MINISTRY OF EDUCATION
MATRICULATION DIVISION

PHYSICS

LABORATORY MANUAL

SP015 & SP025

13th EDITION

MATRICULATION DIVISION
MINISTRY OF EDUCATION MALAYSIA

PHYSICS

LABORATORY MANUAL
SEMESTER I & II
SP015 & SP025

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NATIONAL EDUCATION PHILOSOPHY

Education in Malaysia is an on-going effort towards further developing the potential of individuals in a holistic and integrated manner, so as to produce individuals who are intellectually, spiritually and physically balanced and harmonious based on a firm belief in and devotion to God. Such an effort is designed to produce Malaysian citizens who are knowledgeable and competent, who possess high moral standards and who are responsible and capable of achieving a high level of personal well-being as well as being able to contribute to the betterment of the family, society and the nation at large.

NATIONAL SCIENCE EDUCATION PHILOSOPHY

In consonance with the National Education Philosophy, science education in Malaysia nurtures a science and technology culture by focusing on the development of individuals who are competitive, dynamic, robust and resilient and able to master scientific knowledge and technological competency.

FOREWORD

I am delighted to write the foreword for the Laboratory Manual, which aimed to equip students with knowledge, skills, and the ability to be competitive undergraduates.

This Laboratory Manual is written in such a way to emphasise students' practical skills and their ability to read and understand instructions, making assumptions, apply learnt skills and react effectively in a safe environment. Science process skills such as making accurate observations, taking measurement in correct manner, using appropriate measuring apparatus, inferring, hypothesizing, predicting, interpreting data, and controlling variables are further developed during practical session. The processes are incorporated to help students to enhance their Higher Order Thinking Skills such as analytical, critical and creative thinking skills. These 21^{st} century skills are crucial to prepare students to succeed in Industrial Revolution (I.R.) 4.0.

The manipulative skills such as handling the instruments, setting up the apparatus correctly and drawing the diagrams can be advanced through practical session. The laboratory experiments are designed to encourage students to have enquiry mind. It requires students to participate actively in the science process skills before, during and after the experiment by preparing the pre-report, making observations, analysing the results and in the science process skills before, during, after the experiment by preparing the pre-report, making observations, analysing the results and drawing conclusions.

It is my hope and expectation that this manual will provide an effective learning experience and referenced resource for all students to equip themselves with the skills needed to fulfil the prerequisite requirements in the first-year undergraduate studies.

DR HAJAH ROSNARIZAH BINTI ABDUL HALIM
Director
Matriculation Division

CONTENTS

1.0 Student Learning Time (SLT)

Students will be performing the experiment within the time allocated for each practical work.

Face-to-face	Non face-to-face
2 hours	0

2.0 Learning Outcomes

2.1 Matriculation Science Programme Educational Objectives

Upon a year of graduation from the programme, graduates are:

i. Knowledgeable and technically competent in science disciplines study in-line with higher educational institution requirement.

ii. Able to apply information and use data to solve problems in science disciplines.

iii. Able to communicate competently and collaborate effectively in group work to compete in higher education environment.

iv. Able to use basic information technologies and engage in life-long learning to continue the acquisition of new knowledge and skills.

v. Able to demonstrate leadership skills and practice good values and ethics in managing organisations.

2.2 Matriculation Science Programme Learning Outcomes

At the end of the programme, students should be able to:

i. Acquire knowledge of science and mathematics as a fundamental of higher level education.
(MQF LOC i – Knowledge and understanding)

ii. Apply logical, analytical and critical thinking in scientific studies and problem solving.
(MQF LOC ii – Cognitive skills)

iii. Demonstrate manipulative skills in laboratory works.
(MQF LOC iii a – Practical skills)

iv. Collaborate in group work with skills required for higher education.
(MQF LOC iii b – Interpersonal skills)

v. Deliver ideas, information, problems and solution in verbal and written communication.
(MQF LOC iii c – Communication skills)

vi. Use basic digital technology to seek and analyse data for management of information.
(MQF LOC iii d – Digital skills)

vii. Interpret familiar and uncomplicated numerical data to solve problems.
(MQF LOC iii e – Numeracy skills)

viii. Demonstrate leadership, autonomy and responsibility in managing organization.
(MQF LOC iii f – Leadership, autonomy and responsibility)

ix. Initiate self-improvement through independent learning.
(MQF LOC iv – Personal and entrepreneurial skills)

x. Practice good values attitude, ethics and accountability in STEM and professionalism.
(MQF LOC v – Ethics and professionalism)

2.3 Physics 1 Course Learning Outcome

At the end of the course, student should be able to:

1. Describe basic concepts of mechanics, waves, matters, heat and thermodynamics.
(C2, PLO 1, MQF LOC i)

2. Solve problems related to mechanics, waves, matters, heat and thermodynamics.
(C4, PLO 2, MQF LOC ii)

3. Apply the appropriate scientific laboratory skills in physics experiments.
(P3, PLO 3, MQF LOC iii a)

2.4 Physics 2 Course Learning Outcome

At the end of the course, student should be able to:

1. Explain basic concepts of electricity, magnetism, optics and modern physics.
   (C2, PLO 1, MQF LOC i)

2. Solve problems of electricity, magnetism, optics and modern physics.
   (C4, PLO 2, MQF LOC ii)

4. Apply the appropriate scientific laboratory skills in physics experiments.
   (P3, PLO 3, MQF LOC iii a)

3. Interpret and use familiar and uncomplicated numerical and graphical data to solve problems in basic physics.
   (C4, PLO 7, MQF LOC iii e)

2.5 Physics Practical Learning Outcomes

Physics experiment is to give the students a better understanding of the concepts of physics through experiments. The **aims** of the experiments in this course are to be able to:

1. introduce students to laboratory work and to equip them with the practical skills needed to carry out experiment in the laboratory.

2. determine the best range of readings using appropriate measuring devices.

3. recognise the importance of single and repeated readings in measurement.

4. analyse and interpret experimental data in order to deduce conclusions for the experiments.

5. make conclusions in line with the objective(s) of the experiment which rightfully represents the experimental results.

6. verifying the correct relationships between the physical quantities in the experiments.

7. identify the limitations and accuracy of observations and measurements.

8. familiarise student with standard experimental techniques.
9. choose suitable apparatus and to use it correctly and carefully.
10. gain scientific trainings in observing, measuring, recording and analysing data as well as to determine the uncertainties (errors) of various physical quantities observed in the experiments.
11. handle apparatus, measuring instruments and materials safely and efficiently.
12. present a good scientific report for the experiment.
13. follow instructions and procedures given in the laboratory manual.
14. gain confidence in performing experiments.

3.0 Guidance for Students

3.1 Ethics in the laboratory

a. Follow the laboratory rules.

b. Students must be punctual for the practical session. Students are not allowed to leave the laboratory before the practical session ends without permission.

c. Co-operation between members of the group must be encouraged so that each member can gain experience in handling the apparatus and take part in the discussions about the results of the experiments.

d. Record the data based on the observations and not based on any assumptions. If the results obtained are different from the theoretical value, state the possible reasons.

e. Get help from the lecturer or the laboratory assistant should any problems arise during the practical session.

3.2 Preparation for experiment

3.2.1 Planning for the practical

a. Before entering the laboratory

i) Read and understand the objectives and the theory of the experiment.

ii) Think and plan the working procedures properly for the whole experiment. Make sure you have appropriate table for the data.

iii) Prepare a jotter book for the data and observations of the experiments during pre-lab discussion.

b. Inside the laboratory

i) Check the apparatus provided and note down the important information about the apparatus.

ii) Arrange the apparatus accordingly.

iii) Conduct the experiment carefully.

iv) Record all measurements and observations made during the experiment.

3.3 Report writing

The report must be written properly and clearly in English and explain what has been carried out in the experiment. Each report must contain **name, matriculation number, number of experiment, title, date and practicum group.**

The report must also contain the followings:

i) Objective
- state clearly

ii) Theory
- write concisely in your own words
- draw and label diagram if necessary

iii) Apparatus
- name, range, and sensitivity, e.g
  Voltmeter: 0.0 – 10.0 V
  Sensitivity: ± 0.1 V

iv) Procedure
- write in passive sentences about all the steps taken during the experiment

v) Observation
- data tabulation with units and uncertainties
- data processing (plotting graph, calculation to obtain the results of the experiments and its uncertainties).
- Calculation of uncertainties using LSM method can refer attachment A

vi) Discussion
- give comments about the experimental results by comparing it with the standard value
- state the source of mistake(s) or error(s) if any as well as any precaution(s) taken to overcome them
- answer all the questions given

vii) Conclusion
- state <u>briefly</u> the results with reference to the objectives of the experiment

Reminder: NO PLAGIARISM IS ALLOWED.

4.0 Significant Figures

The significant figures of a number are those digits carry meaning contributing to its precision. Therefore, the most basic way to indicate the precision of a quantity is to write it with the correct number of significant figures.

The significant figures are all the digits that are known accurately plus the one estimated digit. For example, we say the distance between two towns is 200 km, that does not mean we know the distance to be exactly 200 km. Rather, the distance is 200 km *to the nearest kilometres*. If instead we say that the distance is 200.0 km that would indicate that we know the distance to the nearest *tenth* of a kilometre.

More significant figures mean greater precision.

Rules for identifying significant figures:

1. Nonzero digits are always significant.

2. Final or ending zeros written to the right of the decimal point are significant.

3. Zeros written on either side of the decimal point for the purpose of spacing the decimal point are not significant.

4. Zeros written between significant figures are significant.

Example:

Value	Number of significant figures	Remarks
0.5	1	Implies value between 0.45 and 0.55
0.500	3	Implies value between 0.4995 and 0.5005
0.050	2	Implies value between 0.0495 and 0.0505
5.0	2	Implies value between 4.95 and 5.05
1.52	3	Implies value between 1.515 and 1.525
1.52×10^4	3	Implies value between 15150 and 15250
150	2 or 3 (ambiguous)	The zero may or may not be significant. If the zero is significant, the value implied is between 149.5 and 150.5. If the zero is not significant, the value implied is between 145 and 155.

5.0 Uncertainty in Measurements

No matter how careful or how accurate are the instruments, the results of any measurements made at best are only close enough to their true values (actual values). Obviously, this is because the instruments have certain smallest scale by which measurement can be made. Chances are, the true values lie within the smallest scale. Hence, we have uncertainties in our measurements.

The uncertainty of a measurement depends on its type and how it is done. For a quantity x with uncertainty Δx, the measurement should be recorded as $x \pm \Delta x$ with appropriate unit.

The relative uncertainty of the measurement is defined as $\frac{\Delta x}{x}$.

and therefore its percentage of uncertainty, is given by $\frac{\Delta x}{x} \times 100\%$.

5.1 Single Reading

(a) If the reading is taken from a single point or at the end of the scale we use:

$$\Delta x = \tfrac{1}{2} \times \text{(smallest division of the scale)}$$

(b) If the readings are taken from two points on the scale:

$$\Delta x = 2 \times \left[\frac{1}{2} \times \left(\text{smallest division from the scale} \right) \right]$$

(c) If the apparatus has a vernier scale:

$$\Delta x = 1 \times \text{(smallest unit of the vernier scale)}$$

5.2 Repeated Readings

For a set of *n* repeated measurements, the best value is the average value, that is

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

where: n is the number of measurements taken
x_i is the i^{th} measurement value

The uncertainty is given by

$$\Delta x = \frac{\sum_{i=1}^{n} \left| \bar{x} - x_i \right|}{n}$$

The result should be written in the form of

$$x = \bar{x} \pm \Delta x$$

5.3 **Combination** of uncertainties

We adopt maximum uncertainty.

(a) Addition or subtraction

$$x = a + b - c \Rightarrow \qquad \Delta x = \Delta a + \Delta b + \Delta c$$

(b) Multiplication with constant *k*

$$x = ka \qquad \Rightarrow \qquad \Delta x = k\Delta a$$

(c) Multiplication or division

$$x = \frac{ab}{c} \qquad \Rightarrow \qquad \frac{\Delta x}{x} = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c} \right)$$

(d) Powers

$$x = a^n \qquad \Rightarrow \qquad \frac{\Delta x}{x} = n\left(\frac{\Delta a}{a} \right)$$

5.4 Uncertainty gradient and y-intercept using Least Square Method (LSM)

5.4.1 Formula uncertainty for gradient and y-intercept

Straight line graphs are very useful in data analysis for many physics experiments.
From straight line equation, that is, $y = mx + c$ we can easily determine the gradient *m* of the graph and its intercept *c* on the vertical axis.

When plotting a straight line graph, the line does not necessary passes through all the points. Therefore, it is important to determine the uncertainties Δm and Δc for the gradient of the graph and the *y*-interception respectively.

Consider the data obtained is as follows:

x	x_1	x_2	x_3…………………..x_n
y	y_1	y_2	y_3…………………..y_n

(a) Find the centroid $(\bar{x}, \bar{y})$, where

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{and} \quad \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

(b) Draw the best straight line passing through the centroid and balance.

(c) Determine the gradient of the line by drawing a triangle using dotted lines. The gradient is given by

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

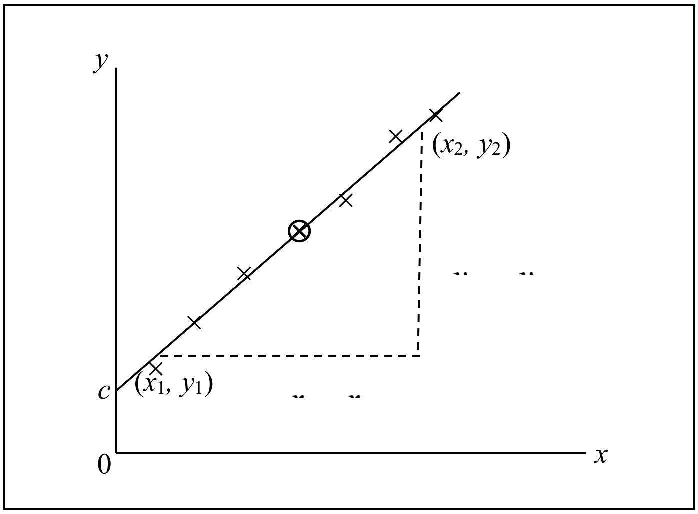


Figure A

(d) The uncertainty of the slope, Δm can be calculated using the following equation

$$\Delta m = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{(n-2)\sum_{i=1}^{n}(x_i - \bar{x})^2}}$$

where n is the number of readings and $\bar{x}$ is the average value of x given by

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

and the estimated value of y, $\hat{y}_i$ is given by,

$$\hat{y}_i = \hat{m}x_i + \hat{c}$$

(e) The uncertainty of the y-intercept, Δc can be calculated using the following equation

$$\Delta c = \sqrt{\frac{1}{n-2}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2\left(\frac{1}{n} + \frac{\bar{x}^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)}$$

5.4.2 Procedure to draw a straight line graph and to determine its gradient with its uncertainty

(a) Choose appropriate scales to use at least 80% of the sectional paper. Draw, label, mark the two axes, and give the units. Avoid using scales of 3, 7, 9, and the likes or any multiple of them. Doing so will cause difficulty in plotting the points later on.

(b) Plot all points clearly with ×. At this stage you can see the pattern of the distribution of the graph points. If there is a point which is clearly too far-off from the rest, it is necessary to repeat the measurement or omit it.

(c) Calculate the centroid and plot it on the graph.

Example:

Suppose a set of data is obtained as below. Graph of T^2 against ℓ is to be plotted.

ℓ (± 0.1 cm)	10.0	20.0	30.0	40.0	50.0	60.0
T^2 (± 0.01 s^2)	0.33	0.80	1.31	1.61	2.01	2.26

From the data:

$$\bar{\ell} = \frac{10.0 + 20.0 + 30.0 + 40.0 + 50.0 + 60.0}{6} = 35.0 \text{ cm}$$

$$\overline{T^2} = \frac{0.33 + 0.80 + 1.31 + 1.61 + 2.01 + 2.26}{6} = 1.39 \text{ s}^2$$

Therefore, the centroid is (35.0 cm, 1.39 s^2).

(d) Draw a best straight line through the centroid and balance. Points above the line are roughly in equal number and positions to those below the line.

(e) Determine the gradient of the line. Draw a fairly large right-angle triangle with part of the line as the hypotenuse.

From the graph in **Figure B**, the gradient of the line is as follows:

For the best line:

$$m = \frac{(2.10 - 0.00)\text{ s}^2}{(53.0 - 0.0)\text{ cm}}$$
$$= 0.040 \text{ s}^2 \text{ cm}^{-1}$$

The gradient of the graph and its uncertainty should be written as follows:

$$m = (0.040 \pm \_\_\_) \text{ s}^2 \text{ cm}^{-1}$$

Take extra precaution so that the number of significant figures for the gradient and its uncertainty are in consistency.

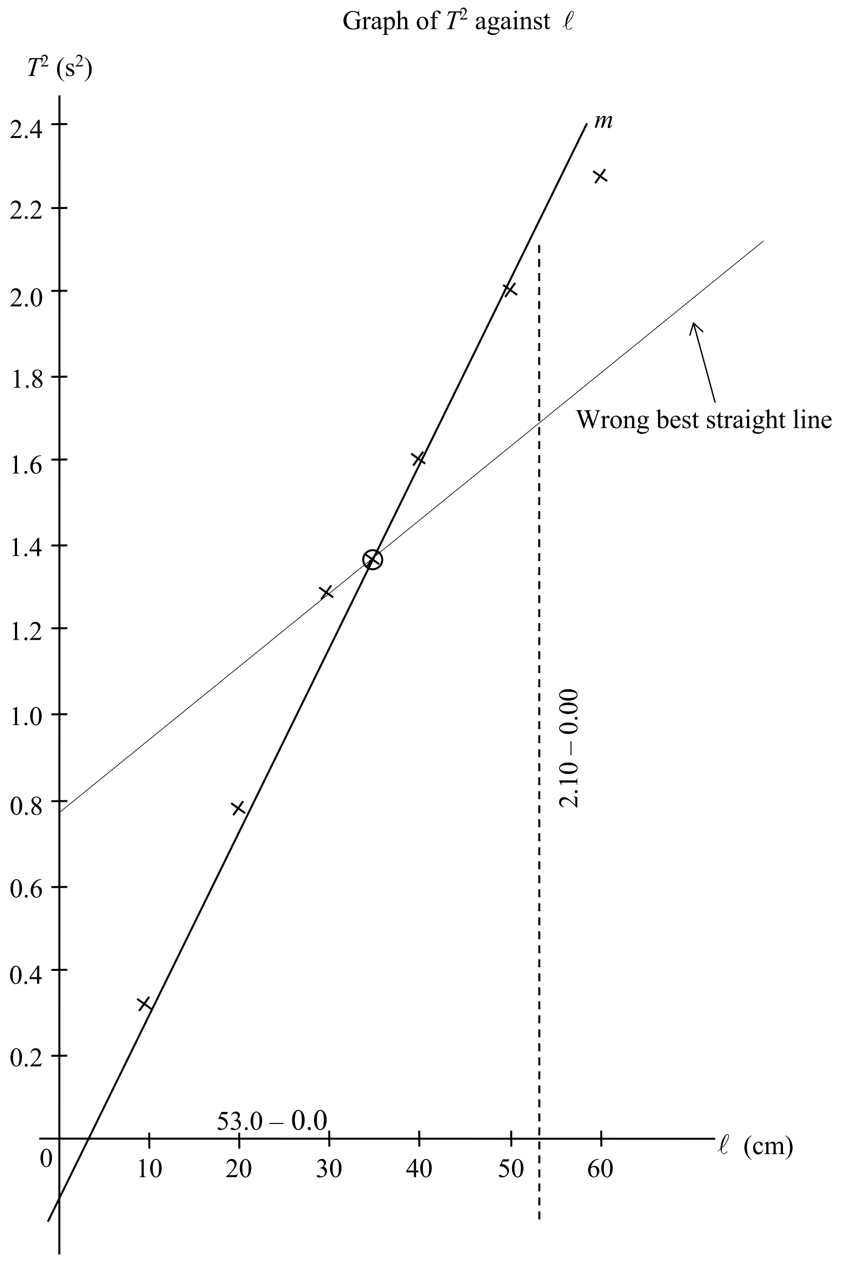

Graph of T^2 against ℓ
T^2 (s^2)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
m
Wrong best straight line
2.10 – 0.00
53.0 – 0.0
10
20
30
40
50
60
ℓ (cm)

Figure B

(f) Calculation of uncertainties

Rewrite the data in the form of

ℓ	$\boldsymbol{\ell} - \overline{\ell}$	$\left(\boldsymbol{\ell} - \overline{\ell}\right)^2$	$\boldsymbol{T^2}$	$\widehat{\boldsymbol{T^2}}$	$\boldsymbol{T^2} - \widehat{\boldsymbol{T^2}}$	$\left(\boldsymbol{T^2} - \widehat{\boldsymbol{T^2}}\right)^2$
10.0	-25.0	625.0	0.33	0.4	-0.070	0.0049
20.0	-15.0	225.0	0.80	0.8	0.000	0.0000
30.0	-5.0	25.0	1.31	1.2	0.110	0.0121
40.0	5.0	25.0	1.61	1.6	0.010	0.0001
50.0	15.0	225.0	2.01	2.0	0.010	0.0001
60.0	25.0	625.0	2.26	2.4	-0.140	0.0196
Σ=210.0		**Σ=1750.0**				**Σ=0.0368**

Where, $\overline{\ell}$ is the average of $\boldsymbol{\ell}$,

$$\overline{\ell} = \frac{210}{6} = 35.0 \text{ cm}$$

Where, $\widehat{T^2}$ is the expected value of T^2

$$\widehat{T^2} = 0.04\boldsymbol{\ell}$$

Calculate the uncertainty of slope, Δm

$$\Delta m = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{(n-2)\sum_{i=1}^{n}(x_i - \bar{x})^2}}$$

$$= \sqrt{\frac{0.0368}{(6-2)(1750)}}$$

$$= \pm 0.002$$

Then, calculate the uncertainty of y-intercept, Δc

$$\Delta c = \sqrt{\left(\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n-2}\right)\left(\frac{1}{n} + \frac{\bar{x}^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)}$$

$$\Delta c = \sqrt{\left(\frac{0.0368}{6-2}\right)\left(\frac{1}{6} + \frac{35^2}{1750}\right)}$$

$$\Delta c = \pm 0.09$$

The data given in section **5.4.2(e)** was obtained from an experiment to verify the relation between T^2 and ℓ. Theoretically, the quantities obey the following relation,

$$T^2 = \left(\frac{k}{p}\right)\ell$$

where k is a natural number equals 39.48 and p is a physical constant. Calculate p and its uncertainty.

Solution:

From the equation, we know that

$$\frac{k}{p} = \text{gradient } m$$

$$\begin{aligned} p &= \frac{k}{m} \\ &= \frac{39.48}{0.040} \\ &= 987 \text{ cm s}^{-2} \end{aligned}$$

Since k is a natural number which has no uncertainties, that is $\Delta k = 0$.

$$\begin{aligned} \Delta p &= \left(\frac{\Delta k}{k} + \frac{\Delta m}{m}\right) p \\ &= \left(0 + \frac{0.002}{0.040}\right) 987 \\ &= 49.35 \end{aligned}$$

so we write,

$p = (987 \pm 49.35)$ cm s^{-2} or $p = (1000 \pm 50)$ cm s^{-2}

5.5 Percentage of difference:

When comparing an experimental result to a value determined by theory or to an accepted known value, the difference between the experimental value and the theoretical value can be determined by:

$$Percentage\,of\ difference = \left|\frac{X_{Theory} - X_{Experiment}}{X_{Theory}}\right| \times 100\%$$

PHYSICS 1
SP015

EXPERIMENT 1: MEASUREMENT AND UNCERTAINTY

Objective:

To measure and determine the uncertainty of physical quantities.

Theory:

Measuring some physical quantities is part and parcel of any physics experiment. It is important to realise that not all measured values are the same as the actual values. This could be due to errors that we made during the measurement, or perhaps the apparatus that we used may not be accurate or sensitive enough. Therefore, as a rule, the uncertainty of a measurement must be taken, and it has to be recorded together with the measured value.

The uncertainty of a measurement depends on the type of measurement and how it is done. For a quantity x with the uncertainty Δx, its measurement is recorded as below:

$$x \pm \Delta x$$

The relative uncertainty of the measurement is defined as:

$$\frac{\Delta x}{x}$$

and therefore, its percentage of uncertainty is $\frac{\Delta x}{x} \times 100\%$.

1.1 Single Reading

(a) If the reading is taken from a single point or at the end of the scale,

$$\Delta x = \frac{1}{2} \times \text{ (smallest division from the scale)}$$

(b) If the readings are taken from two points on the scale,

$$\Delta x = 2 \times \left[\frac{1}{2} \times \text{(smallest division from the scale)}\right]$$

(c) If the apparatus uses a vernier scale,

$$\Delta x = 1 \times \text{(smallest unit from the vernier scale)}$$

1.2 Repeated Readings

For a set of n repeated measurements of x, the best value is the average value given by

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad 1.1$$

where n = the number of measurements taken
x_i = the i^{th} measurement

The uncertainty is given by

$$\Delta x = \frac{\sum_{i=1}^{n} \left| \bar{x} - x_i \right|}{n} \qquad 1.2$$

The result should be written as

$$x = \bar{x} \pm \Delta x \qquad 1.3$$

Apparatus:

A metre rule
A vernier callipers
A micrometer screw gauge
A travelling microscope
A coin
A glass rod
A ball bearing
A capillary tube (1 cm long)

Procedure:

1. Choose the appropriate instrument for measurement of
   (i) length of a laboratory manual.
   (ii) diameter of a coin.
   (iii) diameter of a glass rod.
   (iv) diameter of a ball bearing.

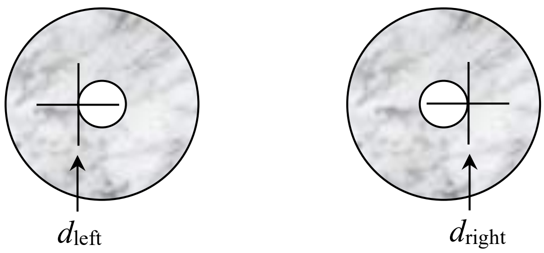
2. For task (i) to (iv), perform the measurement and record the data in a suitable table for at least 5 readings. (Refer to **Table 1.1** as an example)

Table 1.1

No.	Length of the laboratory manual, l ($\pm$ ....)	$\lvert\bar{l} - l_i\rvert$ (..........)
1		
2		
3		
4		
5		
Average	$\bar{l} = \frac{\sum_{i=1}^{n} l_i}{n} =$...........	$\Delta l = \frac{\sum_{i=1}^{n}\lvert\bar{l} - l_i\rvert}{n}$ $=$.......

3. Determine the percentage of uncertainty for each set of readings.

4. Use travelling microscope to measure the internal diameter of the capillary tube. Adjust the microscope so that the cross-hairs coincide with the left and right edge of the internal diameter of the tube as shown in **Figure 1.1**. Record d_{left} and d_{right}.



The internal diameter, $d = \lvert d_{right} - d_{left}\rvert$

Figure 1.1

Determine the uncertainty, Δd and the percentage of uncertainty of the internal diameter of the capillary tube.

EXPERIMENT 2: FREE FALL AND PROJECTILE MOTIONS

Objective:

To determine the acceleration due to gravity, g using free fall and projectile motions.

Theory:

A. Free fall motion

When a body of mass m falls freely from a certain height h above the ground, it experiences a linear motion. The body will obey the equation of motion,

$$s = ut + \frac{1}{2}at^2 \qquad 2.1$$

By substituting the following into equation 2.1,

$s = -h$ (downward displacement of the body from the falling point to the ground)
$u = 0$ (the initial velocity of the body)
$a = -g$ (the downward acceleration due to gravity)

we obtain,

$$h = \frac{1}{2}gt^2 \qquad 2.2$$

Evidently, a graph of h against t^2 is a straight line of gradient equals $\frac{1}{2}g$.

B. Projectile motion

According to **Figure 2.2**, from the law of conservation of energy, the potential energy of a steel ball of mass m equals its kinetic energy,

$$mgh = \frac{1}{2}mv^2 + \frac{1}{5}mv^2 \qquad 2.3$$

where h is the height of the release point above the track
v is the velocity of the steel ball at the end of the track

Note: The rotational kinetic energy for solid sphere is $\frac{1}{5}mv^2$.

The range, R of the steel ball is given by

$$R = vt \qquad 2.4$$

Solving equations 2.3 and 2.4, we obtain

$$h = \frac{7}{10}\frac{R^2}{gt^2} \qquad 2.5$$

where t is the time taken for the steel ball from the end of the curved track to reach the ground.

Evidently, a graph of h against R^2 is a straight line of gradient equals $\frac{7}{10gt^2}$.

Apparatus:

A retort stand with a clamp
A timer
A metre rule
A free fall adaptor (electromagnetic ball release and trap door)
A horizontal table
A steel ball
A curved railing (**Note:** *The lower end of the track must be horizontal*)
A piece of carbon paper
A piece of drawing paper
Cellophane tape
Plasticine
A pair of scissors or a cutter
A piece of string
A pendulum bob
A plywood

Procedure:

A. Free fall motion

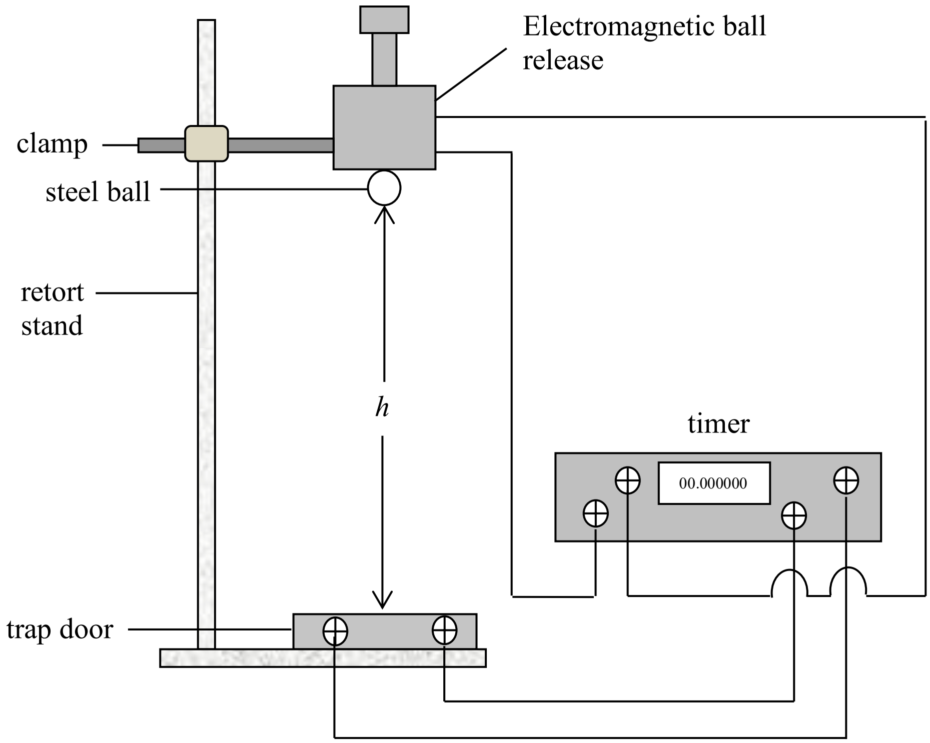


Figure 2.1

Note: *Refer to Figure 2.3 for free fall apparatus with separate power supply for the electromagnet.*

1. Set up the apparatus as in **Figure 2.1**.

2. Switch on the circuit and attach the steel ball onto the upper contact.

3. Adjust the height, h of the electromagnet above the point of impact.

4. Switch off the circuit and let the ball fall. Record the height, h and time, t.

5. Repeat step (3) and (4) for at least six different height, h.

6. Tabulate the data.

7. Plot a graph of h against t^2.

8. Determine the acceleration due to gravity, g from the gradient of the graph.

   Note: *The value range of h-axis should be extended slightly more than the height of the table, H.*

9. Determine the uncertainty of acceleration due to gravity, Δg.

B. Projectile Motion

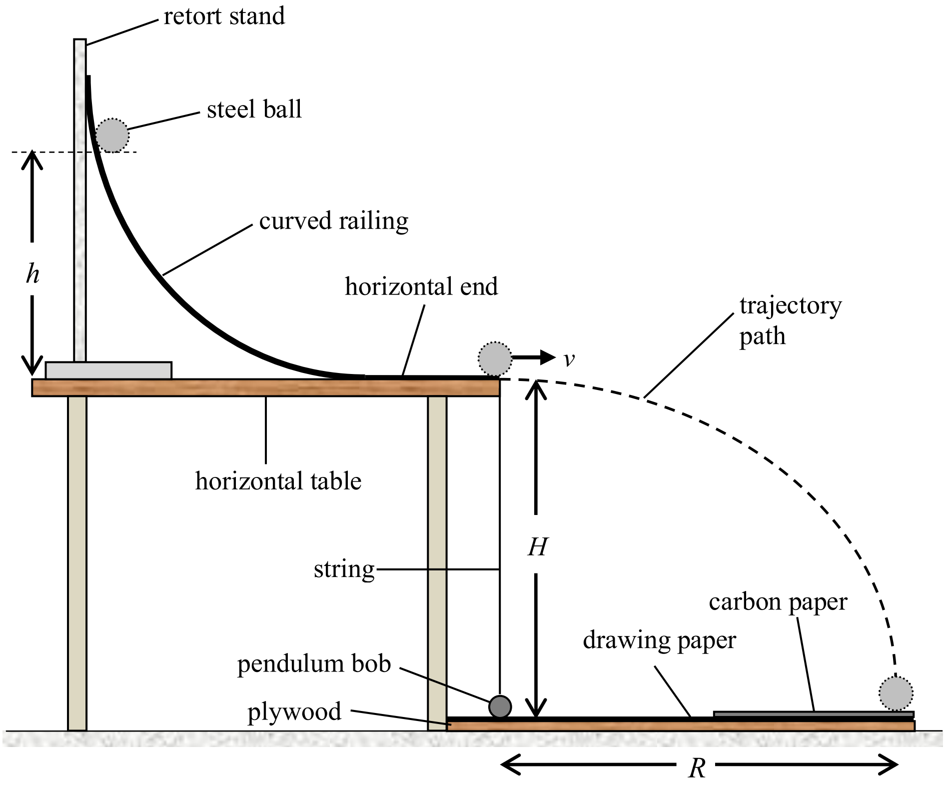


Figure 2.2

1. Set up the apparatus as in **Figure 2.2**.

2. Release the steel ball on the curvature railing at least six different heights, *h* and record the range, *R*.

3. Tabulate the data.

4. Plot a graph of *h* against R^2.

5. Measure the height of the table, *H* (the edge of the railing to the landing surface).

6. By referring to the graph of *h* against t^2 from experiment **A,** obtain the value of t^2 for *H* using extrapolation.

7. Determine the acceleration due to gravity, *g* from the gradient of the graph.

8. Determine the uncertainty of acceleration due to gravity, Δg.

9. Compare the acceleration due to gravity, g obtained from both experiments with the standard value. Write the comments.

Alternative set-up:

Set-up for free fall apparatus with separate power supply to electromagnet.

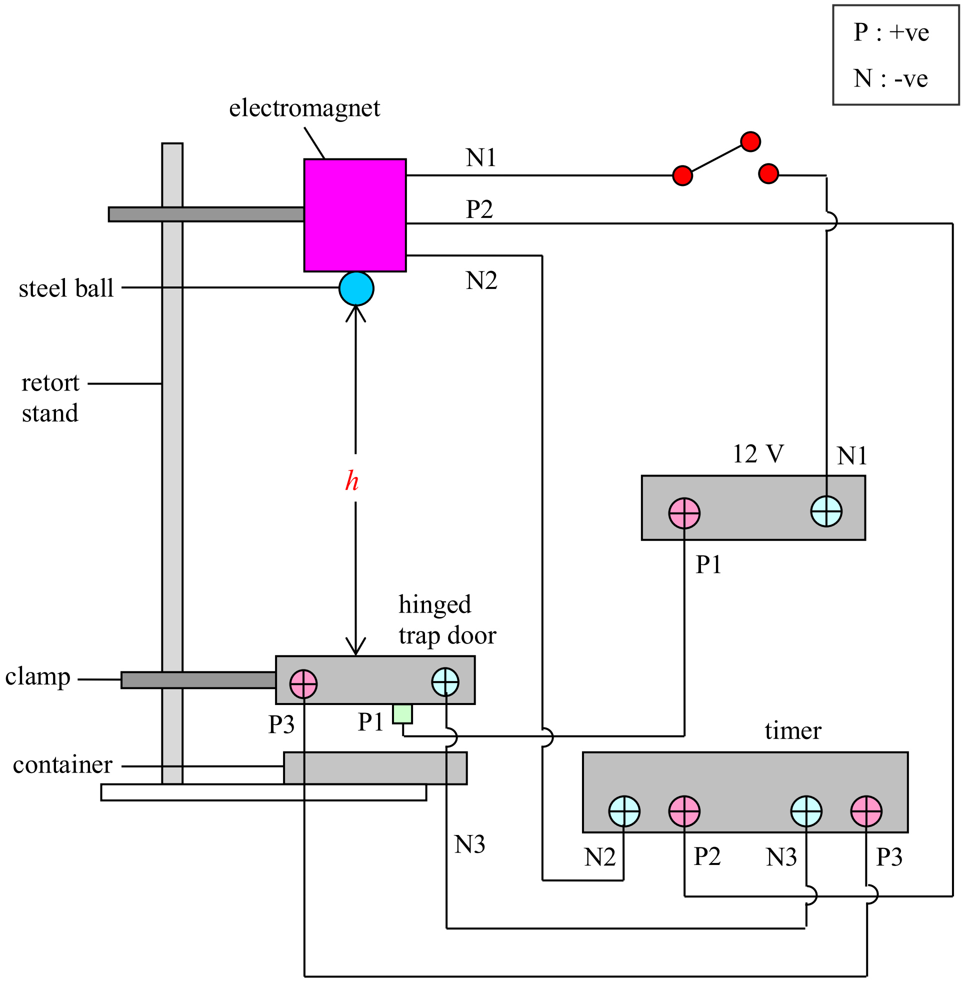


Figure 2.3

EXPERIMENT 3: ENERGY

Objective:

To verify the law of conservation of energy by using free fall motion.

Theory:

Consider a steel ball of mass, m initially at rest at height, h vertically above a velocity detector. By taking the position of the velocity detector as the reference point, the potential energy is mgh and the kinetic energy of the ball is zero. Thus, the total initial energy, E_1 of the steel ball is given by

$$E_1 = mgh \qquad 3.1$$

When the steel ball is released, it falls freely with acceleration due to gravity, g. At the instance it reaches the velocity detector, the gravitational potential energy is zero and its kinetic energy is $\frac{1}{2}mv^2$. Hence, the total final energy, E_2 of the steel ball is given by

$$E_2 = \frac{1}{2}mv^2 \qquad 3.2$$

According to the law of conservation of energy, in the absence of external force the total energy of a system remains constant. In this case, the law is verified if we demonstrate experimentally that E_1 equals E_2, that is,

$$\frac{1}{2}mv^2 = mgh$$

And we obtain

$$v^2 = 2gh \qquad 3.3$$

Consequently, if a graph of v^2 against h is plotted, we should obtain a straight line passing through the origin with gradient equals $2g$.

Apparatus:

A steel ball
A metre rule
A free fall adaptor (electromagnetic ball release)
Two photogates PG A and PG B (Velocity detector)
A timer
A retort stand

Procedure:

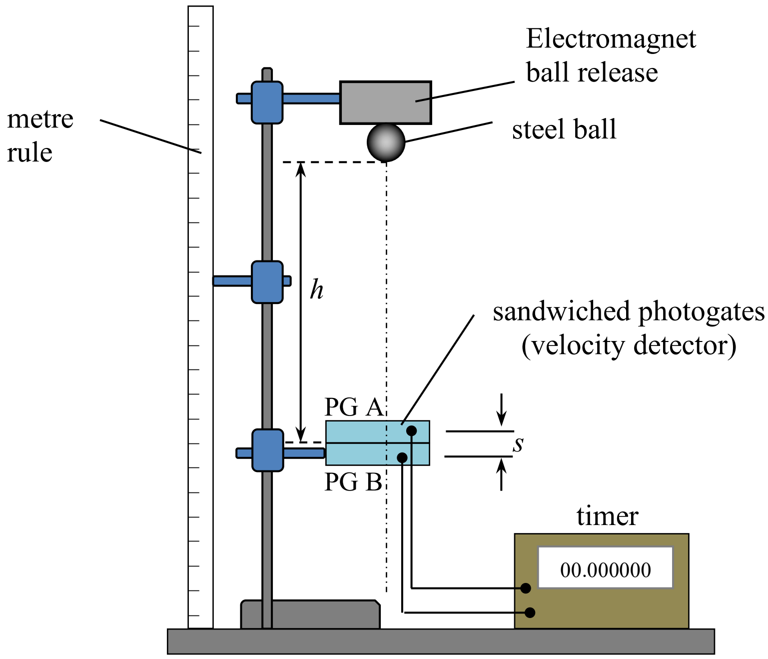


Figure 3.1

1. Construct a velocity detector by sandwiching photogates (PG) A and B using binding tape. Measure the distance, s between the photogates.

2. Set up the apparatus as shown in **Figure 3.1**.

3. Switch on the timer and reset to zero. Set the falling distance, h at 15 cm. Release the steel ball and record the time, t. Repeat the process to obtain the average time.

4. Repeat step (3) for falling distance, h = 20, 25, 30, 35, 40, and 45 cm.

5. For each falling distance, h, calculate the velocity, v using $v = \frac{s}{t}$

6. Tabulate the data.

7. Plot a graph of v^2 against h.

8. Determine the acceleration due to gravity, g from the gradient of the graph.

9. Determine the uncertainty for acceleration due to gravity, Δg obtained in (8).

10. Verify the law of conservation of energy by comparing the acceleration due gravity, g obtained from the experiment with standard value. Write the comments.

EXPERIMENT 4: ROTATIONAL MOTION OF A RIGID BODY

Objective:

To determine the moment of inertia of a fly-wheel, *I*.

Theory:

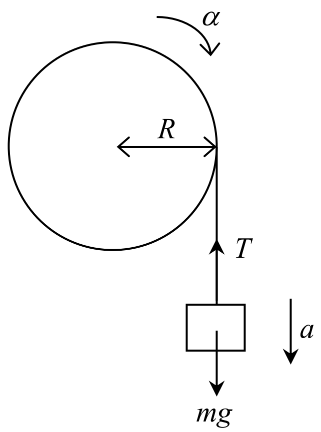


Figure 4.1

By referring to **Figure 4.1**, apply Newton's second law for linear motion,

$$mg - T = ma$$

$$T = m(g - a) \qquad 4.1$$

and applying Newton's second law for rotational motion,

$$TR - \tau = I\alpha \qquad 4.2$$

where a is the downward linear acceleration
τ is the frictional torque (unknown)
α is the angular acceleration
T is the tension in the string
R is the radius of the axle
I is the moment of inertia of the fly-wheel

Therefore,

$$\alpha = \left(\frac{R}{I}\right)T - \left(\frac{\tau}{I}\right) \qquad 4.3$$

The graph α against T is a straight line graph with gradient $\frac{R}{I}$.

Moment of inertia of the fly-wheel,

$$I = \frac{R}{\text{gradient}} \qquad 4.4$$

From kinematics, $s = ut + \frac{1}{2}(-a)t^2$ (negative sign means the acceleration is downward)

By substituting, $s = -h$ and $u = 0$ into the equation above, we obtain

$$h = \frac{1}{2}at^2$$

Hence the linear acceleration,

$$a = \frac{2h}{t^2} \qquad 4.5$$

where h is the height of mass
t is the time taken for the mass to fall to the floor

Angular acceleration,

$$\alpha = \frac{a}{R} \qquad 4.6$$

Apparatus:

A fly-wheel
A stopwatch
A set of slotted mass with hook (**Note**: *Use suitable masses for the fly-wheel to rotate at a suitable rate*)
A metre rule
A G-clamp
A piece of inelastic string to hang the mass to the fly-wheel
A piece of softboard or plywood
A vernier callipers

Procedure:

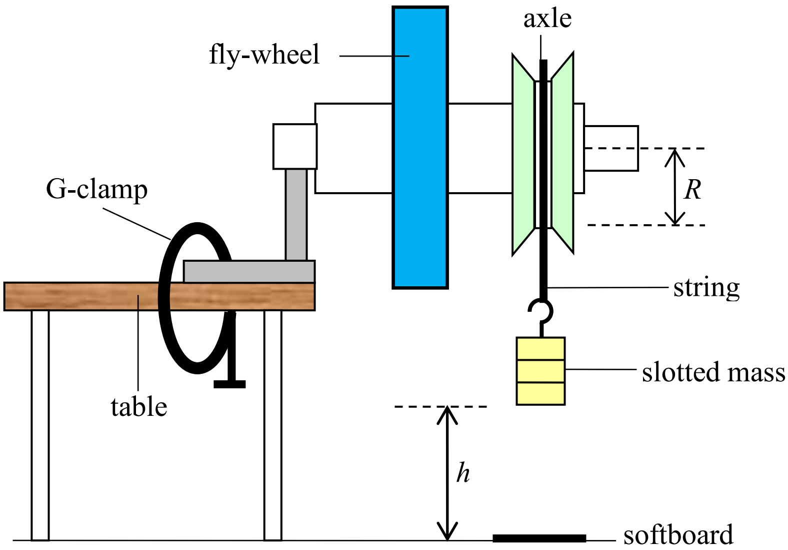


Figure 4.2

1. Set up the apparatus as in **Figure 4.2**.

2. Measure the diameter, *d* of the axle and calculate its radius, *R*.

3. Record the falling slotted mass, *m*.

4. Choose a fixed point at a height, *h* above the floor. Record height, *h*.

5. Release the slotted mass, *m* from the fixed height, *h* after the string has been wound around the axle.

6. Record the time, t for the slotted mass, m to reach the floor.

7. Calculate the linear acceleration, a, tension, T and angular acceleration, α using equations 4.5, 4.1 and 4.6 respectively.

8. Repeat steps (3) to (7) for at least six different slotted mass, m.

9. Tabulate the data.

10. Plot a graph of α against T.

11. Determine the moment of inertia of the fly-wheel, I from the gradient of the graph.

12. Determine the uncertainty of moment of inertia of the fly-wheel, ΔI.

13. Compare the moment of inertia of the fly-wheel, I to the standard value. Write the comments.

EXPERIMENT 5: SIMPLE HARMONIC MOTION (SHM)

Objectives:

(i) To determine the acceleration, g due to gravity using simple pendulum.
(ii) To investigate the effect of large amplitude oscillation to the accuracy of acceleration due to gravity, g obtained from the experiment.

Theory:

An oscillation of a simple pendulum is an example of a simple harmonic motion (SHM) if

(i) the mass of the spherical bob is a point mass
(ii) the mass of the string is negligible
(iii) amplitude of the oscillation is small (< 10°)

According to the theory of SHM, the period of oscillation of a simple pendulum, T is given by

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad 5.1$$

where l is the length of pendulum
g is the acceleration due to gravity

Rearrange equation 5.1, we obtain

$$T^2 = \frac{4\pi^2}{g} \qquad 5.2$$

Evidently, a graph of T^2 against l is a straight line of gradient equals $\frac{4\pi^2}{g}$.

Hence, from the gradient of the graph, the acceleration due to gravity, g can be calculated.

Apparatus:

A piece of string (≈105 cm)
A small pendulum bob
A pair of small flat pieces of wood or cork
A retort stand with a clamp
A stopwatch
A metre rule
A protractor with a hole at the centre of the semicircle
An optical pin
A pair of scissors or a cutter
A stabilizing weight or a G-clamp

Procedure:

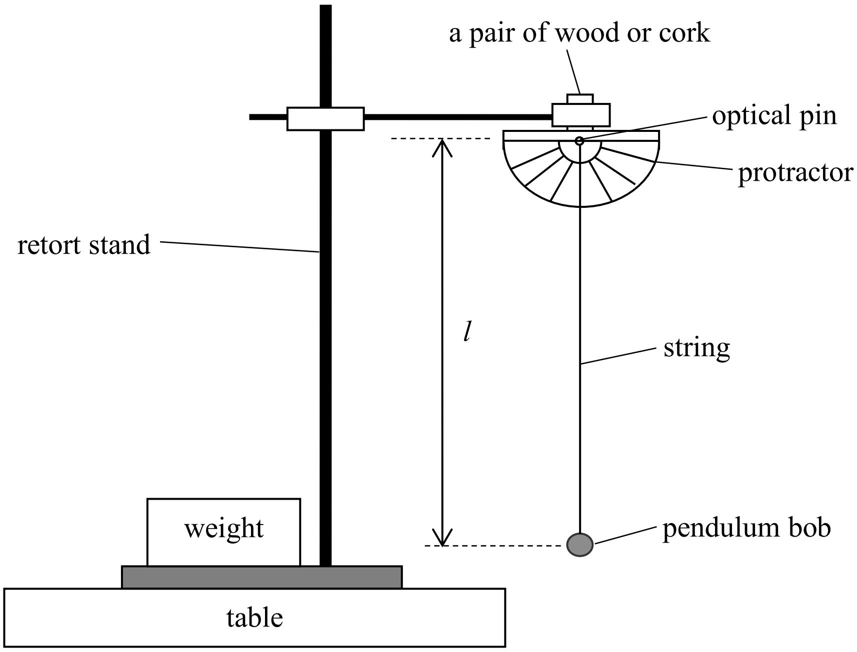


Figure 5.1

1. Set up a simple pendulum as in **Figure 5.1**.

2. Measure the length, l of the pendulum at 40 cm.

3. Release the pendulum at less than 10° from the vertical in one plane and measure the time, t for 10 complete oscillations.

Note: *Start the stopwatch after several complete oscillations.*

4. Calculate the average time, t.

5. Calculate the period of oscillation, T of the pendulum.

6. Repeat step (3) to (5) for length, l of 50 cm, 60 cm, 70 cm, 80 cm and 90 cm.

7. Tabulate the data.

8. Plot a graph of T^2 against l.

9. Determine the acceleration due to gravity, g from the gradient of the graph.

10. Determine the uncertainty of acceleration due to gravity, Δg.

11. Fix the length, l of pendulum at 100 cm.

12. Release the pendulum through a large arc of about 70° from the vertical and measure the time, t for 5 complete oscillations. Repeat the step for three times.

13. Calculate the average time, t and the period of oscillation, T of the pendulum.

14. Calculate the acceleration due to gravity, g using equation 5.1 by using the length, l and period, T from step (11) to (13).

15. Compare the acceleration due to gravity, g obtained from step (9) and (14) with the standard value. Write the comments.

EXPERIMENT 6: STANDING WAVES

Objectives:

(i) To investigate standing waves formed in a stretched string.
(ii) To determine the mass per unit length, μ of the string.

Theory:

When a stretched string is vibrated at a frequency, f the standing waves formed have both ends as nodes. The frequency in the string obeys the following relation

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

Hence, the tension of the string,

$$T = 4\mu f^2 l^2 \qquad 6.1$$

where f is the frequency
l is the length between two nodes
T is the tension in the string
μ is the mass per unit length

Evidently, a graph of T against l^2 is a straight line of gradient equals $4\mu f^2$. Hence, the mass per unit length, μ can be calculated.

Apparatus:

A G-clamp
A solenoid (about 100 turns) or ticker timer
An AC supply (2 – 4 V)
A metal rod (soft iron)
Two bar magnets
A magnet holder
A piece of string approximately 2 m long
A pulley with clamp
A wooden wedge
Set of slotted mass 2 g, 5 g, 10 g and 20 g
A metre rule
Connecting wires

Procedure:

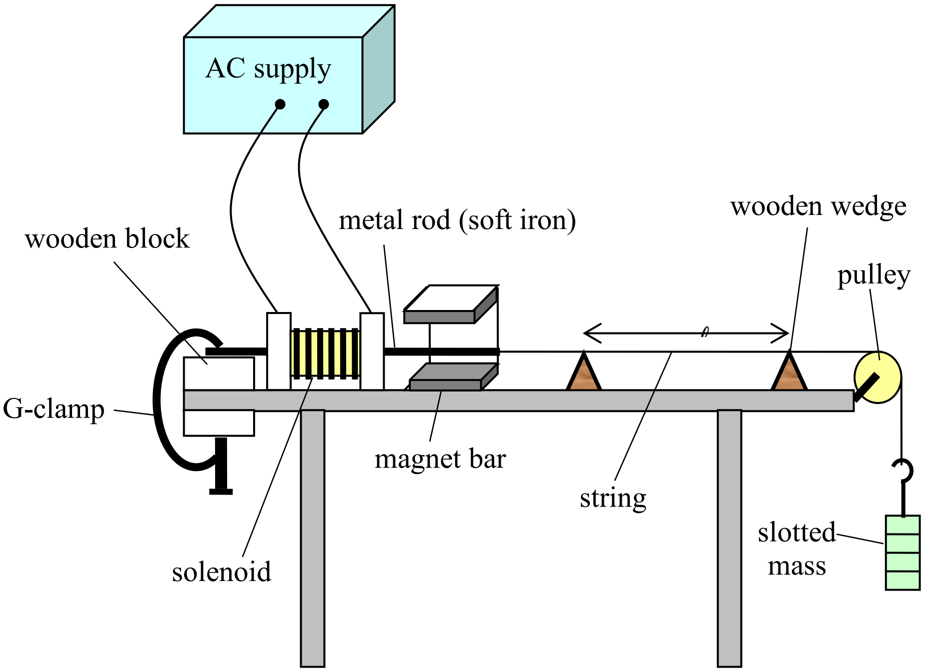


Figure 6.1

1. Set up the apparatus as in **Figure 6.1**.

2. Connect the terminals of the solenoid to the AC power supply (2 V, 50 Hz).

   Caution: *Do not exceed 4 V to avoid damage to the solenoid.*

3. Place the metal rod between the two bar magnets.

4. Tie one end of the string to the rod and the other to the hook of the slotted mass. Make sure that the length of the string from the end of the rod to the pulley is **not less than 1.5 m**.

5. Clamp the metal rod properly. Switch on the power supply. Adjust the position of the metal rod to get maximum vibration.

6. Place the wooden wedges below the string **as close as possible to the pulley**.

7. Adjust the position of the wooden wedges until a clear single loop standing wave (fundamental mode) is observed.

8. Record the distance, l between the wedges and total mass, m (mass of the hook and the slotted mass). Calculate weight, W where $W = mg$.

   Note: *Weight, W = Tension, T*

9. Add a small mass, preferably 10 g to the hook and repeat step (7) and (8) for at least six different readings.

10. Tabulate the data.

11. Plot a graph of T against l^2.

12. Determine the mass per unit length, μ from the gradient of the graph and its uncertainty, $\Delta\mu$ if the frequency of the vibration is 50 Hz.

13. Weigh the mass of the string and measure the total length of the string. Calculate the mass per unit length, μ of the string.

14. Compare the mass per unit length, μ in step (12) with the result obtained in step (13). Write the comments.

PHYSICS 2
SP025

EXPERIMENT 1: CAPACITOR

Objectives:

(i) To determine the time constant, τ of an RC circuit.
(ii) To determine the capacitance, C of a capacitor using an RC circuit.

Theory:

Time constant is defined as the time taken of a discharge current decreases to 37% of its maximum current. The time constant can be calculated by using

$$\tau = RC \qquad 1.1$$

Where τ is time constant
R is the resistance of a resistor
C is the capacitance of a capacitor

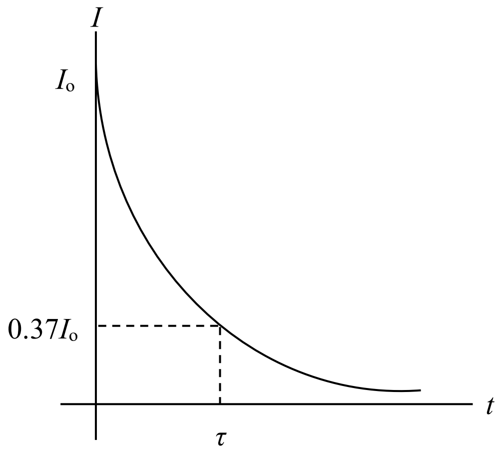


Figure 1.1

During discharging, the magnitude of the current, I varies with time as shown in **Figure 1.1**.

From Figure 1.1, the magnitude of the discharge current is

$$I = I_o e^{-\frac{t}{\tau}} \qquad 1.2$$

Rearrange equation 1.2 we obtain

$$\ln\left(\frac{I_o}{I}\right) = \frac{t}{\tau} \qquad 1.3$$

Where I_o is the maximum current in the circuit
I is current in the circuit at time t

By using equation 1.3, the time constant can be determined from the gradient of the straight-line graph.

Apparatus:

A DC power supply (4 – 6 V)
A switch
A DC microammeter
A digital stopwatch
A 100 kΩ resistor
Connecting wires
Two capacitors labelled C_1 and C_2 (470 – 1000 μF)

Procedure:

Note: *Before starting or repeating this experiment, make sure that the capacitors are fully discharged. This can be attained by short circuiting the capacitors.*

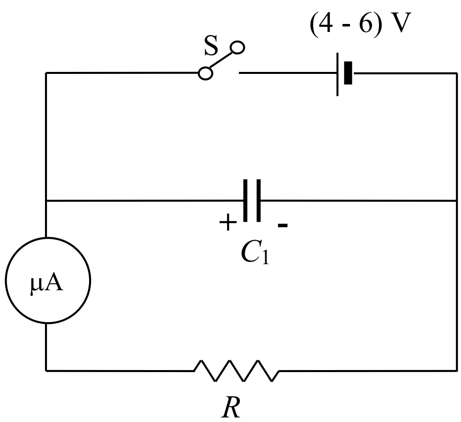


Figure 1.2

1. Set up the circuit as shown in **Figure 1.2**.

2. Close switch S to fully charge the capacitor C_1. Record the reading of the microammeter for maximum current, I_o.

3. Open switch S and start the stopwatch simultaneously.

4. Use the 'lap' function on the stopwatch when the current reaches at least six different values. Record the time for each value of current.

5. Repeat steps (1) to (4) and calculate the average time, t.

6. Tabulate the data.

7. Plot a graph of $\ln\left(\frac{I_o}{I}\right)$ against t.

8. Determine the time constant, τ from the gradient of the graph.

9. Calculate the capacitance of the capacitor C_1 by using equation 1.1.

10. Connect capacitor C_2 to the circuit as shown in **Figure 1.3**.

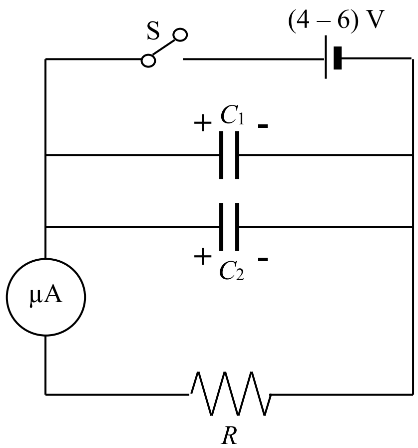


Figure 1.3

11. Repeat steps (1) to (6) to obtain the readings of the microammeter I' and the stopwatch t'. Record the readings.

12. Tabulate the data.

13. Plot a graph of $\ln\left(\dfrac{I_o}{I}\right)'$ against t'.

14. Determine the time constant, τ' from the gradient of the graph.

15. Calculate the effective capacitance, C_{eff} of capacitors by using equation 1.1.

16. Compare all the results with their respective standard values. Write a comment.

EXPERIMENT 2: OHM'S LAW

Objectives:

(i) To sketch V-I graph.
(ii) To verify Ohm's law.
(iii) To determine the effective resistance, R_{eff} of the resistors in series and parallel by graphing method.

Theory:

At constant temperature, the potential difference V across a conductor is directly proportional to the current I that flows through it. The constant of proportionality is known as the resistance of the conductor denoted by R.

Mathematically, $V \propto I$

$$V = IR \qquad 2.1$$

For resistors in series, the effective resistance is

$$R_{\mathbf{eff}} = R_1 + R_2 + R_3 + \ldots + R_n \qquad 2.2$$

For resistors in parallel, the effective resistance is

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... + \frac{1}{R_n} \qquad 2.3$$

Apparatus:

A DC power supply (4 – 6 V)
Three resistors of the same resistance (27 – 100 Ω)
A DC milliammeter
A DC ammeter (1 A)
A DC voltmeter
A rheostat
A switch
Connecting wires

Procedure:

1. Determine the resistance, R of each resistor from their colour bands.
2. Set up the circuit as in **Figure 2.1**. Connect the three resistors in series.

   Note: *Ask your lecturer to check the circuit before switching ON the power.*

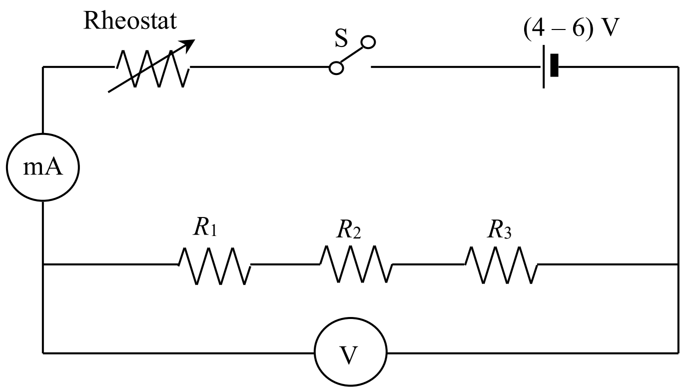


Figure 2.1

3. Adjust sliding contact on the rheostat to change the resistance values to obtain a minimum reading of the milliammeter. Record the reading of the voltmeter, V and the milliammeter, I.

4. Adjust sliding contact on the rheostat to change the resistance values to obtain at least six different values of V and I.

5. Tabulate the data.

6. Plot a graph of V against I.

7. Determine the effective resistance, R_{eff} of the three resistors connected in series from the gradient of graph.

8. Set up the circuit as in **Figure 2.2**.

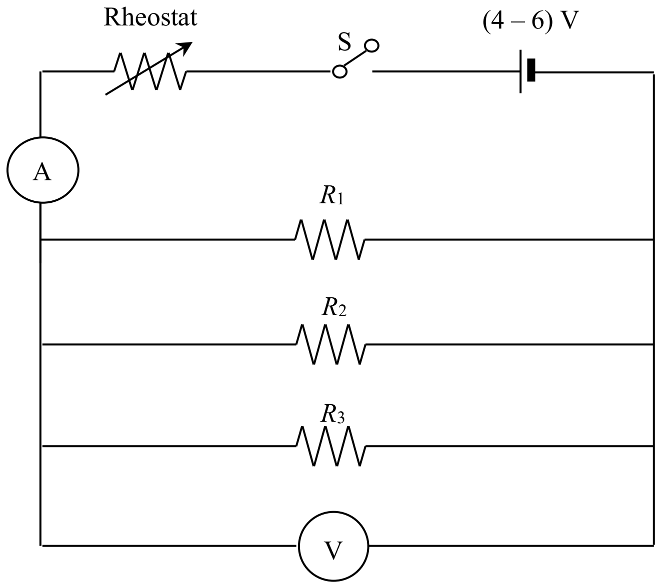


Figure 2.2

9. Repeat steps (3) to (6).

10. Determine the effective resistance, R_{eff} of the three resistors connected in parallel from the gradient of the graph.

11. Compare all the results with their respective standard values.

12. Verify Ohm's law from the plotted graphs. Write a comment.

EXPERIMENT 3: POTENTIOMETER

Objective:

To determine the internal resistance *r* of a dry cell by using a potentiometer.

Theory:

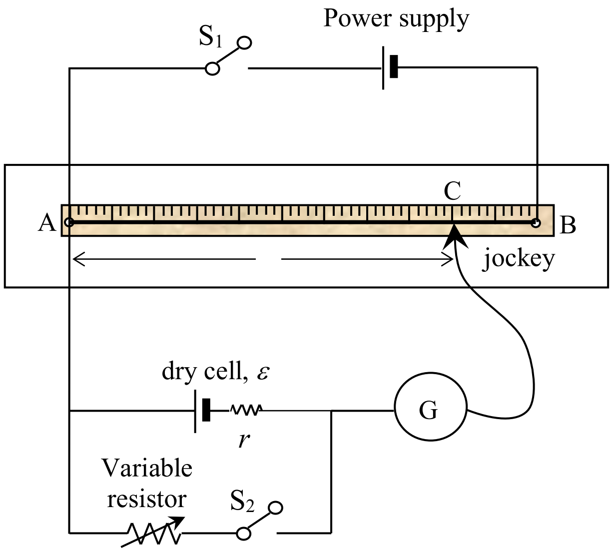


Figure 3.1

Let ε be the electromotive force (emf) and *r* the internal resistance of the dry cell. The emf of the dry cell is balanced by the potential difference across wire AB provided by the power supply when the jockey is tapped at balance point, C with S_1 close and S_2 open. The balance condition is indicated when there is no deflection in the galvanometer. If l_o is the length of the wire from A to C,

$$\varepsilon \propto l_o$$

Hence,

$$\varepsilon = kl_o \qquad 3.1$$

where *k* is a constant.

With both S_1 and S_2 closed, the new length of wire at the balance point is equal to *l*
Hence,

$$V \propto l$$

$$V = kl \qquad 3.2$$

$$\varepsilon = V + Ir \qquad 3.3$$

Rearrange equation 3.1, 3.2 and 3.3, we obtain

$$\frac{l_o}{l} = r\left(\frac{1}{R}\right) + 1 \qquad 3.4$$

The graph $\frac{l_o}{l}$ against l is a straight-line graph and its gradient is *r*.

Apparatus:

A potentiometer
A variable resistor (0 – 1 Ω) (A breadboard, six 1 Ω resistor and jumpers)
Two switches
A jockey
A regulated power supply
A 1.5 V dry cell
A galvanometer
Connecting wires

Procedure:

1. Set up the apparatus as shown in **Figure 3.1**.

   Note:
   i. *Make sure the polarity of the batteries is connected in right configuration. Ask your lecturer to check the circuit before switch ON the power.*
   ii. *Make sure that the galvanometer deflected at both sides when the jockey is tapped at two different extreme points.*

2. With S_1 closed and S_2 opened, tap the jockey along the wire until the galvanometer reading is zero (balanced) and determine l_o.

3. With both S_1 and S_2 closed, repeat step (2) and determine l for at least six different values of *R*.

4. Tabulate the data.
   Note:
   Use 1 Ω resistor in parallel combination to obtain resistance

1 Ω, $\frac{1}{2}\Omega$, $\frac{1}{3}\Omega$, $\frac{1}{4}\Omega$, $\frac{1}{5}\Omega$ *and* $\frac{1}{6}\Omega$ *as shown in* ***Figure 3.2****.*

5. Plot a graph of $\frac{l_o}{l}$ against $\left(\frac{1}{R}\right)$.

6. Determine the internal resistance of the dry cell, r from the gradient of the graph. Write a comment.

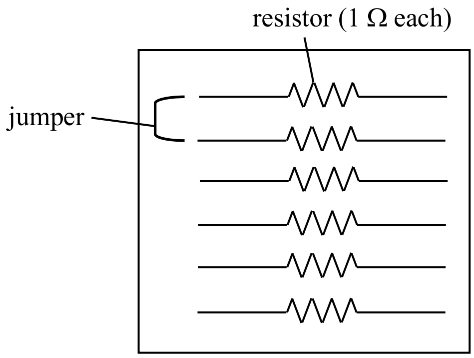


Figure 3.2

EXPERIMENT 4 (a): MAGNETIC FIELD

Objective:

To determine the value of the horizontal component of the earth magnetic field $\vec{B}_E$.

Theory:

The magnetic field strength $\vec{B}$ is a vector quantity so the addition of two magnetic fields obeys the parallelogram law. For example, if $\vec{B}_E$ is the horizontal component of earth magnetic field and $\vec{B}_C$ is the magnetic field of a coil which is perpendicular to $\vec{B}_E$ then the resultant of the two fields $\vec{B}$ is as shown in **Figure 4.1**. A compass needle is situated at the place where the two fields meet will be aligned to the direction of the resultant field $\vec{B}$.

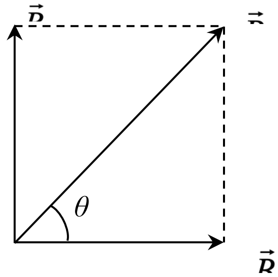


Figure 4.1

From Biot-Savart's Law, the magnetic field strength of the coil at the centre as shown in **Figure 4.2** is given by

$$B_c = \frac{\mu_o NI}{D} \qquad 4.1$$

where $\mu_o = 4\pi \times 10^{-7}$ H m^{-1} (permeability of free space)

I is the current in ampere

N is the number of turns in the coil

D is the diameter of the coil

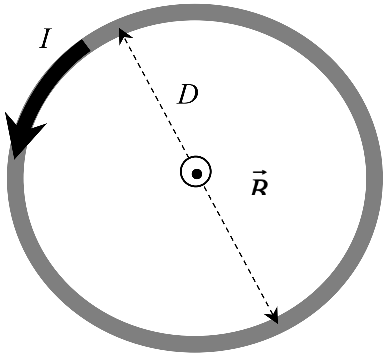


Figure 4.2

From **Figure 4.1**,

$$\tan\theta = \frac{B_c}{B_E}$$

$$\tan\theta = \frac{\mu_o N}{D(B_E)} I \qquad 4.2$$

The gradient of graph $\tan\theta$ against I

$$m = \frac{\mu_o N}{D(B_E)} \qquad 4.3$$

Therefore,

$$B_E = \frac{\mu_o N}{Dm} \qquad 4.4$$

Apparatus:

Earth magnetic field measurement kit (EM-01)
Connecting wires of about 50 cm long with crocodile clips
A DC ammeter (0 – 1 A)
A rheostat
A DC power supply (2 - 4 V)

Procedure:

1. Set up apparatus as shown in **Figure 4.3**.

   Note:
   Make sure the EM-01 kit is located far away from other electrical devices to avoid magnetic disturbance.

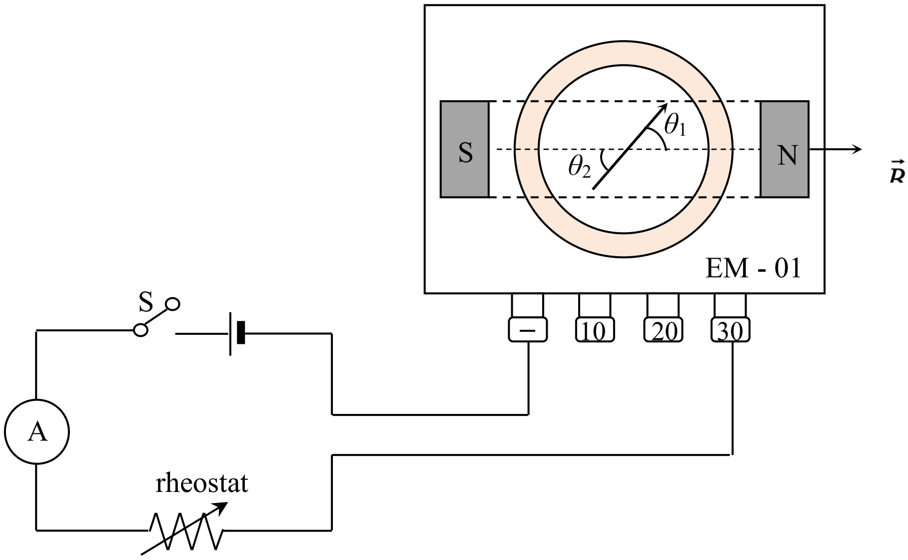


Figure 4.3

2. Align the compass needle of EM-01 until it is pointed North as in **Figure 4.4**.

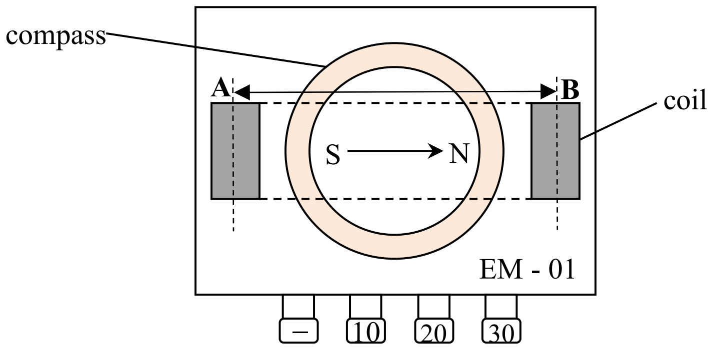


Figure 4.4

3. Set the rheostat to its maximum value and switch on the circuit. Reduce the resistance of rheostat to increase the current I and hence the corresponding value of θ_1 for at least six sets of readings. Record the readings of the ammeter I and the angle of deflection θ_1 in **Table 4.1.**

   Note: *The deflection angle should not be more than 80°.*

4. Repeat step (3) by changing the polarity of the power supply. Record the angle θ_2, pointed by the compass needle in **Table 4.1**.

5. Measure the diameter of the coil.

   Note: *Make sure the diameter is measured from A to B as in* **Figure 4.4**

   Diameter of coil D = (……… ± ………) cm
   Number of turns N = 30

No.	current, I (±……..)	θ_1 (±……..)	θ_2 (±……..)	average θ_A (…...)	tan θ_A
1					
2					
3					
4					
5					
6					
7					
8					
9					

Table 4.1

6. Plot a graph of tan θ against I.

7. Determine B_E from the gradient of the graph.

8. Compare the result with the standard value given by the lecturer. Write a comment.

EXPERIMENT 4(b): MAGNETIC FIELD

Objective:

To determine the value of the horizontal component of the earth magnetic field, $\vec{B}_{\text{E}}$.

Student Learning Time (SLT):

Face-to-face	Non face-to-face
2 hours	0

Theory:

The magnetic field strength $\vec{B}$ is a vector quantity so the addition of two magnetic fields obeys the parallelogram law. For example, if $\vec{B}_{\text{E}}$ is the horizontal component of earth magnetic field and $\vec{B}_{\text{s}}$ is the magnetic field of a solenoid which is perpendicular to $\vec{B}_{\text{E}}$ then the resultant of the two fields $\vec{B}$ is as shown in **Figure 4.1**. A compass needle is situated at the place where the two fields meet will be aligned to the direction of the resultant field $\vec{B}$.

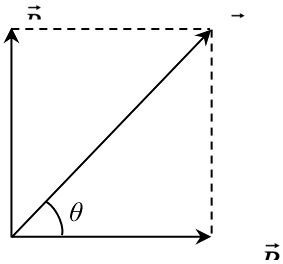


Figure 4.1

The magnetic field strength at the end of an *N*-turn solenoid of length *l* and carries current *I* as shown in **Figure 4.2** is given by

$$B_{\text{S}} = \frac{1}{2}\left(\frac{\mu_{\text{o}} NI}{l}\right) \qquad 4.1$$

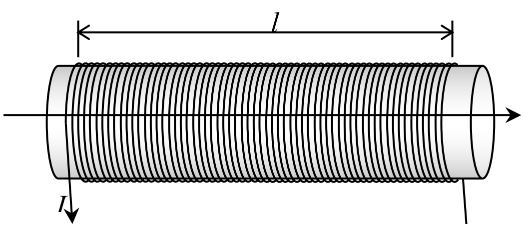


Figure 4.2

From **Figure 4.1**,

$$\tan\theta = \frac{B_s}{B_E}$$

$$\tan\theta = \frac{\frac{1}{2}\mu_o\left(\frac{N}{l}\right)I}{B_E} \qquad 4.2$$

The gradient of graph $\tan\theta$ against I is

$$m = \frac{\frac{1}{2}\mu_o\left(\frac{N}{l}\right)}{B_E} \qquad 4.3$$

Therefore,

$$B_E = \frac{\frac{1}{2}\mu_o\left(\frac{N}{l}\right)}{lm} \qquad 4.4$$

where $\mu_o = 4\pi\times10^{-7}$ H m^{-1} (permeability of free space).

Apparatus:

A 50 turns or 100 turns solenoid
A DC power supply (2 – 4 V)
A DC ammeter (0 – 1 A)
A switch
Connecting wires of about 50 cm long with crocodile clips
A rheostat
A compass

Procedure:

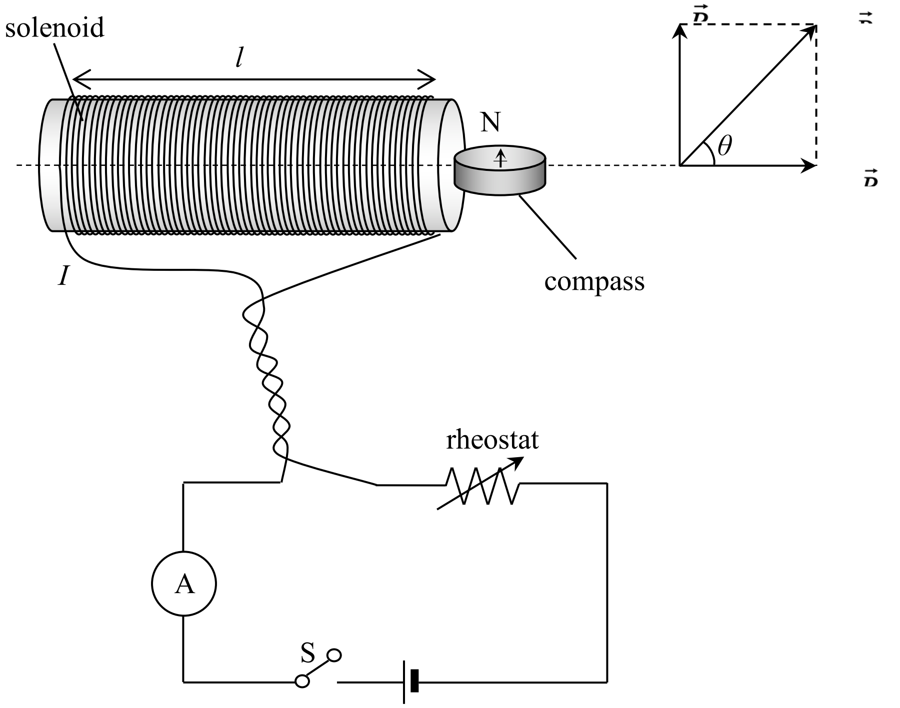


Figure 4.3

1. Place a compass at one end of the solenoid. Let the compass stay still in N−S direction where the magnet pointer is perpendicular to the axis of the solenoid. The north direction of the compass must be pointed to the north.

   Note: *Choose a position to place your compass away from any iron structure to avoid any influence on the alignment of the compass needle.*

2. Connect the solenoid in series with the rheostat, the ammeter, the power supply and the switch. The ammeter must be at least 50 cm away from the compass. A complete set up is as in **Figure 4.3**.

3. Set the rheostat to its maximum value and switch on the circuit. Reduce the resistance of rheostat to increase the current I and hence the corresponding value of θ_1 for at least six sets of readings. Record the readings of the ammeter I and the angle of deflection θ_1 in **Table 4.1.**

   Note: *The deflection angle should not be more than 80°.*

4. Repeat step (3) by changing the polarity of the power supply. Record the angle θ_2, pointed by the compass needle in **Table 4.1**.

Table 4.1

No.	Current, I (±……..)	θ_1 (±……..)	θ_2 (±……...)	Average θ_A (…..)	tan θ_A
1					
2					
3					
4					
5					
6					
7					
8					
9					

5. Remove the solenoid from the clamp and measure the length, l of the solenoid.

6. Plot a graph of tan θ against I.

7. Determine B_E from the gradient of the graph.

8. Compare the result with the standard value given by the lecturer. Write a comment.

EXPERIMENT 5: GEOMETRICAL OPTICS

Objective:

To determine the focal length, *f* of a convex lens.

Theory:

From the thin lens equation,

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v} \qquad 5.1$$

where f is the focal length
u is the object distance
v is the image distance

Multiply equation 5.1 with v,

$$\frac{v}{f}=\frac{v}{u}+1$$

$$M=-\frac{v}{f}+1 \qquad 5.2$$

Where $M=\frac{\text{height of image}}{\text{height of object}}=\frac{h_{\text{i}}}{h_{\text{o}}}=-\frac{v}{u}$ is the linear magnification.

For this experiment the image formed is always real, then negative sign for magnification indicates that the image is inverted.

Hence the graph M against v is a straight-line graph.

The equation also shows that M is proportional to v.

When $v=2f, \quad M=-1$.

Apparatus:

A convex lens

A piece of card with narrow triangle shaped slit or any suitable objects
A screen
A light source
A metre rule
A lens holder
Plasticine

Procedure:

1. Use the convex lens to focus a distant object such as a tree outside the laboratory on a screen. The distance between the screen and the lens is the estimated focal length, f_o of the lens. Record the estimated focal length.

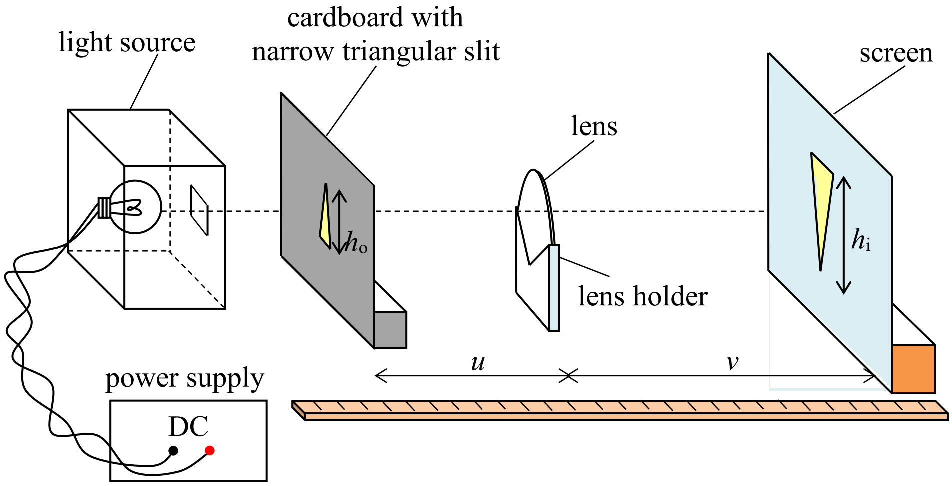


Figure 5.1

2. Set up the apparatus as in **Figure 5.1**.

3. Place the object in front of the lens at a suitable distance ($f_o < u < 2f_o$) and adjust the position of the screen so that a sharp real, inverted image is projected on the screen.

4. Record the measurement for the object distance u and the image distance v.

5. Calculate the magnification of the image, $M = -\dfrac{v}{u}$.

6. Change the location of the object. Repeat steps (4) and (5) until six sets of u, v and M are obtained.

7. Tabulate the data.

8. Plot a graph of M against v.

9. Determine the focal length of the lens, f_1 from the gradient of the graph.

10. Determine the image distance v from the graph by using extrapolation when $M = -1$ and calculate the focal length, f_2 by using equation 5.2.

11. Compare the results f_1 and f_2 with f_0. Write a comment.

EXPERIMENT 6: DIFFRACTION GRATING

Objectives:

(i) To determine the wavelength, **λ** of laser beam using a diffraction grating.
(ii) To the number of diffraction grating lines per unit length, N.

Student Learning Time (SLT):

Face-to-face	Non face-to-face
2 hour	0

Theory:

When a laser beam is incident on a diffraction grating, a diffraction pattern in the form of a series of bright dots can be seen on the screen as shown in **Figure 6.1**

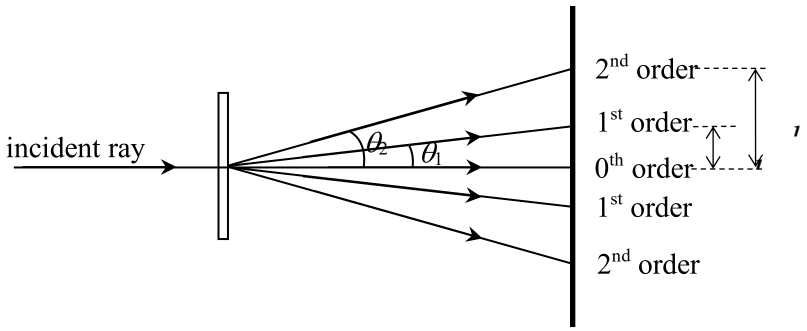


Figure 6.1

The relationship between the angle θ_n of the nth order and the wavelength of laser λ is

$$\sin\ \theta_n = \frac{n\lambda}{d} \qquad 6.1$$

where *d* is the distance between two consecutive lines of the diffraction grating, known as grating spacing.

Usually, the grating spacing is specified in number of lines per meter, such as *N* lines per meter. Hence,

$$N = \frac{1}{d} \qquad 6.2$$

Then

$$\sin\theta_{\mathrm{n}} = Nn\lambda \qquad 6.3$$

By measuring the angle θ_n for each order of diffraction n, λ can be determined.

Apparatus:

A laser pen
Two retort stands with clamps
A metre rule
A screen
Two diffraction gratings (A and B)

Note: *Suggestion A is 100 lines/mm and B is 300 lines/mm.*

Procedure:

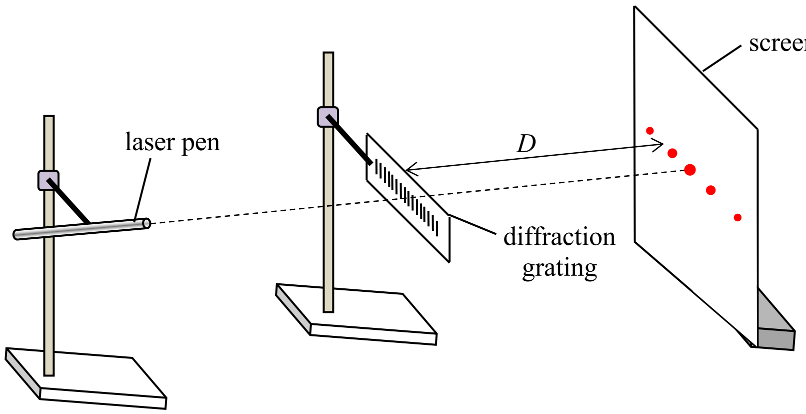


Figure 6.2

1. Set up the apparatus as shown in **Figure 6.2**. Ensure that the laser ray is pointed perpendicularly to the diffraction grating A.

   Note: *Make sure that*
   i) the incident ray is normal to the diffraction grating.
   ii) the screen is parallel to the diffraction grating.

2. The distance D from the diffraction grating to screen must be adjusted so that the spacing between the spots on the screen is as far as possible from one another. Measure and record the value of D.

   Caution: *A laser pen is NOT a toy. It is dangerous to look directly at the laser beam because it may cause permanent damage to your eyesight.*

3. Measure the distance l_1, l_2, l_3, …, l_n that correspond to the diffraction order of n = 1, 2, 3, … where l_n is the distance between spots of order, n to the centre spot.

4. Determine values of sin θ_n for order of n = 1, 2, 3, ... using equation

$$\sin\theta_n = \frac{l_n}{\sqrt{(l_n)^2 + D^2}}$$

5. Tabulate the data.

6. Plot a graph of sin θ_n against n.

7. Determine the wavelength, λ of the laser beam from the gradient of the graph.

   Note: *Take the value of N printed on the grating A.*

8. Repeat steps (1) to (6) using grating B.

9. Determine the number of lines per mm, N of grating B from the gradient of the graph by using the value of λ in step (7).

10. Compare the value of λ and N for grating B with their standard values. Write a comment.

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