evidence for the repeated readings required.
2. Whenever you measure the time, take the repeated values, to decrease effect of the human reaction error in the measurement.
3. If the body is in motion, or oscillating, then repeat the measurements (position or time measurements)

Types of Uncertainty

$$a = (a \pm \Delta a) \text{ units}$$

- Absolute Uncertainty Δa**

The value of uncertainty reported with the measured quantity in same units, is the absolute uncertainty.

Example: $a = 8.0 \pm 0.1 \text{ cm}$

$$\Delta a = \pm 0.1 \text{ cm}$$

- Fractional/Relative Uncertainty $\frac{\Delta a}{a}$**

$$\text{Fractional uncertainty in } a = \frac{\text{Absolute Uncertainty}}{\text{Measured Value}} = \frac{\Delta a}{a}$$

Example: $a = 8.0 \pm 0.1 \text{ cm}$

$$\text{Fractional uncertainty in } a = \frac{\Delta a}{a} = \frac{0.1}{8.0} = 0.01 \quad (0.0125 \text{ from calculator})$$

- Percentage Uncertainty**

$$\text{Percentage uncertainty in } a = \frac{\text{Absolute Uncertainty}}{\text{Measured Value}} \times 100 = \frac{\Delta a}{a} \times 100$$

Example: $a = 8.0 \pm 0.1 \text{ cm}$

$$\text{Percentage uncertainty in } a = \frac{\Delta a}{a} \times 100 = \frac{0.1}{8.0} \times 100 = 0.01 \times 100 = 1 \%$$

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Treatment of Uncertainty

For finding the **absolute / percentage / fractional uncertainty**, keep in mind the following rules:

- Rule 1 (Multiplication or division by a constant)**

If a *measured quantity* is multiplied or divided by a constant then the **absolute uncertainty is multiplied or divided by the same constant**. (In other words the relative uncertainty stays the same.)

- Rule 2 (Addition or Subtraction)**

If two (or more) measured quantities are *added or subtracted* then **their absolute uncertainties are added**.

- Rule 3 (Multiplication or Division)**

If two (or more) measured quantities are *multiplied or divided* then their **relative uncertainties are added**.

- Rule 4 (Power rule)**

If a measured quantity is raised to a power then the **relative uncertainty is multiplied by that power**. (If you think about this rule, you will realize that it is just a special case of rule 3.)

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Combining Uncertainties

For quantities which are added or subtracted to give the final result, add the actual uncertainties

Two physical quantities x and y are measured

$$x = x \pm \Delta x$$

$$y = y \pm \Delta y$$

- If the Physical quantity z obtain by

$$z = nx$$

The uncertainty in z is

$$\Delta z = n\Delta x$$

- If the Physical quantity z obtain by

$$z = \frac{y}{n}$$

The uncertainty in z is

$$\Delta z = \frac{\Delta y}{n}$$

- If the physical quantity z is given by

$$z = x + y$$

$$z = x - y$$

The uncertainty in z is

$$\Delta z = \Delta x + \Delta y$$

For quantities which are multiplied together or divided to give the final result, add the fractional/percentage uncertainties.

- If physical quantity z is given by

$$z = Axy \text{ or } z = \frac{x}{By}$$

Where A and B are constant.

The fractional uncertainty in z is

$$\frac{\Delta z}{z} = \frac{\Delta x}{x} + \frac{\Delta y}{y}$$

- If physical quantity z is given by

$$z = Ax^a y^b \text{ or } z = Ax^a / y^b$$

Where A is constant.

The fractional uncertainty in z is

$$\frac{\Delta z}{z} = a \left(\frac{\Delta x}{x} \right) + b \left(\frac{\Delta y}{y} \right)$$

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Estimating Uncertainties

Usually the absolute uncertainty is the least count of the device

- But in Q2, for most of the cases it is greater –

Examples:

- You are measuring angle, and protractor is in your hand, your shaking hand increase the uncertainty in the measurements. If you are not repeating the measurements, then you may write the uncertainty value great than the least count of protractor in the range ($2^\circ - 5^\circ$)
- You are measuring position of a moving object using meter rule, the uncertainty in the measurements is more than the least count. If you are not repeating the measurements, then you may write the uncertainty value great than the least count of protractor in the range ($0.2 \text{ cm} - 0.5 \text{ cm}$)
- You are measuring diameter using meter rule, the uncertainty in the measurements is more than the least count because the centre is not known exactly. If you are not repeating the measurements, then you may write the uncertainty value great than the least count of protractor in the range ($0.2 \text{ cm} - 0.5 \text{ cm}$)

Note:

In all these cases you can repeat the measurements, and report the average values with absolute uncertainty equal to the half of the range of the data.

Percentage Uncertainty Calculation

$$a = (a \pm \Delta a) \text{ units}$$

After measurement, the examiner may ask you to find the percentage uncertainty in the measurement of (e.g.) “a”.

Use the formula

$$\text{Percentage uncertainty in } a = \frac{\text{Absolute Uncertainty}}{\text{Measured Value}} \times 100$$

or

$$\text{Percentage uncertainty in } a = \frac{\Delta a}{a} \times 100$$

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Example - 9702/32/M/J/07-Q2

- (iii) Explain how you used the apparatus to ensure that the rebound height h was measured as accurately as possible.

Use of set squares to indicate height and repeat to refine position.....

.....

- (iv) Estimate the percentage uncertainty in h .

$$\% \Delta h = \frac{\Delta h}{h} \times 100$$

$$\% \Delta h = \frac{0.5}{26.5} \times 100 = 2 \%$$

percentage uncertainty in $h = 2 \%$

Use

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Calculating the Value

- *Calculating another value* using a given formula by putting in the measure values.

JUSTIFY THE NUMBER OF SIGNIFICANT FIGURES

- After calculations involving a given formula to find a certain value, the candidate is usually asked to '*justify the number of significant figures*' in the final answer to the value you were asked to calculate
- Here you need to keep in mind that when you are calculating a certain value, *its significant figures must be in accordance with the rules of treatment of significant figures (Slides 11 and 12)*
- Link the number of significant figure in the calculated value to the significant figures of quantities of raw data (those used in calculation). Mention these quantities.

Drawing conclusions

- Sometimes there is a limited number of results and it is not possible to plot a graph. In these cases, it often still possible to determine the value of a constant.
- A relationship is usually suggested between the values you measured or calculated in previous parts.
- It is suggested that the d and h are related by the equation

$$e = \sqrt{\frac{h}{d}}$$

- *you are required to find 2 different values of a constant 'e' for the respective data sets using the given relationship.*

Example - 9702/32/M/J/07-Q2

(v) Calculate a value for e .

$$e = \sqrt{\frac{26.5}{35.0}} = 0.870$$

$$e = \dots\dots\dots 0.870$$

(b) Repeat (a)(ii) and (b)(v) using a different value of d .

$$h_1 = 17.5 \text{ cm}$$

$$h_2 = 18.0 \text{ cm}$$

$$h_3 = 19.0 \text{ cm}$$

$$h = \frac{17.5 + 18.0 + 19.0}{3} = 18.1 \text{ cm}$$

$$\Delta h = \frac{19.0 - 17.5}{2} = 0.8 \text{ cm}$$

$$h = (18.1 \pm 0.8) \text{ cm}$$

$$e = \sqrt{\frac{18.1}{25.0}} = 0.850$$

$$d = \dots\dots\dots (25.0 \pm 0.1) \text{ cm}$$

$$h = \dots\dots\dots (18.1 \pm 0.8) \text{ cm}$$

$$e = \dots\dots\dots 0.850$$

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Drawing conclusions

- The number of significant figures chosen when writing down these values should be **equal to the least number of significant figures** in the data used.
- If you are asked to justify the number of significant figures you give for your value of e , state the number of significant figures that d and h were measured to and that you will choose the smallest.
- Do not quote your values of e to 1 significant figure to make them look equal when d and h were measured to 3 significant figures.

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Drawing conclusions

- To determine whether this relationship containing a constant is supported by experimental data, the percentage difference between the two values of the constant should be calculated and compared with a calculated percentage uncertainty.
- To calculate percentage difference, use the relation

$$\%age\ Difference\ in\ e = \left(\frac{e_{max} - e_{min}}{e_{min}} \right) \times 100$$

- Compare the *percentage difference in the two values of k with your clearly stated criterion.*
- In the part following calculation of two values of e, you are asked '*Explain whether your results support the suggested relationship.*'
- *Some time the criterion is given by the examine, if not then*

You need to set a certain criterion for yourself.

Two Approaches to Set A Criterion

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Approach 1 - Criterion

- A simple approach is to assume that the *percentage uncertainty in the value of e is about equal to the percentage uncertainty in either d or h; choose the larger percentage uncertainty of either d or h.*

$$\% \Delta h = \frac{0.5}{26.5} \times 100 = 2 \%$$

$$\% \Delta d = \frac{0.1}{35.0} \times 100 = 1.4 \%$$

- You first look at the percentage uncertainty in both *h* and *d* and decide which is bigger.
- Let us assume that *the larger percentage uncertainty is in h.*

$$Criteria < 2 \%$$

Your stated criterion is then that

- *If the % difference in e values is less than the criteria, the readings are consistent with the relationship.*
- *If the % difference in e values is greater than the criteria, the readings are not consistent with the relationship.*

Approach 2 - Criterion

- Another criterion is to state that the e values should be the same within 5% or 10% or 15% depending on the experiment and the uncertainty that you think sensible.

Sensible Criterion:

- A thing to keep in mind is that there is no specified criterion to judge the validity of a relationship; **it is entirely up to the candidate to set it**. A candidate can set the criterion to be <15% or <5%; it is entirely up to the candidate!
- However, *setting a criterion like <50% difference for the relationship to be valid is totally stupid. So set a sensible criterion.*

Example - 9702/32/M/J/07-Q2

- (c) Do the results of your experiment indicate that e is a constant within the limits of experimental accuracy? Explain your reasoning clearly.

$$\text{Percentage difference in } e = \frac{e_{\max} - e_{\min}}{e_{\min}} \times 100$$

$$\text{Percentage difference in } e = \frac{0.870 - 0.850}{0.850} \times 100 = 2.4 \%$$

$$\text{Criteria} < 2 \%$$

Since the percentage difference in e is greater than the specified criteria.
Therefore, results do support the suggested relationship.

Error and Improvements

This last part is worth 6 marks which asks you to describe four sources of error and suggest the appropriate remedies.

Throughout this question you should think:

- Why I am feeling that this is difficult?
 - What is the problem with this experiment?
 - How can I modify it to take better readings?
- If you thought about these points while performing, you would have definitely no problem dealing with this part of the question.
 - *There are no set “errors and improvements”, as the errors are specific to a particular experiment you perform.*

Error and Improvements

The most general Error and Improvement valid for all the Q2 from any area of physics in the P3 are

Error:

- Two data sets are not enough to draw a valid conclusion about a relationship.

Improvement:

- Take more data sets and plot a graph.

Example - 9702/32/M/J/07-Q2

(d) (i) State four sources of error or limitations of the procedure in this experiment.

Use

1. Two sets of readings not enough to draw valid conclusion.
2. Hard to judge rebound height, because ball is in motion
3. Difficult to release without applying a force
4. Inconsistent bounce.



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Example - 9702/32/M/J/07-Q2

(ii) Suggest four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. Take more sets of readings and plot graph
2. Use slow motion camera to record the video and play back slowly to record the value of h
3. Use card gate to release the ball by holding the ball against stop
4. Use flat and hard surface and turn off fans



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Thanks For your Attentions

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Attachments

- Few of the lab sheets are attached to these notes to give you guys idea, how to show your working.
- Lists of *Error and Improvements are also attached for the different situations.*

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General Tips For Errors and Improvements Q2 Last Part

9702/P3 - Experiment

This last part is worth 8 marks which asks you to describe four sources of error and suggest the appropriate remedies. At the start of this guide for question 2, we mentioned this:

“Throughout this question you should think: Why I am feeling that this is difficult? What is the problem with this experiment? How can I modify it to take better readings? This critical thinking is very important to do the last part of this question, but the observations are made while doing experiment and setting up the apparatus.”

If you thought about these points while performing, you would have definitely no problem dealing with this part of the question. There are no set “errors and improvements”, as the errors are specific to a particular experiment you perform. However, some general errors and improvements are given below:

Pro-Tip: The first error and improvement works for ALL experiments. So better memorize it as it is)

Error:

Two readings are not enough to draw a (valid) conclusion

Improvement:

Take many readings and plot a graph or take more values of ‘k’ and compare.

Different Experiment Scenarios and their potential errors and improvements

A) Water related experiment:

Error:

- (1) Hard to see water surface due to refraction effects/ meniscus effect
- (2) Labels get wet/ink runs

Improvement:

- (1) Use coloured liquid
- (2) Use waterproof labels/ink

Rejected: Bottle not vertical

B) Ball related experiment

Error:

- (1) Locating the centre of the ball when reading rule
- (2) Inconsistent bounce

Improvement:

- (1) Mark the centre of the ball with marker
- (2) Use a flat surface/ Turn off fan

C) Fast- moving object experiment

Error:

- (1) Difficult to judge when the ball is at its (maximum displacement, highest point etc)
- (2) Hard to see when object strikes floor.
- (3) Difficult to judge end point
- (4) Difficulty in deciding the toppling point

Improvement:

- (1) Position sensor above or below with data logger/ Video camera to play back frame by frame.
- (2) Use pressure sensor to stop timer.
- (3) Mark distance with lines on ramp (to eliminate parallax)
- (4) Move by increments

Rejected:

Reject reaction time ideas/difficult to release from the same point each time.

D) Releasing object from rest experiment

Error:

- (1) Difficulty in releasing the object due to (applied force etc)
- (2) (Object) falls at an angle due to wind.-Light object
- (3) Rod falls sideways/not entering sand vertically. – Heavy object

Improvement:

- (1) Use a remote-controlled clamp to release the object/ slot in tube + card/electromagnet
- (2) Turn off fans
- (3) Practical method to keep rod vertical e.g. guide for rod.

E) Oscillation experiment

Error:

- (1) T or time short/large uncertainty in T
- (2) Object does not swing freely/ friction between pivot and object
- (3) Not swinging in one plane only/idea of non-uniform oscillation (Light object only)
- (4) Oscillations die out quickly/ heavy damping (Light object only)
- (5) Difficult to judge end/start/ centre of swing/difficult to judge complete swing

Improvement:

- (1) A marker to time as reaches maximum displacement with (motion sensor) at end with video with timer (playback) in slow motion/ Increase the magnitude of the independent variable
- (2) Make hole bigger/bush or bearing idea
- (3) Turn off fan(Light object only) * For heavy object, no improvement available.
- (4) Use increased thickness of object
- (5) Use of fiducial marker/pointer

Rejected: Do the experiment in a vacuum, switch the fans off, not just 'use video', light gates, Camera, High speed camera, Too fast, Time too fast, Time more swings , Time large no. of swings,not 'repeated readings', not just 'use computer/data logger', Difficult to release from same point each time/human error/reaction time/unqualified use of light gates/sensors

F) Electricity experiment

Error:

- (1) Resistance / current fluctuating
- (2) Voltmeter scale not sensitive enough
- (3) Wires not straight

Improvement:

- (1) Clean contacts
- (2) Use digital voltmeter
- (3) Method of keeping wire (during experiment) straight e.g. tape to ruler, hang weights off end, clamp wire.

Rejected: Voltmeter not accurate enough. More accurate voltmeter/ Parallax error/zero error on meters/heating effects of wire

G) Force experiment

Error:

- (1) Maximum force reached without warning
- (2) Weights move.

Improvement:

- (1) Practical method of recording maximum value e.g force sensor with data logger
- (2) Method of fixing cotton loop to rule e.g. tape, glue.

Rejected: Increase force slowly/reaction time error

H) Pulley experiment

Error:

- (1) Masses hit each other
- (2) Friction at pulley
- (3) Uncertain starting position

Improvement:

- (1) Use larger pulley
- (2) Lubricate pulley
- (3) Method of fixing rule e.g. clamp rule/electromagnetic with steel /magnetic material ball) release mechanism

Rejected: Friction between pulley and string

I) Moment experiment

Error:

(1) Rule hits bench

(2) Ruler slips on support

Improvement:

(1) Method of preventing rule hitting bench, e.g. project end of cylinder over bench or elevate apparatus.

(2) Glue support to block

Rejected: Difficult to start at the same amplitude each time

J) Magnetism experiment

Error:

Glass may affect magnetic force / effect of surrounding magnetic materials

Improvement: Use a variety of materials to separate magnets and test if material affects results

Rejected: Reference to Earth's field/Move object further away

K) Bench/ Ramp (Surface) related experiment

Error:

(1) Some parts of board rougher than others/surface of board is uneven/board not flat

(2) Board tends to slip/board not stable/supporting block can topple

Improvement:

(1) Method to ensure same section of board used in each experiment (e.g. mark one section)

(2) Method described to secure board/block/support e.g. clamp the board, fix the supporting block to the bench with tape/blu-tack

Rejected: Board is rough/there is friction between the block and the board/use a smoother surface/references to oil/lubricants

L) Heat loss experiment

Error:

- (1) Heat lost through sides and /or Bottom
- (2) Low precision of thermometer
- (3) Bulb of thermometer is not completely immersed
- (4) Resistor continues to give out heat when switched off/ temperature continues to rise after switching off

Improvement:

- (1) Method to reduce heat loss/lag/insulate/polystyrene container
- (2) Thermometer with specified better precision, e.g. 0.1°C, 0.5°C
- (3) Use larger volume of water/use of thermocouple/other small temperature sensor(e.g. probe)
- (4) Wait until temperature reaches a maximum before reading

Rejected: Switch off fans to reduce convection/Just “weigh water”/ different starting temperatures of water; uneven temperature distribution in beaker/ parallax errors in reading volume or temperature/use of lid/heat loss in warming bowl/cup/draughts/heat loss to surroundings/use more accurate thermometer/thermometer not precise enough/not just ‘digital thermometer’

M) Terminal velocity experiment**Error:**

(Object) may not have reached terminal velocity.

Improvement:

Time constant over three markers

N) Light dependent experiment

Error:

External light affects (LDR)

Improvement:

Conduct experiment in dark room.

ERRORS AND IMPROVEMENT OF COMMON APPARATUS

A) Metre rule

Error:

- (1) Ruler not vertical
- (2) Parallax error
- (3) Difficult to hold rule still
- (4) Difficult to take measurements because the ruler moves / is not vertical
- (5) Reason for difficulty in measuring d e.g. viewed through ruler/parallax error in d
- (6) String too wide for markings on rule
- (7) Rules have different thicknesses /different lengths so not a fair test

Improvement:

- (1) Sensible method to ensure ruler vertical
- (2) Put coloured paper behind (object) /Description of method of reducing parallax error requiring additional equipment, e.g. !shadow projection/ extend mark to wood or track / pointer on rule / travelling microscope*)
- (3) Mount ruler in stand
- (4) Clamp rule / ensure rule is vertical using a set square on the bench
- (5) Method to improve measurement of d e.g. travelling microscope
- (6) Use thinner string
- (7) Use rulers of similar thicknesses/ readings/method to take thickness into account /use rulers of the same length

* If the diameter is quite wide, meter rule is prefer over calipers! Accuracy of metre rule is increased by using set square held against ruler.

Rejected: View at eye level.

B) Newton metre

Error:

- (1) Difficult to pull newton-meter parallel to ruler/bench

(2) Difficult to judge reading on newton-meter when detaches with reason e.g. ruler moves suddenly/without warning (so difficult to read newton-meter at the instant the ruler starts to move)/force drops to zero immediately after detachment

(3) Difficult to zero newton-meter when used horizontally

Improvement:

(1) Method to ensure force is parallel to ruler e.g. use a long string/pulley and weights*

(2) Method to read force at detachment e.g. newton meter with a 'max hold' facility/video and playback or freeze frame/ use system of pulley and weights or sand to measure F^* / use force sensor and data logger or computer*

(3) Improved method to measure F : e.g. use system of pulley and weights or sand*/use force sensor with datalogger or computer*

Rejected: Video to take reading/digital (electronic) newton meter/parallax related to newton meter/difficult to measure force/issue of viewing ruler and meter simultaneously/zero error in newton-meter/just a pulley

C) Slotted mass

Error:

Labelled values of mass may not be accurate.

Improvement:

Use balance/method of weighing mass.

Rejected: Weigh mass.

D) Objects with unfixed diameter (Circular objects)

Error:

(1) Difficult to measure diameter because (object) is flexible/not circular.

(2) Difficult to form a perfect sphere or disc/diameter of sphere or disc varied

Improvement:

(1) Measure diameter of (object) in two directions and average/ Use vernier calipers or micrometer screw gauge to measure average diameter

(2) Method to make uniform spheres/discs e.g. moulds

E) Protractor

Error:

(1) Protractor “wobbles” when being held by hands/ Difficulty in measuring θ owing to container not perfectly right angled (curved) at the bottom/difficult to line up protractor/horizontal line of protractor not on table

(2) parallax error in θ measurement

(3) θ (or reading) is difficult (or inaccurate, or imprecise) because pointer is thick

Improvement:

(1) use protractor with horizontal line flush to table top/freestanding or clamped protractor.

(2) use mirror scale

Rejected: View at right angles

If the value of the quantity measured is very small, can write increase the magnitude of the quantity of the independent variable.

Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating average or avoiding parallax errors by looking at an instrument “square on”.

Ask yourself whether the improvement is practical or not.

Common answers that are rejected by mark scheme :

Repeat experiment

Human error

Use a computer to improve the experiment

Use assistant

If clay/plasticine/heavy object is used in the experiment, wind movement doesn't affect it anymore.

(Think whether turning off fan will make a difference or not).

You may not need to use all of the materials provided.

For
Examiner's
Use

- 1** In this experiment, you will investigate how the motion of a pendulum bob is affected by the height of the bob above the bench.

(a) (i) Set up the apparatus as shown in Fig. 1.1.

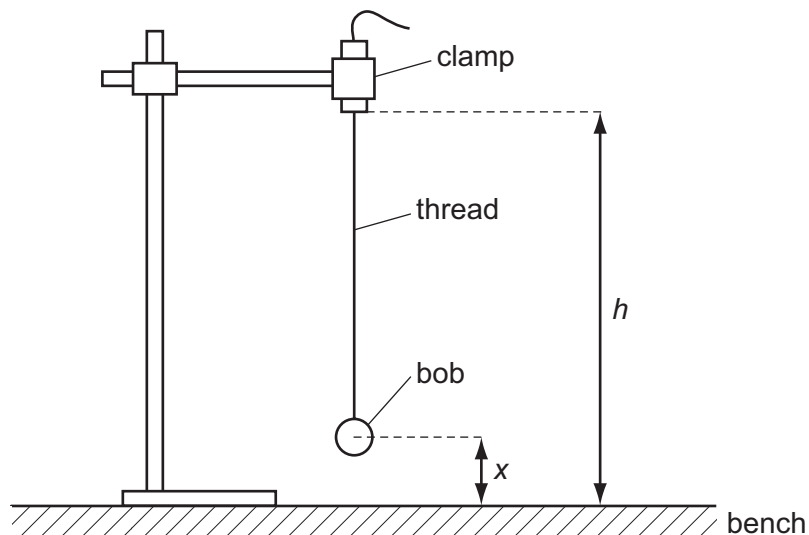


Fig. 1.1

The distance h from the point of suspension to the bench should be as large as possible.

The distance x between the centre of the bob and the bench should be approximately 5 cm.

(ii) Measure and record distance h .

Throughout this experiment, do not change the distance h .

$$h = (76.0 \pm 0.1) \text{ cm}$$

(iii) Measure and record distance x .

$$x = (5.0 \pm 0.1) \text{ cm}$$

- (b) Displace the bob a small distance to the left. Release the bob and watch the movement.

The time the bob takes for each complete swing, first to the right and then back to the left, as shown in Fig. 1.2, is T .

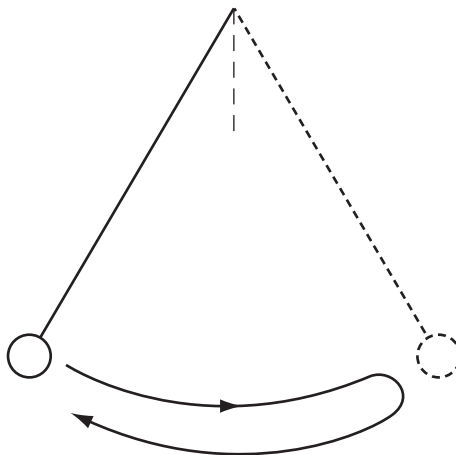


Fig. 1.2

By timing several of these complete swings, determine an accurate value of T .

Time for 10 Oscillations

$$t_1 = 16.8 \text{ s}$$

$$t_2 = 16.9 \text{ s}$$

$$t_3 = 17.0 \text{ s}$$

$$t_a = \frac{16.8 + 16.9 + 17.0}{3} = 16.9 \text{ s}$$

$$\Delta t_a = \frac{17.0 - 16.8}{2} = 0.1 \text{ s}$$

$$t = t_a \pm \Delta t_a$$

$$t = (16.9 \pm 0.1) \text{ s}$$

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

$$T = \frac{16.9 \pm 0.1}{10}$$

$$T = (1.69 \pm 0.01) \text{ s}$$

$$T = (1.69 \pm 0.01) \text{ s}$$



- (c) Keeping h constant, change x and repeat (a)(iii) and (b) until you have six sets of values for x and T . Include values for T^2 in your table of results.

For
Examiner's
Use

#	x/cm	Time for 10 Oscillations				T/s	T^2/s^2
		t_1/s	t_2/s	t_3/s	t/s		
1	5.0	16.8	16.9	17.0	16.9	1.69	2.85
2	15.0	15.6	15.6	15.8	15.7	1.57	2.46
3	25.0	14.3	14.3	14.6	14.4	1.44	2.07
4	35.0	12.8	12.6	12.8	12.7	1.27	1.61
5	50.0	10.1	10.2	10.3	10.2	1.02	1.04
6	65.0	6.9	6.9	6.9	6.90	0.690	0.470

- (d) (i) Plot a graph of T^2 on the y-axis against x on the x-axis.

(ii) Draw the straight line of best fit.

(iii) Determine the gradient and y-intercept of this line of best fit.

From best fit line

$$(x_1, y_1) = (9.0, 2.675) \text{ and}$$

$$(x_2, y_2) = (60.0, 0.675)$$

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\text{Gradient} = \frac{(0.675 - 2.675) s^2}{(60.0 - 9.0) cm}$$

$$\text{Gradient} = -0.0392 s^2 cm^{-1}$$

From best fit line

$$(x, y) = (60.0, 0.675)$$

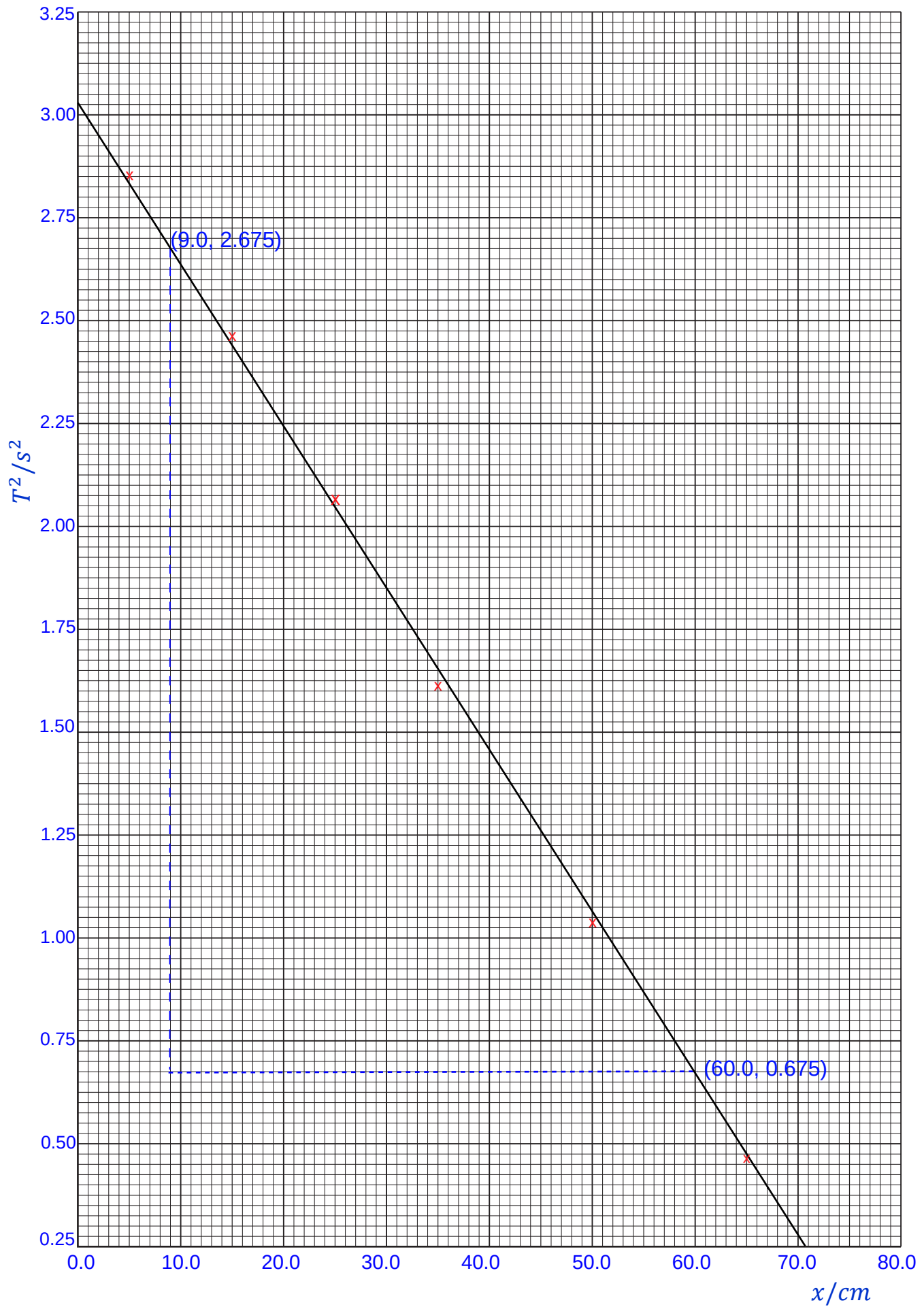
$$y \text{ intercept} = y - mx$$

$$y \text{ intercept} = 0.675 - (-0.0392 \times 60.0)$$

$$y \text{ intercept} = 3.03 s^2$$

$$\text{gradient} = -0.0392 s^2 cm^{-1}$$

$$y\text{-intercept} = 3.03 s^2$$



- (e) The quantities T and x are related by the equation

$$T^2 = A - Bx$$

where A and B are constants.

Use your answers to (d)(iii) to determine the value of $\frac{A}{B}$.

Give an appropriate unit.

Re-arrange the given equation

$$T^2 = -Bx + A$$

Compare with

$$y = mx + c$$

This implies that

$$y = T^2 \text{ and } x = x$$

The equation for the gradient and y-intercepts are

$$\text{Gradient} = -B$$

$$\Rightarrow B = -\text{Gradient}$$

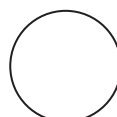
$$B = 0.0392 \text{ s}^2 \text{ cm}^{-1}$$

$$y \text{ intercept} = A$$

$$A = 3.03 \text{ s}^2$$

$$\frac{A}{B} = \frac{3.03 \text{ s}^2}{0.0392 \text{ s}^2 \text{ cm}^{-1}} = 77.2 \text{ cm}$$

$$\frac{A}{B} = 77.2 \text{ cm}$$



You may not need to use all of the materials provided.

- 2** In this experiment you will investigate how the rebound height h of a table-tennis ball is related to the height d from which it is dropped.

If air resistance is ignored, then theory predicts that

$$e = \sqrt{\frac{h}{d}}$$

where e is a constant. Air resistance may be ignored if $d < 40$ cm.

- (a)** **(i)** Mount a half-metre rule vertically using a stand, boss and clamp.
(ii) Place the table-tennis ball next to the rule and record d . Release the ball and make measurements to determine the rebound height h , as shown in Fig. 2.1.

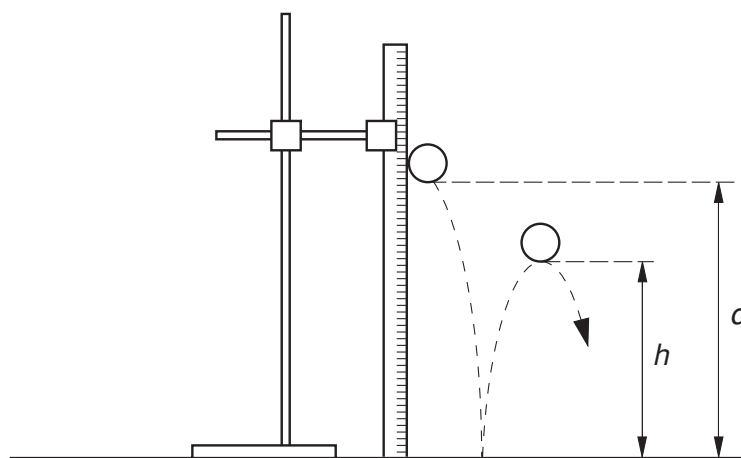


Fig. 2.1

$$h_1 = 26.0 \text{ cm}$$

$$h_2 = 26.5 \text{ cm}$$

$$h_3 = 27.0 \text{ cm}$$

$$h = \frac{26.0 + 26.5 + 27.0}{3} = 26.5 \text{ cm}$$

$$\Delta h = \frac{27.0 - 26.0}{2} = 0.5 \text{ cm}$$

$$h = (26.5 \pm 0.5) \text{ cm}$$

$$d = \dots\dots\dots (35.0 \pm 0.1) \text{ cm}$$

$$h = \dots\dots\dots (26.5 \pm 0.5) \text{ cm}$$

- (iii)** Explain how you used the apparatus to ensure that the rebound height h was measured as accurately as possible.

Use of set squares to indicate height and repeat to refine position.

.....

.....

.....

.....

(iv) Estimate the percentage uncertainty in h .

$$\% \Delta h = \frac{\Delta h}{h} \times 100$$

$$\% \Delta h = \frac{0.5}{26.5} \times 100 = 2 \%$$

percentage uncertainty in $h = \dots\dots\dots 2 \%$

(v) Calculate a value for e .

$$e = \sqrt{\frac{h}{d}}$$

$$e = \sqrt{\frac{26.5}{35.0}} = 0.870$$

$e = \dots\dots\dots 0.870$

(b) Repeat (a)(ii) and (b)(v) using a different value of d .

$$h_1 = 17.5 \text{ cm}$$

$$h_2 = 18.0 \text{ cm}$$

$$h_3 = 19.0 \text{ cm}$$

$$h = \frac{17.5 + 18.0 + 19.0}{3} = 18.1 \text{ cm}$$

$$\Delta h = \frac{19.0 - 17.5}{2} = 0.8 \text{ cm}$$

$$h = (18.1 \pm 0.8) \text{ cm}$$

$$e = \sqrt{\frac{18.1}{25.0}} = 0.850$$

$d = \dots\dots\dots (25.0 \pm 0.1) \text{ cm}$

$h = \dots\dots\dots (18.1 \pm 0.8) \text{ cm}$

$e = \dots\dots\dots 0.850$

(c) Do the results of your experiment indicate that e is a constant within the limits of experimental accuracy? Explain your reasoning clearly.

$$\% \text{age difference in } e = \frac{\text{max} - \text{min}}{e_{\text{min}}} \times 100$$

$$\% \text{age difference in } e = \frac{0.870 - 0.850}{0.850} \times 100 = 2.4 \%$$

Criteria < 2 %

Since the percentage difference in e is greater than the specified criteria. Therefore, results do support the suggested relationship.

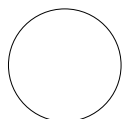
$$\% \Delta d = \frac{\Delta d}{d} \times 100 = \frac{0.1}{35.0} \times 100 = 1.4 \%$$

(d) (i) State four sources of error or limitations of the procedure in this experiment.

1. Two sets of readings not enough to draw valid conclusion.
2. Hard to judge rebound height, because ball is in motion
3. Difficult to release without applying a force
4. Inconsistent bounce.

(ii) Suggest four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. Take more sets of readings and plot graph
2. Use slow motion camera to record the video and play back slowly to record the value of h
3. Use card gate to release the ball by holding the ball against stop
4. Use flat and hard surface and turn off fans



You may not need to use all of the materials provided.

1 In this experiment, you will investigate the oscillations of a chain.

- (a) (i) • Assemble the apparatus as shown in Fig. 1.1 with each nail held securely in a boss and at the same height above the bench. Position the stands so that the distance between the nails is approximately 60 cm.

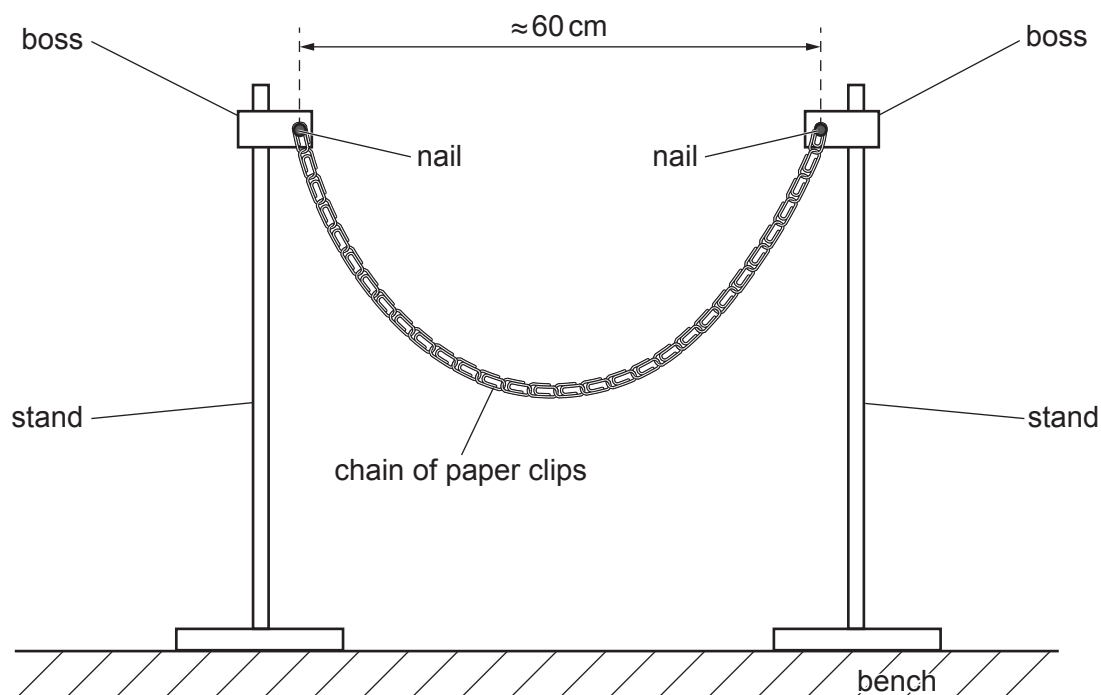


Fig. 1.1

- Rest one of the metre rules on the nails, as shown in Fig. 1.2.

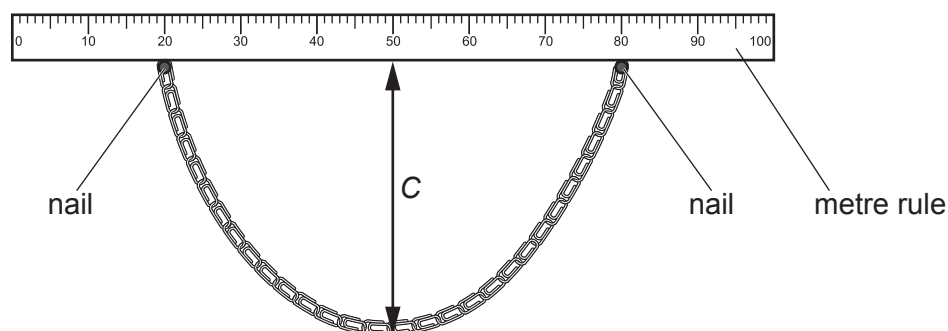


Fig. 1.2

- The vertical distance between the horizontal metre rule and the lowest part of the chain is C .

Using the other metre rule, measure and record C .

$C = \dots\dots\dots 31.2 \pm 0.1 \dots\dots\dots \text{ cm [1]}$

- (ii) • Push the bottom of the chain a short distance away from you. Release it so that it swings towards and away from you.
- Take measurements to determine the period T of these oscillations.

Time for 10 Oscillations

$$t_1 = 9.8 \text{ s}$$

$$t_2 = 9.7 \text{ s}$$

$$t_3 = 9.8 \text{ s}$$

$$t = \frac{9.8 + 9.7 + 9.8}{3} = 9.8 \text{ s}$$

$$\Delta t = \frac{9.8 - 9.7}{2} = 0.1 \text{ s}$$

$$t = (9.8 \pm 0.1) \text{ s}$$

$$T = \dots\dots\dots (0.98 \pm 0.01) \text{ s} \quad [2]$$

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

$$T = \frac{9.8 \pm 0.1}{10}$$

$$T = (0.98 \pm 0.01) \text{ s}$$

- (b) Repeat (a) with different distances between the stands until you have six sets of values of C and T .

All values of C must be greater than 15 cm.

Record your results in a table. Include values of $\frac{1}{T}$ and $\frac{1}{\sqrt{C}}$ in your table.

#	C/cm	Time for 10 Oscillations				T/s	$\frac{1}{T}/\text{s}^{-1}$	$\frac{1}{\sqrt{C}}/\text{cm}^{-1/2}$
		t_1/s	t_2/s	t_3/s	t/s			
1	45.0	11.3	11.2	11.2	11.2	1.12	0.892	0.149
2	38.5	10.7	10.6	10.5	10.6	1.06	0.943	0.161
3	31.2	9.8	9.7	9.8	9.8	0.98	1.02	0.179
4	26.2	8.9	8.9	9.1	9.0	0.90	1.11	0.195
5	19.5	7.8	7.9	7.7	7.8	0.78	1.28	0.226
6	15.5	7.1	7.0	7.0	7.0	0.70	1.43	0.254

[9]

- (c) (i) Plot a graph of $\frac{1}{T}$ on the y-axis against $\frac{1}{\sqrt{C}}$ on the x-axis.

[3]

- (ii) Draw the straight line of best fit.

[1]

- (iii) Determine the gradient and y-intercept of this line.

From best fit line

$$(x_1, y_1) = (0.160, 0.92)$$

$$(x, y) = (0.246, 1.385)$$

$$(x_2, y_2) = (0.246, 1.385)$$

$$y = mx + c$$

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$y \text{ intercept} = 1.385 - (5.41 \times 0.246)$$

$$y \text{ intercept} = 0.054 \text{ s}^{-1}$$

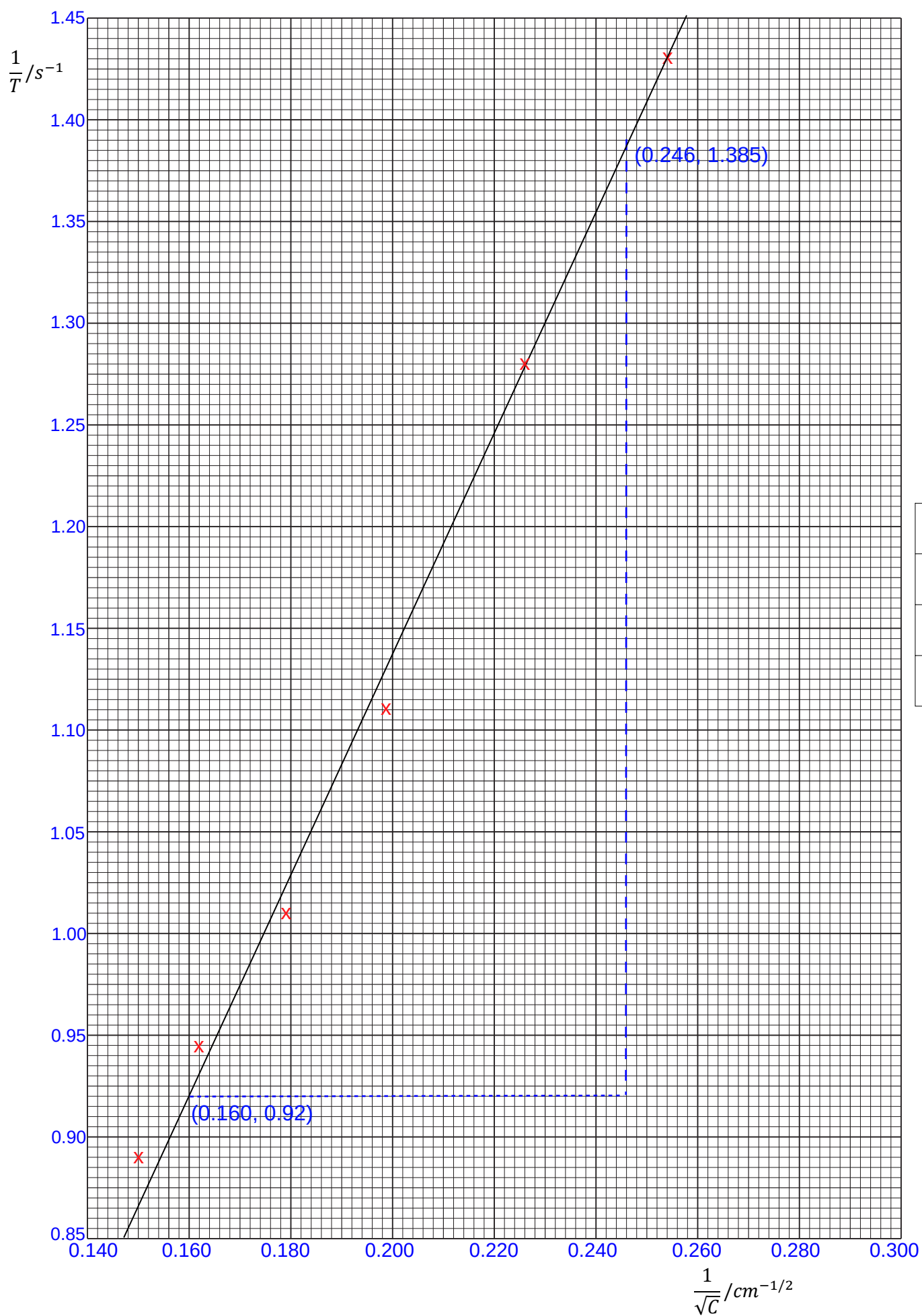
$$\text{Gradient} = \frac{(1.385 - 0.92) \text{ s}^{-1}}{(0.246 - 0.160) \text{ cm}^{-1/2}}$$

$$\text{Gradient} = 5.41 \text{ cm}^{1/2} \text{ s}^{-1}$$

$$\text{gradient} = \dots\dots\dots 5.41 \text{ cm}^{1/2} \text{ s}^{-1}$$

$$y\text{-intercept} = \dots\dots\dots 0.054 \text{ s}^{-1}$$

[2]



(d) It is suggested that the quantities T and C are related by the equation

$$\frac{1}{T} = \frac{a}{\sqrt{C}} + b$$

where a and b are constants.

Use your answers in (c)(iii) to determine the values of a and b .

Give appropriate units.

$$\frac{1}{T} = a \times \frac{1}{\sqrt{C}} + b$$

Compare with $y = mx + c$

$a = \text{gradient}$

$b = y \text{ intercept}$

$$a = 5.41 \text{ cm}^{1/2} \text{ s}^{-1}$$

$$b = 0.051 \text{ s}^{-1}$$

$$a = \dots\dots\dots 5.41 \text{ cm}^{1/2} \text{ s}^{-1} \dots\dots\dots$$

$$b = \dots\dots\dots 0.051 \text{ s}^{-1} \dots\dots\dots$$

[2]

[Total: 20]

You may not need to use all of the materials provided.

2 In this experiment, you will investigate the deformation of a foam ring.

- (a) (i) • Assemble the apparatus as shown in Fig. 2.1.
The wooden rod should pivot freely on the nail.

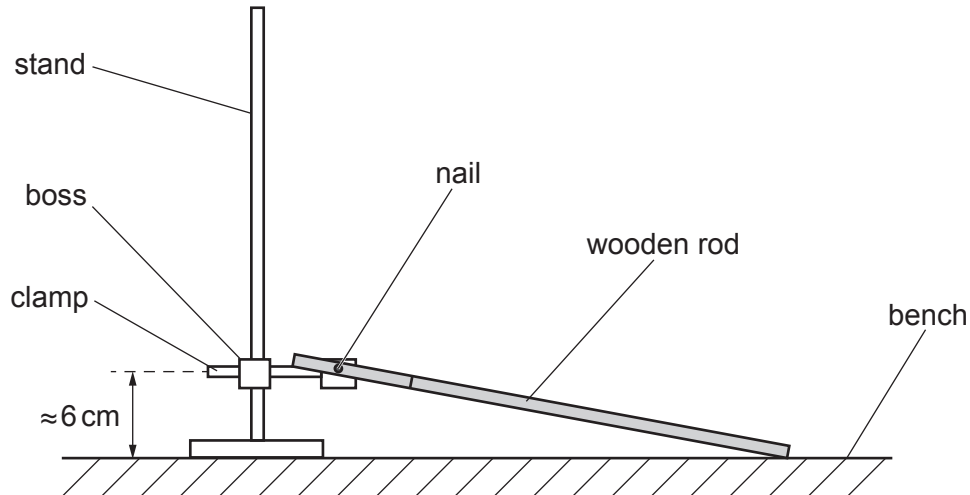


Fig. 2.1

- Take the **larger** of the two foam rings.
- Using the metre rule, measure and record the inner diameter D_1 and the outer diameter D_2 , as shown in Fig. 2.2.

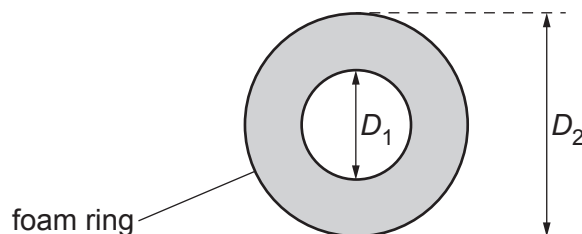


Fig. 2.2

$$D_{11} = 11 \text{ mm}$$

$$D_{12} = 13 \text{ mm}$$

$$D_{13} = 12 \text{ mm}$$

$$D_1 = \frac{11 + 13 + 12}{3} = 12 \text{ mm}$$

$$\Delta D_1 = \frac{13 - 11}{2} = 1 \text{ mm}$$

$$D_1 = (12 \pm 1) \text{ mm}$$

$$D_1 = \dots\dots\dots 12 \pm 1 \dots\dots\dots \text{ mm}$$

$$D_{21} = 30 \text{ mm}$$

$$D_{22} = 31 \text{ mm}$$

$$D_{23} = 32 \text{ mm}$$

$$D_2 = \frac{30 + 31 + 32}{3} = 31 \text{ mm}$$

$$\Delta D_2 = \frac{32 - 30}{2} = 1 \text{ mm}$$

$$D_2 = (31 \pm 1) \text{ mm}$$

$$D_2 = \dots\dots\dots 31 \pm 1 \dots\dots\dots \text{ mm}$$

[2]

(ii) Estimate the percentage uncertainty in your value of D_2 . Show your working.

$$\% \Delta D_2 = \frac{\Delta D_2}{D_2} \times 100 = \frac{1}{31} \times 100 = 3.2 \%$$

percentage uncertainty = ... 3.2 % [1]

- (b) • Position the ring under the line on the rod and centrally on the wooden block, as shown in Fig. 2.3.

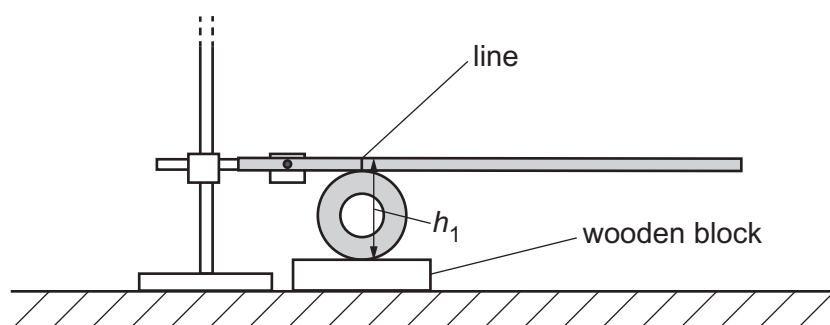


Fig. 2.3

- Adjust the height of the boss so that the rod is horizontal.
- The vertical distance, next to the ring, of the top of the rod above the block is h_1 , as shown in Fig. 2.3. mm.

Using the calipers, measure and record h_1 .

$$h_1 = 38 + (11 \times 0.05) = 38.55 \text{ mm}$$

$$h_1 = (38.55 \pm 0.05) \text{ mm}$$

$$h_1 = \dots\dots\dots (38.55 \pm 0.05) \dots\dots\dots \text{ mm}$$

- Place the slotted mass at the end of the rod, as shown in Fig. 2.4.

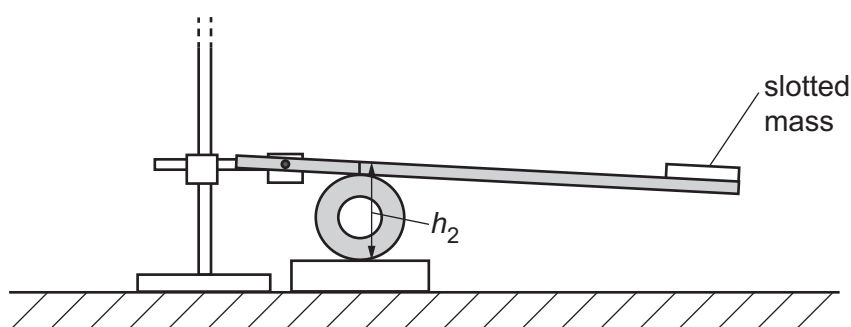


Fig. 2.4

- The vertical distance, next to the ring, of the top of the rod above the block is now h_2 , as shown in Fig. 2.4.

Measure and record h_2 .

$$h_2 = 28 + (12 \times 0.05) = 28.60 \text{ mm}$$

$$h_2 = (28.60 \pm 0.05) \text{ mm}$$

$$h_2 = \dots\dots\dots (28.60 \pm 0.05) \dots\dots\dots \text{ mm}$$

- Calculate y where $y = h_1 - h_2$.

$$y = 38.055 - 28.60 = 9.95 \text{ mm}$$

$$y = \dots\dots\dots 9.95 \dots\dots\dots \text{ mm} \quad [2]$$

- (c) (i) The distance between the nail and the line is A and the distance between the nail and the centre of the slotted mass is B , as shown in Fig. 2.5.

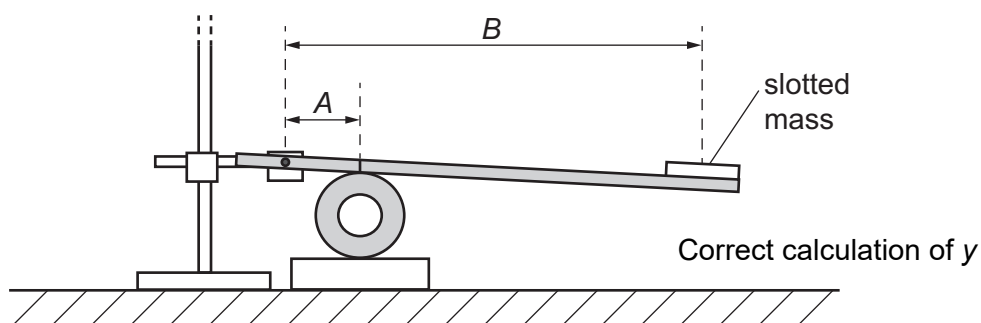


Fig. 2.5

Measure and record A and B .

$$A = (12.8 \pm 0.2) \text{ cm}$$

$$A = \dots\dots\dots (12.8 \pm 0.2) \dots\dots\dots \text{ cm}$$

$$B = (47.7 \pm 0.2) \text{ cm}$$

$$B = \dots\dots\dots (47.7 \pm 0.2) \dots\dots\dots \text{ cm} \quad [1]$$

- (ii) Calculate the additional force F on the ring using

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

where $g = 9.81 \text{ N kg}^{-1}$ and $m = 0.100 \text{ kg}$.

$$F = \frac{0.100 \times 9.81 \times 47.7 \times 10^{-2}}{12.8 \times 10^{-2}} = 3.66 \text{ N}$$

$$F = \dots\dots\dots 3.66 \dots\dots\dots \text{ N} \quad [1]$$

- (iii) Justify the number of significant figures you have given for your value of F .

Since m , g , B and A all are in 3 significant figures, so F must be in 3 significant figure.

.....

 [1]

(d) • Take the **smaller** of the two foam rings.

- Using the metre rule, measure and record the inner diameter D_1 and the outer diameter D_2 .

$$D_{11} = 20 \text{ mm}$$

$$D_{12} = 21 \text{ mm}$$

$$D_{13} = 21 \text{ mm}$$

$$D_1 = \frac{20 + 21 + 21}{3} = 21 \text{ mm}$$

$$\Delta D_1 = \frac{21 - 20}{2} = 1 \text{ mm}$$

$$D_1 = (21 \pm 1) \text{ mm}$$

$$D_{21} = 36 \text{ mm}$$

$$D_{22} = 37 \text{ mm}$$

$$D_{23} = 38 \text{ mm}$$

$$D_2 = \frac{36 + 37 + 38}{3} = 37 \text{ mm}$$

$$\Delta D_2 = \frac{38 - 36}{2} = 1 \text{ mm}$$

$$D_2 = (37 \pm 1) \text{ mm}$$

$$D_1 = \dots\dots\dots 21 \pm 1 \dots\dots\dots \text{ mm}$$

$$D_2 = \dots\dots\dots 37 \pm 1 \dots\dots\dots \text{ mm}$$

- Repeat (b) using the smaller ring.

$$h_1 = 39 + (15 \times 0.05) = 39.75 \text{ mm}$$

$$h_1 = (39.75 \pm 0.05) \text{ mm}$$

$$h_1 = \dots\dots\dots 39.75 \pm 0.05 \dots\dots\dots \text{ mm}$$

$$h_2 = 30 + (2 \times 0.05) = 30.10 \text{ mm}$$

$$h_2 = (30.10 \pm 0.05) \text{ mm}$$

$$h_2 = \dots\dots\dots 30.10 \pm 0.05 \dots\dots\dots \text{ mm}$$

$$y = h_1 - h_2$$

$$y = 39.75 - 30.10 = 9.65 \text{ mm}$$

$$y = \dots\dots\dots 9.65 \dots\dots\dots \text{ mm}$$

[2]

- (e) It is suggested that the relationship between D_1 , D_2 , F and y is

$$\frac{(D_2^2 - D_1^2)}{D_2^3} = \frac{kF}{y}$$

where k is a constant.

- (i) Using your data, calculate two values of k .

$$k = \frac{y(D_2^2 - D_1^2)}{FD_2^3}$$

$$k_1 = \frac{9.95 \times ((31)^2 - (12)^2)}{3.66 \times (31)^3} = 0.044 \text{ N}^{-1}$$

$$k_2 = \frac{9.95 \times ((37)^2 - (21)^2)}{3.66 \times (37)^3} = 0.048 \text{ N}^{-1}$$

$$\text{first value of } k = \dots\dots\dots 0.044 \text{ N}^{-1}$$

$$\text{second value of } k = \dots\dots\dots 0.048 \text{ N}^{-1}$$

[1]

- (ii) Explain whether your results support the suggested relationship.

$$\%age \text{ difference in } k = \frac{k_{max} - k_{min}}{k_{min}} \times 100$$

$$\%age \text{ difference in } k = \frac{0.048 - 0.044}{0.044} \times 100 = 9.0 \%$$

Criteria < 17 %

Since the %age difference in k is less than the specified criteria, so results support

the suggested relationship.

[1]

$$D_1^2 = 144 \pm 24$$

$$D_2^2 = 961 \pm 62$$

$$(D_2^2 - D_1^2) = 817 \pm 86$$

$$D_1^3 = 29791 \pm 1922$$

$$X = \frac{(D_2^2 - D_1^2)}{D_2^3}$$

$$\%age \Delta X = \left(\frac{86}{817} + \frac{1922}{29791} \right) \times 100 = 17\%$$

$$\%age \Delta F = \left(\frac{0.2}{12.8} + \frac{0.2}{477} \right) \times 100 = 2\%$$

$$\%age \Delta y = \left(\frac{0.1}{9.95} \right) \times 100 = 10\%$$

(f) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment.

1. Two readings are not enough to draw a (valid) conclusion.
.....
Difficult to judge/determine whether rod is horizontal.
.....
2. Difficult to measure h with reason e.g. parallax error/wooden block or ring getting in way.....
Large percentage uncertainty in y .
.....
3. Difficult to measure A or B with reason e.g. judging centre of slotted mass when measuring B
.....
4. A or B /parallax error in A or B /difficult to hold ruler steady when measuring A
.....

[4]

(ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. Take more readings and plot a graph or take more readings and compare
.....
use a spirit level/use set square(s) with description of method.
.....
2. Method to reduce error in measuring h
.....
e.g. use wider rod/move ring to edge of block/use travelling microscope.
.....
3. Method to reduce percentage uncertainty in V
.....
e.g. measure change in height at end of rod/use larger mass/increase B
.....
4. clamp ruler/method to locate and mark centre of slotted mass e.g. measure
.....
diameter and halve to find radius.
.....

[4]

[Total: 20]

You may not need to use all of the materials provided.

1 In this experiment, you will investigate the equilibrium of a wooden rod.

- (a) (i) • Assemble the apparatus as shown in Fig. 1.1 with the nail held securely in the cork. Check that the rod can swing freely.

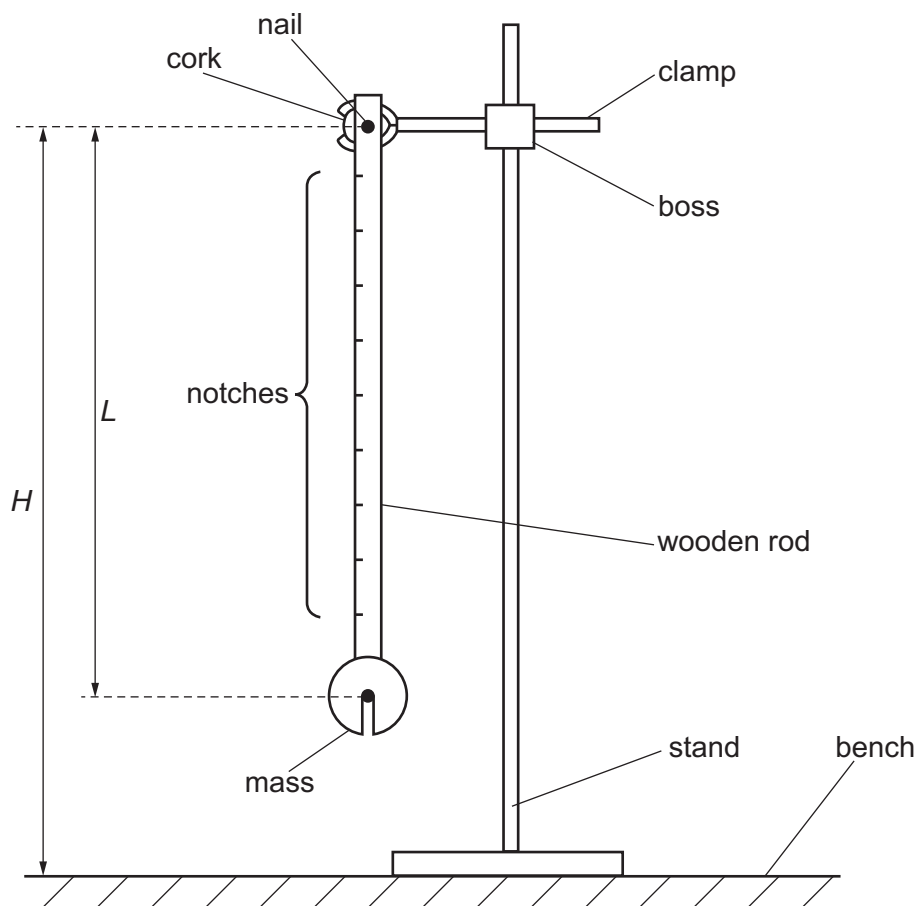


Fig. 1.1

- The height of the nail above the bench is H . Measure and record H .

$$H = \dots\dots\dots (75.0 \pm 0.1)m$$

This height must be **kept constant** throughout the experiment.

- The distance between the nail and the centre of the mass is L . Measure and record L .

$$L = \dots\dots\dots (45.5 \pm 0.1)m$$

[1]

- (ii) • Assemble the remaining apparatus as shown in Fig. 1.2. Place the string loop in a notch near the mid-point of the rod.

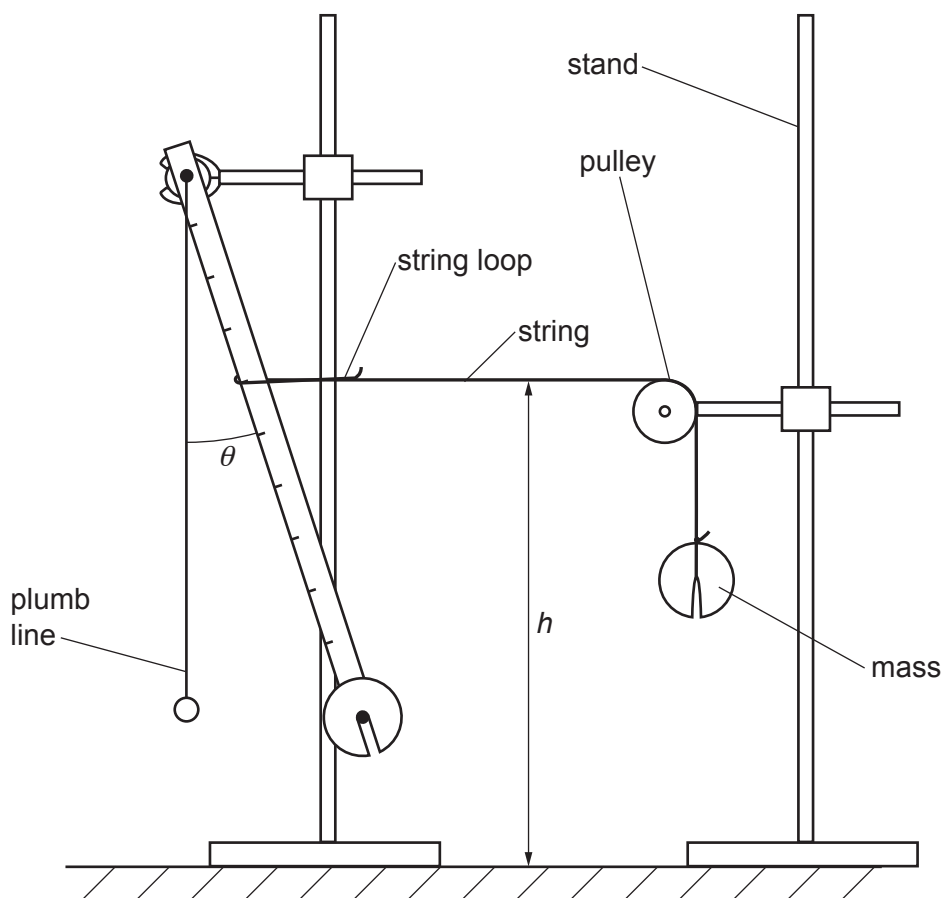


Fig. 1.2

- Adjust the height of the pulley so that the string pulling the rod is parallel to the bench.
- The height of the string above the bench is h , as shown in Fig. 1.2. Measure and record h .

$$h = \dots\dots\dots (58.9 \pm 0.1) \text{ m}$$

- The angle between the plumb line and the rod is θ , as shown in Fig. 1.2. Measure and record θ .

$$\theta = \dots\dots\dots (18 \pm 1) \dots\dots\dots^\circ$$

[1]

- (b) Move the string loop to another notch and adjust the height of the pulley and the position of its stand so that the string pulling the rod is parallel to the bench.

Repeat until you have six sets of values of h and θ .

Record your results in a table. Include values of $\sin \theta$ to 3 significant figures in your table.

#	h/cm	$\theta/^\circ$	$\sin \theta$
1	70.8	6	0.105
2	66.5	10	0.174
3	63.3	13	0.225
4	58.9	18	0.309
5	56.3	22	0.375
6	53.2	26	0.438
7	49.6	29	0.489
8	47.0	33	0.545
9	44.7	36	0.588

[9]

- (c) (i) Plot a graph of $\sin \theta$ on the y-axis against h on the x-axis.

[3]

- (ii) Draw the straight line of best fit.

[1]

- (iii) Determine the gradient and y-intercept of this line.

From best fit line

$$(x_1, y_1) = (41.5, 0.640)$$

$$(x_2, y_2) = (69.0, 0.135)$$

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\text{Gradient} = \frac{(0.135 - 0.640)}{(69.0 - 41.5) \text{ cm}}$$

$$\text{Gradient} = -0.0184 \text{ cm}^{-1}$$

$$(x, y) = (69.0, 0.135)$$

$$y = mx + c$$

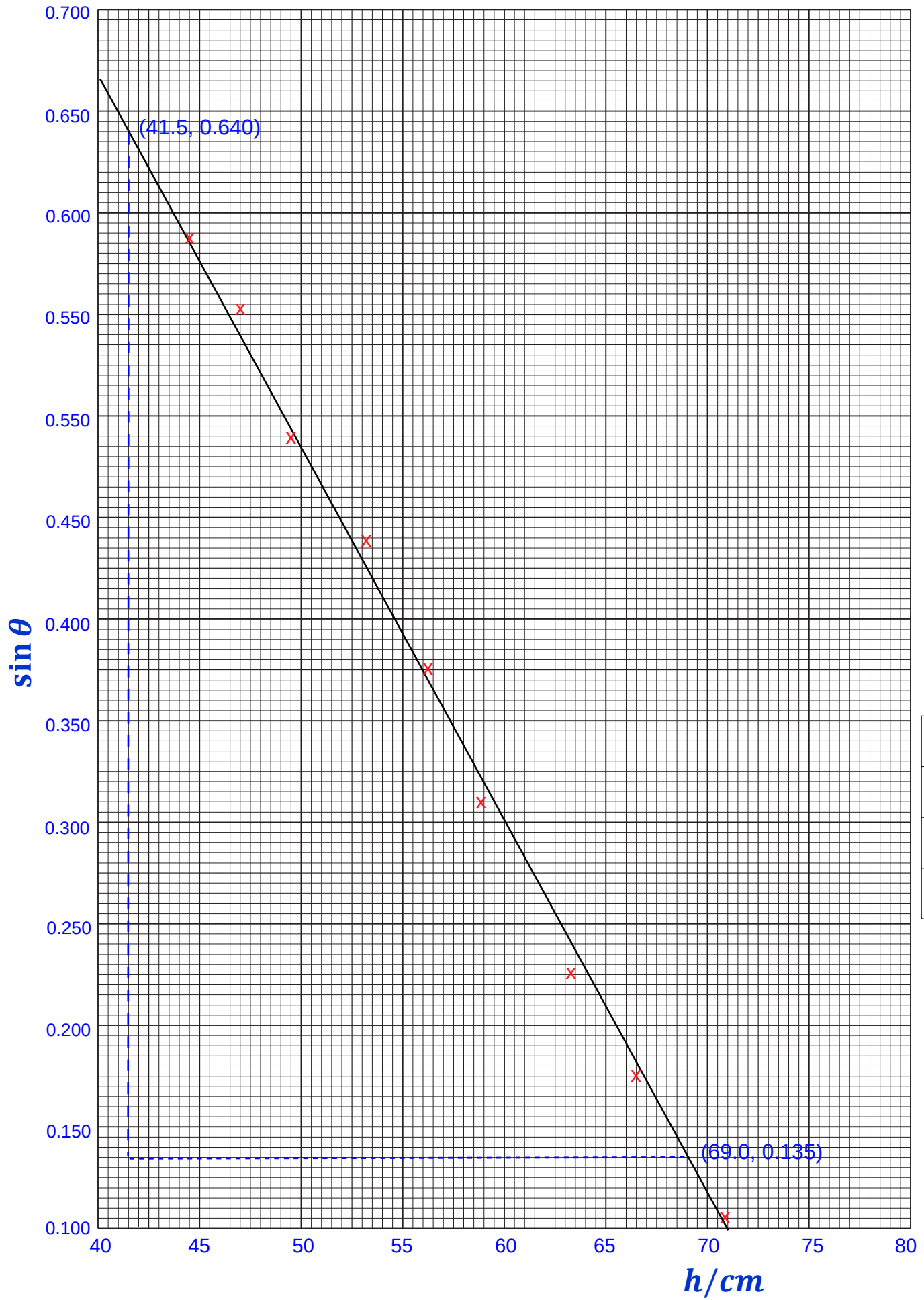
$$y \text{ intercept} = 0.135 - (-0.0184 \times 69.0)$$

$$y \text{ intercept} = 1.40$$

$$\text{gradient} = \dots\dots\dots -0.0184 \text{ cm}^{-1}$$

$$y\text{-intercept} = \dots\dots\dots 1.40$$

[2]



- (d) It is suggested that the quantities θ and h are related by the equation

$$\sin \theta = ah + b$$

where a and b are constants.

Using your answers in (c)(iii), determine the values of a and b .
Give appropriate units.

Compare with $y = mx + c$

$a = \text{gradient}$

$b = y \text{ intercept}$

$a = -0.0184 \text{ cm}^{-1}$

$b = 1.40$

$a = \text{.....} -0.0184 \text{ cm}^{-1}$

$b = \text{.....} 1.40$

[2]

- (e) The mass of the wooden rod is M .
Calculate M using the relationship

$$-\frac{1}{a} = L + \frac{ML}{N}$$

where N is 200 g.

$$\frac{ML}{N} = -\frac{1}{a} - L$$

$$M = \frac{N}{L} \left(-\frac{1}{a} - L \right)$$

$$M = \frac{200}{45.5} \left(-\frac{1}{(-0.0184)} - 45.5 \right)$$

$$M = \frac{200}{45.5} (54.3 - 45.5)$$

$$M = 38.7 \text{ g} \approx 39 \text{ g}$$

$M = \text{.....} 38.7 \approx 39 \text{ g [1]}$

[Total: 20]

You may not need to use all of the materials provided.

2 In this experiment, you will investigate a potential divider circuit.

- (a) (i) • Connect the voltmeter across the cell as shown in Fig. 2.1.

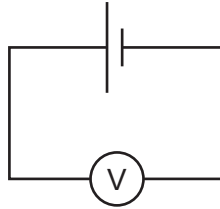


Fig. 2.1

- The reading on the voltmeter is the electromotive force (e.m.f.) E of the cell.

Record E .

$$E = \dots\dots\dots (1.55 \pm 0.01) \text{ V}$$

- Measure and record the diameter d of wire A.

Zero Corection = 0

$$d = 0 + (23 \times 0.01) = 0.23 \text{ mm}$$

$$d = 0.23 \text{ mm}$$

$$d = \dots\dots\dots 0.23 \text{ mm} \quad [1]$$

- (ii) Calculate Ed^2 .

$$Ed^2 = 1.55 \times (0.23 \times 10^{-3})^2 = 9.6 \times 10^{-8} \text{ Vm}^2$$

$$Ed^2 = \dots\dots\dots 9.6 \times 10^{-8} \text{ Vm}^2 \quad [1]$$

- (iii) Justify the number of significant figures that you have given for your value of Ed^2 .

E has 3, and d has 2 significant figures. Least number of significant figures carry forwards, so we report Ed^2 in 2 S.F.

.....
..... [1]

- (b) (i) You have been provided with a wooden strip with some wire connected between two nails.

- Set up the circuit shown in Fig. 2.2.

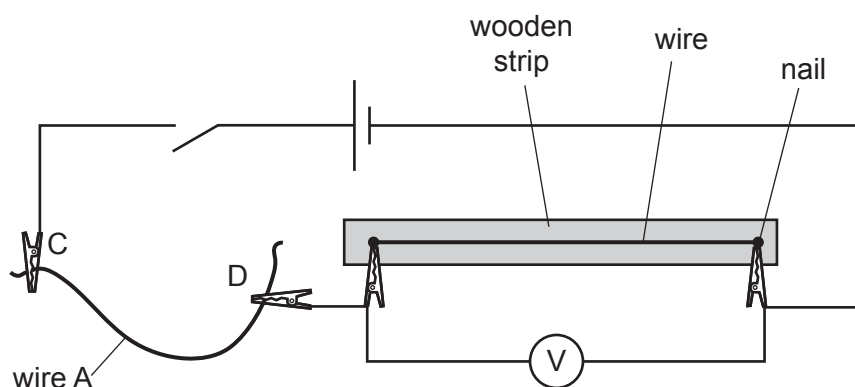


Fig. 2.2

- C and D are crocodile clips.

Place the clips on wire A so that the length L of wire between C and D is equal to the length of wire between the two nails.

- Measure and record L .

$$L = (50.0 \pm 0.3) \text{ cm} \quad [1]$$

- (ii) Estimate the percentage uncertainty in your value of L . Show your working.

$$\% \Delta L = \frac{\Delta L}{L} \times 100 = \frac{0.3}{50.0} \times 100 = 0.6 \%$$

$$\text{percentage uncertainty} = 0.6 \% \quad [1]$$

- (c) • Close the switch.
- Record the voltmeter reading V .

$$V = \dots\dots\dots (0.55 \pm 0.01) \text{ V}$$

- Open the switch.
- Remove the wire between C and D.

[1]

- (d) • Measure and record the diameter d of wire B.

$$d = 0 + (15 \times 0.01) = 0.15 \text{ mm}$$

$$d = \dots\dots\dots 0.15 \text{ mm}$$

- Calculate Ed^2 .

$$Ed^2 = 1.45 \times (0.15 \times 10^{-3})^2 = 3.5 \times 10^{-8} \text{ Vm}^2$$

$$Ed^2 = \dots\dots\dots 3.5 \times 10^{-8} \text{ Vm}^2$$

- Connect length L of wire B between C and D and repeat (c).

$$V = \dots\dots\dots (0.45 \pm 0.01) \text{ V}$$

[3]

- (e) It is suggested that the relationship between V , E and d is

$$\frac{1}{V} = \frac{k}{Ed^2} + \frac{1}{E}$$

where k is a constant.

- (i) Using your data, calculate two values of k .

$$k = Ed^2 \left(\frac{1}{V} - \frac{1}{E} \right)$$

$$k_1 = (8.2 \times 10^{-8}) \left(\frac{1}{0.55} - \frac{1}{1.55} \right) = 9.6 \times 10^{-8} \text{ m}^2$$

$$k_1 = (3.5 \times 10^{-8}) \left(\frac{1}{0.47} - \frac{1}{1.55} \right) = 5.5 \times 10^{-8} \text{ m}^2$$

first value of $k = \dots\dots\dots 9.6 \times 10^{-8} \text{ m}^2$

second value of $k = \dots\dots\dots 5.5 \times 10^{-8} \text{ m}^2$

[1]

- (ii) Explain whether your results support the suggested relationship.

$$\% \text{age difference in } k = \frac{k_{\max} - k_{\min}}{k_{\min}} \times 100$$

$$\% \text{age difference in } k = \frac{9.6 \times 10^{-8} - 5.5 \times 10^{-8}}{5.5 \times 10^{-8}} \times 100 = 75 \%$$

Criteria < 15 %

Since the %age difference in k is 86% which is greater than specified criteria, so results donot
support the suggested relationship.

[1]

- (f) Theory suggests that

$$k = D^2$$

where D is the diameter of the wire on the wooden strip.

Use your second value of k to calculate a value for D .

$$D = \sqrt{k}$$

$$D = \sqrt{5.5 \times 10^{-8}}$$

$$D = 2.3 \times 10^{-4} \text{ m} = 0.23 \times 10^{-3} \text{ m}$$

$$D = 0.23 \text{ mm}$$

$D = \dots\dots\dots 0.23 \text{ mm}$ [1]

(g) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment.

1. Two readings are not enough to draw a valid conclusion
Clips slide on wire.
2. Contact poor between clip and thinnest wire.
3. Resistance of wires and internal resistance of cell may distort results.
Difficult to measure L with reason related to wire e.g. kinks/not straight.
4. Difficult to measure length of wire on wooden strip e.g. nails obstruct measurement.

[4]

(ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. Take more readings and plot a graph
Improved method of gripping e.g. screw clips to wire.
2. Use thicker wires/improved method to improve contact with (thinnest)
wire e.g. solder connections.
3. Monitor p.d. across cell/use shorter connecting wires.
Solder wires A and B to (different) nails (to ensure wires are straight).
4. Improved method e.g. use longer wire and attach clips/use nails with smaller heads.

[4]

[Total: 20]

You may not need to use all of the materials provided.

- 1** In this experiment you will measure the potential difference across a resistor R_2 of resistance R_2 as the resistance of the circuit is varied.

(a) (i) Connect the circuit shown in Fig. 1.1 using one of the resistors in the chain.

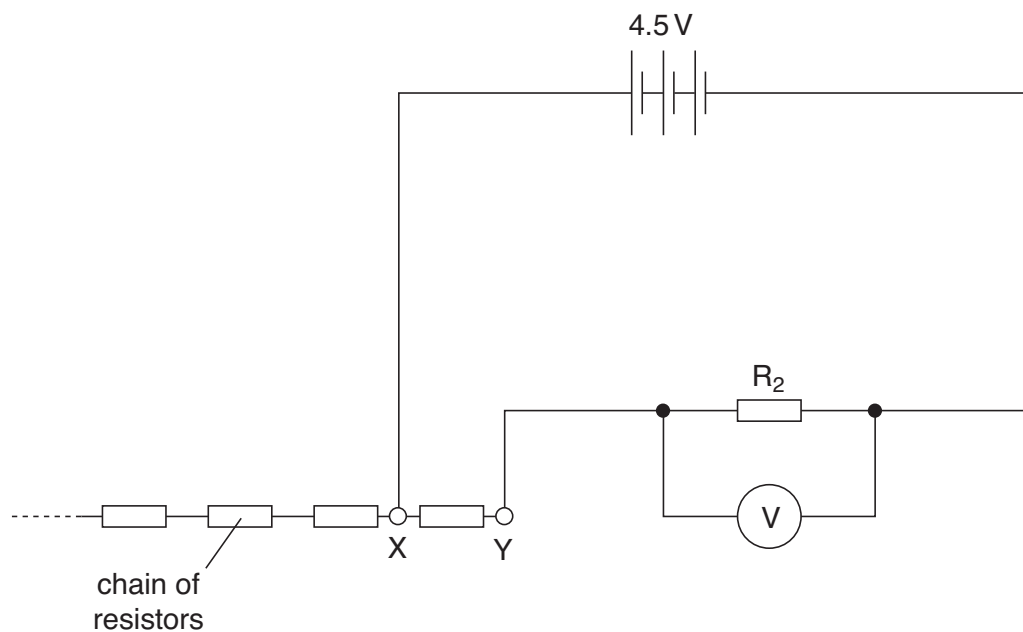


Fig. 1.1

- (ii)** Record the value of the potential difference V across R_2 .

$V =$ 3.70 V

- (b) Change the number n of resistors between X and Y and repeat (a)(ii) until you have six sets of readings for V and n . Include values of $1/V$ in your table of results.

#	n	V/V	$\frac{1}{V}/V^{-1}$
1	1	3.70	0.270
2	3	2.74	0.365
3	5	2.18	0.459
4	7	1.80	0.556
5	9	1.54	0.649
6	11	1.34	0.746

- (c) (i) Plot a graph of $1/V$ (y -axis) against n (x -axis).
(ii) Draw the line of best fit.
(iii) Determine the gradient and the y -intercept of the graph.

From graph,

$$(x_1, y_1) = (1.6, 0.300) \text{ and } (x_2, y_2) = (12, 0.793)$$

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.793 - 0.300}{12 - 1.6} = 0.47 \text{ V}^{-1}$$

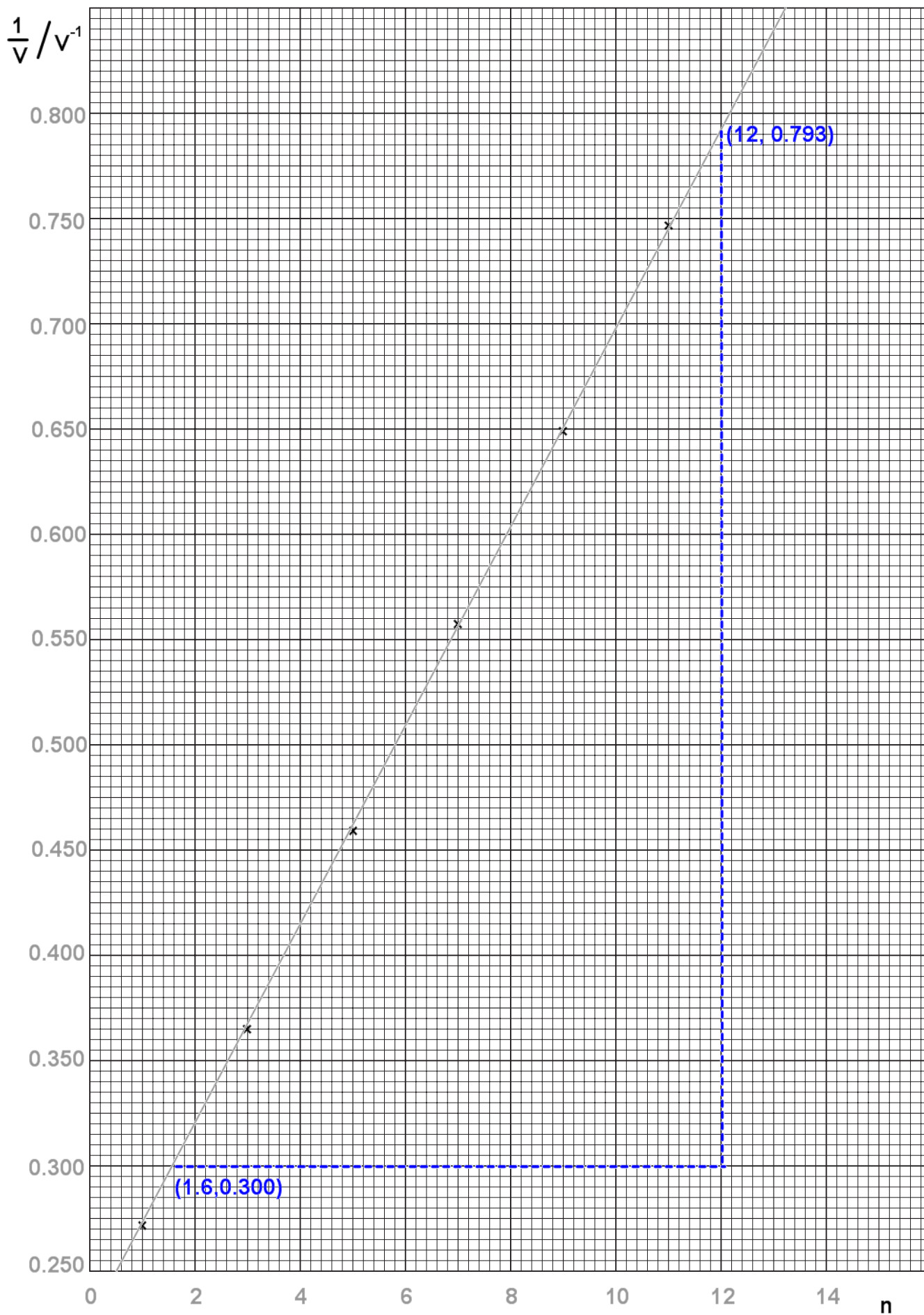
For point $(x, y) = (12, 0.793)$

$$c = y - m x$$

$$y \text{ intercept} = 12 - (0.047)(12) = 0.224 \text{ V}^{-1}$$

$$\text{gradient} = 0.047 \text{ V}^{-1}$$

$$y\text{-intercept} = 0.224 \text{ V}^{-1}$$



(d) V and n are related by the equation

$$\frac{1}{V} = \frac{nR_1}{ER_2} + \frac{1}{E}$$

where R_1 is the resistance of each of the resistors in the chain and E is the e.m.f. of the battery.

Using your answers from (c)(iii), determine values of E and the ratio $\frac{R_1}{R_2}$.

You should include units where appropriate.

Compare with

$$y = mx + c$$

$$y = \frac{1}{V}$$

$$x = n$$

$$\text{Gradient} = \frac{R_1}{ER_2}$$

$$y \text{ intercept} = \frac{1}{E}$$

$$E = \frac{1}{y \text{ intercept}}$$

$$E = \frac{1}{0.224} = 4.46 \text{ V}$$

$$\frac{R_1}{R_2} = E \times \text{Gradient}$$

$$\frac{R_1}{R_2} = 4.46 \times 0.047 = 0.21$$

$$E = 4.46 \text{ V}$$

$$\frac{R_1}{R_2} = 0.21$$

You may not need to use all of the materials provided.

For
Examiner's
Use

- 1 In this experiment, you will investigate the variation of a potential difference in a resistor network.

(a) Set up the circuit of Fig. 1.1. The resistor R should have a resistance R where $R = 2.2\text{ k}\Omega$.

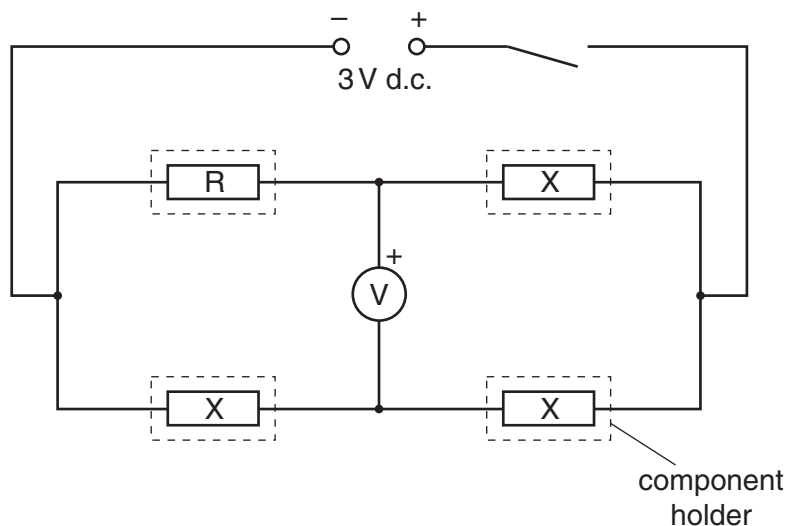


Fig. 1.1

- (b) Close the switch and record the voltmeter reading V , which should be in the range $+0.10\text{ V}$ to $+0.90\text{ V}$.
Open the switch.

$V = 0.54\text{ V}$ [1]

- (c) (i) Change resistor R for one of another value. Close the switch and record the new resistance R and the voltmeter reading V .
Open the switch.

$R = 6.8$ $\text{k}\Omega$

$V = 1.10\text{ V}$

- (ii) Repeat (c)(i) until you have six sets of readings for R (in $\text{k}\Omega$) and V . Include in your table of results values for $\left(\frac{R}{R+1}\right)$, where R is in $\text{k}\Omega$.

For
Examiner's
Use

Some resistors may give negative values for V .

#	$R / \text{k}\Omega$	V / V	$\frac{R}{R+1}$
1	0.22	- 0.95	0.18
2	0.47	- 0.53	0.32
3	1.0	0.00	0.50
4	2.2	0.54	0.69
5	4.7	0.96	0.82
6	6.8	1.10	0.87

[11]

- (d) (i) Plot a graph of V on the y -axis against $\left(\frac{R}{R+1}\right)$ on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

[1]

- (iii) Determine the gradient and y -intercept of this line.

From graph,

$$(x_1, y_1) = (0.25, -0.74) \text{ and } (x_2, y_2) = (0.8, 0.9)$$

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.9 - (-0.74)}{0.8 - 0.25} = 2.98 = 3.0 \text{ V}$$

For point $(x, y) = (0.50, 0.0)$

$$c = y - m x$$

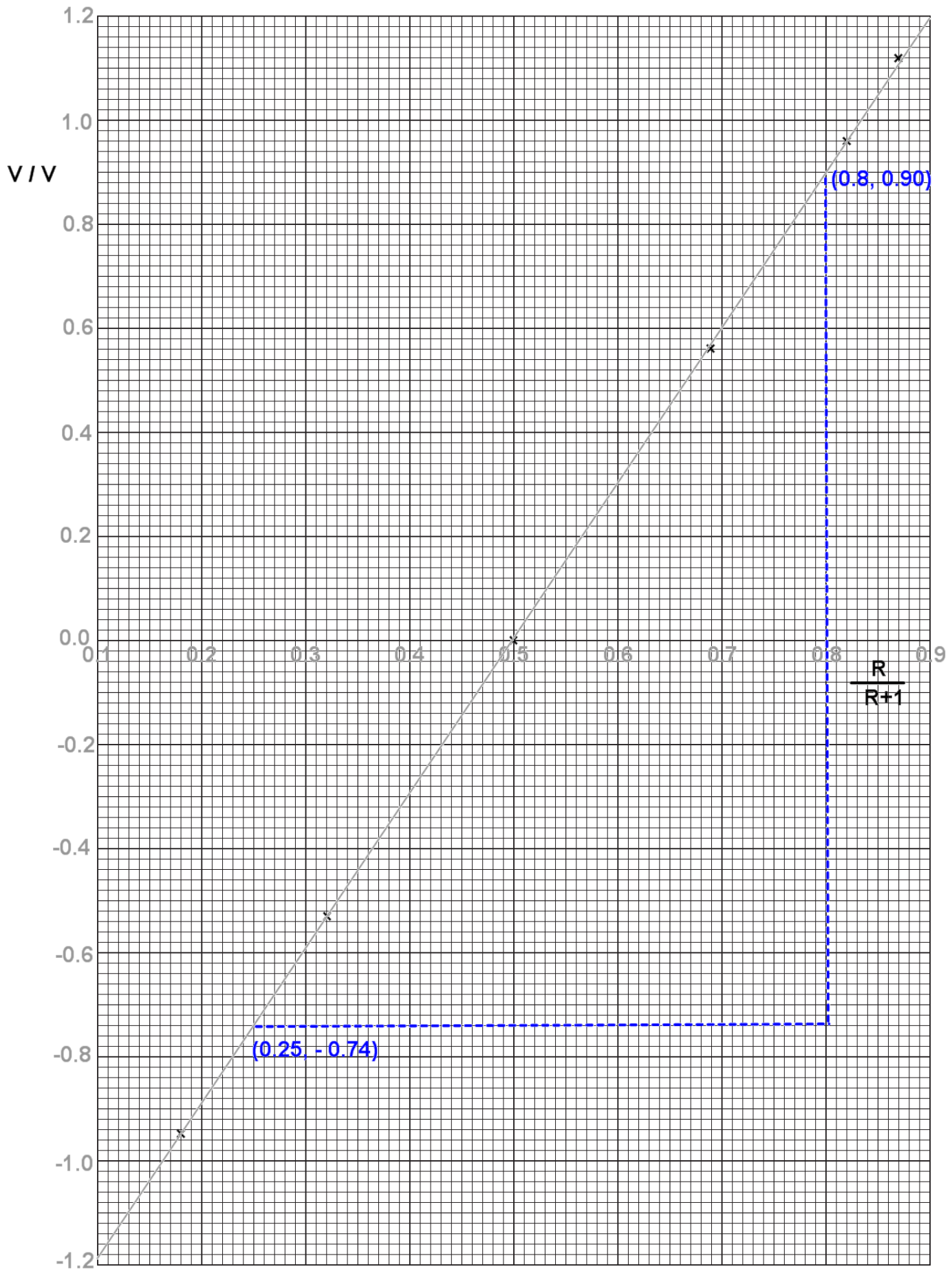
$$y \text{ intercept} = 0 - (3.0)(0.50) = -1.5 \text{ V}$$

$$\text{gradient} = \frac{3.0 \text{ V}}{1.5 \text{ V}}$$

$$y\text{-intercept} = \dots\dots\dots$$

[2]

For
Examiner's
Use



- (e) The relationship between V and R is

$$V = a \left(\frac{R}{R+1} \right) - b$$

where a and b are constants, and R is in $\text{k}\Omega$.

Using your answers from (d)(iii), determine the values of a and b .
Give an appropriate unit for b .

Compare with

$$y = mx + c$$

$$y = V$$

$$x = \frac{R}{R+1}$$

$$\text{Gradient} = a$$

$$y \text{ intercept} = -b$$

$$a = 3.0 \text{ V}$$

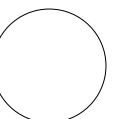
$$b = -(-1.5 \text{ V}) = 1.5 \text{ V}$$

$$a = \dots\dots\dots 3.0 \text{ V}$$

$$b = \dots\dots\dots 1.5 \text{ V}$$

[2]

For
Examiner's
Use



You may not need to use all of the materials provided.

- 2 In this experiment, you will investigate the equilibrium position of a pivoted wooden strip and determine the density of water.

- (a) Assemble the apparatus as shown in Fig. 2.1. The nail should pass through the hole in the wooden strip and be held in the boss. The bottom of the plastic pipe should be approximately 2 cm above the bottom of the container.

Position the string loop with paper clips so that the wooden strip is parallel to the bench.

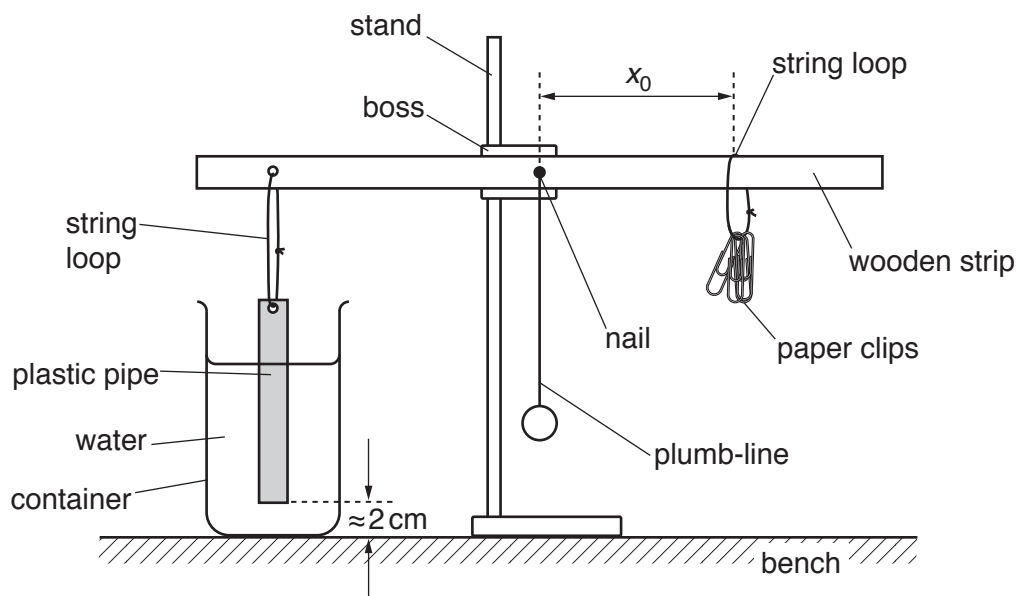


Fig. 2.1 (not to scale)

The distance from the nail to the string loop holding the paper clips is x_0 , as shown in Fig. 2.1.

Measure and record x_0 .

$x_0 =$ (9.2 ± 0.1) cm [1]



- (b) (i) Move the string loop holding the paper clips approximately 4 cm further from the nail. Let the wooden strip settle at an angle, as shown in Fig. 2.2.

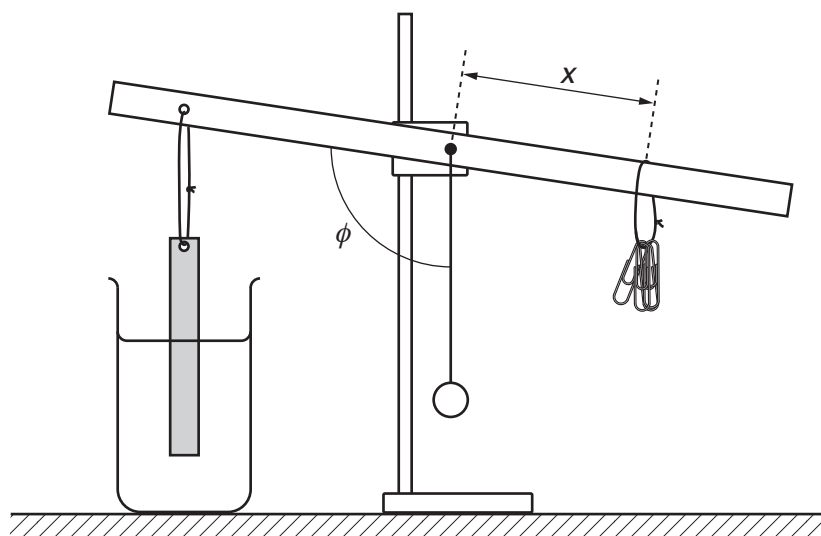


Fig. 2.2 (not to scale)

- (ii) Measure and record the new distance x from the nail to the string loop holding the paper clips, as shown in Fig. 2.2.

$$x = (13.2 \pm 0.1) \text{ cm [1]}$$

- (iii) Measure and record the larger angle ϕ between the wooden strip and the plumb-line, as shown in Fig. 2.2.

$$\begin{aligned}\phi_1 &= 94^\circ \\ \phi_2 &= 95^\circ \\ \phi_3 &= 96^\circ\end{aligned}$$

$$\begin{aligned}\phi_a &= \frac{94^\circ + 95^\circ + 96^\circ}{3} = 95^\circ \\ \Delta\phi_a &= \frac{96^\circ - 94^\circ}{2} = 1^\circ\end{aligned}$$

$$\begin{aligned}\phi &= \phi_a \pm \Delta\phi_a \\ \phi &= (95 \pm 1)^\circ\end{aligned}$$

$$\phi = (95 \pm 1)^\circ \text{ [1]}$$

- (iv) Calculate $(\phi - 90^\circ)$.

$$\phi - 90^\circ = 95 - 90 = 5^\circ$$

$$\Delta(\phi - 90^\circ) = 1^\circ + 1^\circ = 2^\circ$$

$$\phi - 90^\circ = (5 \pm 2)^\circ$$

$$(\phi - 90^\circ) = (5 \pm 2)^\circ$$

- (v) Estimate the percentage uncertainty in your value of $(\phi - 90^\circ)$.

$$\frac{\Delta(\phi - 90^\circ)}{(\phi - 90^\circ)} \times 100 = \frac{2}{5} \times 100 = 20\%$$

$$\text{percentage uncertainty} = 20\% \text{ [1]}$$

- (c) (i) Move the string loop holding the paper clips approximately 3 cm further from the nail. Let the wooden strip settle at a new angle.

(ii) Repeat (b)(ii), (b)(iii) and (b)(iv).

$$x = (16.2 \pm 0.1) \text{ cm}$$

$$\phi_1 = 101^\circ$$

$$\phi_2 = 102^\circ$$

$$\phi_3 = 103^\circ$$

$$\phi_a = \frac{101^\circ + 102^\circ + 103^\circ}{3} = 102^\circ$$

$$\Delta\phi_a = \frac{103^\circ - 101^\circ}{2} = 1^\circ$$

$$\phi = \phi_a \pm \Delta\phi_a$$

$$\phi = (102 \pm 1)^\circ$$

$$\phi - 90^\circ = 102 - 90 = 12^\circ$$

$$\phi - 90^\circ = (12 \pm 2)^\circ$$

$$x = \dots\dots\dots (16.2 \pm 0.1) \dots\dots\dots \text{ cm}$$

$$\phi = \dots\dots\dots (102 \pm 1) \dots\dots\dots ^\circ$$

$$(\phi - 90^\circ) = \dots\dots\dots (12 \pm 2) \dots\dots\dots ^\circ$$

[3]

Question 2 continues on page 10.

- (d) It is suggested that the relationship between ϕ , x_0 and x is

$$\sin(\phi - 90^\circ) = k(x - x_0)$$

where k is a constant.

- (i) Using your data, calculate two values of k .

$$k = \frac{\sin(\phi - 90^\circ)}{(x - x_0)}$$

$$k = \frac{\sin(5^\circ)}{(13.2 - 9.2)} = 0.022$$

$$k = \frac{\sin(12^\circ)}{(16.2 - 9.2)} = 0.023$$

first value of $k = \dots\dots\dots 0.022 \text{ cm}^{-1}$

second value of $k = \dots\dots\dots 0.023 \text{ cm}^{-1}$

[1]

- (ii) Justify the number of significant figures you have given for your values of k .

Since the significant figures in $(\phi - 90^\circ)$ and $(x - x_0)$ are two, so the k must be in two significant figures

..... [1]

- (iii) Explain whether your results in (d)(i) support the suggested relationship.

$$\% \text{age difference in } k = \frac{k_{\max} - k_{\min}}{k_{\min}} \times 100$$

$$\% \text{age difference in } k = \frac{0.023 - 0.022}{0.022} \times 100$$

$$\% \text{age difference in } k = 4.5 \%$$

Criteria $< 10 \%$

Since the percentage difference in k is less than the specified criteria.

Therefore, results do support the suggested relationship.

..... [1]

- (e) (i) Remove the plastic pipe from the water.
- (ii) Measure and record the outside diameter D and the inside diameter d of the pipe, as shown in Fig. 2.3.

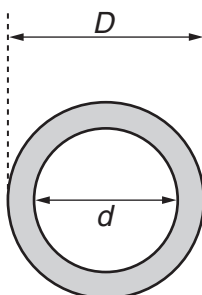


Fig. 2.3

$$D = \dots\dots\dots (2.0 \pm 0.2) \dots\dots\dots \text{cm}$$

$$d = \dots\dots\dots (1.5 \pm 0.2) \dots\dots\dots \text{cm}$$

[1]



- (iii) The mass m of the paper clips and string loop is written on the card. Record m .

$$m = \dots\dots\dots 9.36 \dots\dots\dots \text{g}$$

- (iv) Using your second value of k , calculate the density ρ of the water using the relationship

$$\rho = \frac{m}{Ck(D^2 - d^2)}$$

where $C = 201 \text{ cm}^2$.

$$\rho = \frac{m}{Ck(D^2 - d^2)}$$

$$\rho = \frac{9.36}{201 \times 0.023 \times ((2.0)^2 - (1.5)^2)}$$

$$\rho = 1.16 \text{ g cm}^{-3}$$

$$\rho = \dots\dots\dots 1.16 \dots\dots\dots \text{g cm}^{-3} [1]$$



- (f) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment.

1. Two readings are not enough to draw a valid conclusion
.....
.....
2. Difficult to measure angle, because it hard to hold protractor steady/ difficult to align protractor correctly.
.....
.....
3. Large percentage uncertainty in ($\phi - 90^\circ$) or ($\phi - 90^\circ$) is small.
.....
.....
4. Difficult to measure D (or d) with ruler because center of the tube is not known.
.....

[4]



- (ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. Take more readings and plot a graph
.....
.....
2. Hold protractor in a clamp/take photograph and measure angle on photo
.....
.....
3. Method to increase ($\phi - 90^\circ$) e.g. more paper clips / larger values of x
.....
.....
4. Use vernier/digital calipers or travelling microscope.
.....

[4]



[Total: 20]

