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SCHOOL-BASED ASSESSMENT OF PRACTICAL PHYSICS

1.0 General information

1.1 Continuous assessment of practical work will be carried out at school throughout form six.

1.2 This assessment is expected to commence in early July 2007 and to end before 30 August 2008.

1.3 Majlis Peperiksaan Malaysia (MPM) has determined 20 experiments to be carried out by students. Of these 20 experiments, only 15 compulsory experiments will be assessed by the teacher. (Refer to the Table of Summary of Experiments on pages 5 and 6.) The assessment of practical work will be done by the teacher while an experiment is being carried out and also based on the student’s practical work report.

1.4 Students should plan their practical work first before an experiment is carried out.

1.5 Compulsory experiments are to be carried out by students individually, in pairs, in stations, or in groups as recommended in the Table of Summary of Experiments.

1.6 Students may write their practical work report in either English or Bahasa Malaysia. The report is to be submitted to the teacher on the same day the experiment is carried out unless otherwise stated. (Refer to the Table of Summary of Experiments.) Practical work reports which are not submitted on the day of the experiment are to be awarded ‘0’ mark.

1.7 Practical work report which can be completed at home is to be submitted to the teacher not later than 3 days from the date of the experiment. A penalty of 2 marks is to be imposed for the report submitted late to the teacher. Practical work reports which are submitted later than 7 days from the date of the experiment are to be awarded ‘0’ mark.

1.8 For a student who is absent from an experiment, the teacher can fix another date for the student to carry out the experiment.

1.9 Practical work reports which have been submitted to the teacher can be returned to students only after the teacher has completed assessing the reports and recording the marks of all students. However, the teacher will collect all the practical work reports before 15 October 2007 for the first year of the course and before 15 September 2008 for the second year.

1.10 Students can check their Student Record which has been completed by the teacher to ensure that the mark for each experiment and the overall total mark awarded are correct.

1.11 For a student who has transferred to another school, the previous school is to send the student’s Student Record, which is partially completed and signed by the subject teacher, to the student’s new school.

1.12 A student whose Student Record has not been sent by the school to MPM will be considered as not having carried out the practical work and not having attended paper 960/3.
2.0 Practical Work Assessment Guide

2.1 To facilitate assessment by the teacher, it is suggested that the practical work report should consist of the structures below.

(a) Purpose
(b) Procedure
(c) Observations and measurements
(d) Processing and analysis of data
(e) Results and discussion
(f) Conclusion

2.2 The total mark for each of the experiments is 20 marks. The aspects to be assessed are as follows.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Procedure</td>
<td>4</td>
</tr>
<tr>
<td>B: Observations and measurements</td>
<td>5</td>
</tr>
<tr>
<td>C: Processing and analysis of data</td>
<td>6</td>
</tr>
<tr>
<td>D: Results and discussion</td>
<td>3</td>
</tr>
<tr>
<td>E: General</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
</tr>
</tbody>
</table>

2.3 The assessment of **A: Procedure** for an experiment is to be carried out by the teacher by observing individual student performing actual practical work in the laboratory. In certain cases, the teacher may refer to the descriptions of the procedure in the student’s practical work report.

2.4 The assessment of aspects B, C, D, and E is to be carried out based mainly on the students’ practical work report.

2.5 The details of the aspects to be assessed by the teacher are as follows.

2.5.1 **A: Procedure (4 marks)**

The student is able to

(a) choose the correct and suitable apparatus,
(b) use the apparatus skilfully and correctly,
(c) set up the apparatus correctly without assistance,
(d) set up the apparatus which is safe and easy to manage,
(e) follow instructions correctly and accurately,
(f) plan the experiment so that it will run smoothly and effectively,
(g) practise good procedures,
(h) show manipulative skills during practical work,
(i) take steps to ensure accurate results,
(j) take necessary precautions to ensure the safety of apparatus and other users.

2.5.2 **B: Observations and measurements (5 marks)**
The student is able to
(a) make relevant observations without assistance,
(b) record readings with reasonable precision,
(c) determine a good and reasonable range of readings including sufficient number of readings,
(d) obtain a suitable and good distribution of readings,
(e) check over observations by a good procedure, eg taking readings repeatedly,
(f) check up on abnormal or unexpected observations,
(g) perform correct calculations,
(h) present derived data to appropriate number of significant figures,
(i) state the correct units for data,
(j) use the correct symbols or labels for data.

2.5.3 **C: Processing and analysis of data (6 marks)**
The student is able to
(a) choose appropriate procedures, eg using a suitable graph for data analysis,
(b) choose suitable scales for a graph,
(c) label and plot a graph correctly and accurately,
(d) obtain the expected pattern of data or shape of a graph,
(e) make correct deductions or interpretations from the data or graph obtained,
(f) use appropriate methods to obtain information, eg using the gradient of graph,
(g) interpret or analyse data or graphs to obtain physical relations, etc,
(h) perform calculations correctly,
(i) state the value obtained with correct unit,
(j) state the value obtained to appropriate number of significant figures.
2.5.4  **D: Results and discussion (3 marks)**

The student is able to

(a) obtain accurate results,

(b) state the results with correct units and to appropriate number of significant figures,

(c) draw conclusions consistent with the processed observations,

(d) recognise the sources of error or the limitations of the experiment,

(e) make a reasonable estimate of the reliability of the results,

(f) suggest steps or modifications to overcome the weaknesses of the experiment,

(g) give useful comments on the experiment.

2.5.5  **E: General (2 marks)**

The student is able to

(a) complete the experiment within the stipulated time,

(b) cover all the major features of practical work in the practical work report,

(c) use precise language and terminology in the practical work report,

(d) produce a good practical work report in accordance with a logical sequence,

(e) exhibit good attitudes or behaviours, eg independent, cooperative, honest, curious, etc.
### 3.0 Table of Summary of Experiments

<table>
<thead>
<tr>
<th>Experiment number</th>
<th>Topic</th>
<th>Purpose</th>
<th>Mode of working</th>
<th>Completion of practical report</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>Physical Quantities and Units</td>
<td>To determine the density of a substance</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>2</td>
<td>Kinematics and Dynamics</td>
<td>To verify the principle of conservation of linear momentum</td>
<td>In pairs</td>
<td>At home</td>
</tr>
<tr>
<td>3*</td>
<td>Rotational Motion of a Rigid Body</td>
<td>To determine the moment of inertia of a flywheel</td>
<td>In pairs/Stationed</td>
<td>In the lab</td>
</tr>
<tr>
<td>4*</td>
<td>Statics</td>
<td>To determine the coefficient of static friction between two surfaces</td>
<td>Individual</td>
<td>At home</td>
</tr>
<tr>
<td>5*</td>
<td>Simple Harmonic Motion (SHM)</td>
<td>To determine the acceleration due to gravity using a simple pendulum</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>6</td>
<td>Oscillation</td>
<td>To study the damped oscillation of a spring-mass system in the air</td>
<td>In pairs</td>
<td>At home</td>
</tr>
<tr>
<td>7*</td>
<td>Stationary Waves</td>
<td>To study stationary waves in a string</td>
<td>In pairs/Stationed</td>
<td>In the lab</td>
</tr>
<tr>
<td>8*</td>
<td>Sound Waves</td>
<td>To determine the velocity of sound using a resonance tube</td>
<td>Stationed/In groups of 5</td>
<td>At home</td>
</tr>
<tr>
<td>9*</td>
<td>Deformation of Solids</td>
<td>To determine Young’s modulus by cantilever method</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>10</td>
<td>Kinetic Theory of Gases</td>
<td>To verify Charles’ law using the air column trapped in a capillary tube</td>
<td>Individual</td>
<td>At home</td>
</tr>
<tr>
<td>11*</td>
<td>Thermal Conduction</td>
<td>To determine the thermal conductivity of glass</td>
<td>In groups of 5</td>
<td>At home</td>
</tr>
<tr>
<td>12*</td>
<td>Capacitors</td>
<td>To determine the time constant and the capacitance of capacitors in $R-C$ circuit</td>
<td>In pairs</td>
<td>In the lab</td>
</tr>
</tbody>
</table>

* Compulsory experiments to be carried out for assessment.
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<thead>
<tr>
<th>Experiment number</th>
<th>Topic</th>
<th>Purpose</th>
<th>Mode of working</th>
<th>Completion of practical report</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Electric Current</td>
<td>To study Ohm’s law and to determine the total resistance of resistors in series and parallel</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>14*</td>
<td>Wheatstone Bridge</td>
<td>To determine the resistivity of the material of a wire using a Wheatstone bridge</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>15*</td>
<td>Potentiometer</td>
<td>To determine the internal resistance of a cell using a potentiometer</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>16*</td>
<td>Magnetic Fields</td>
<td>To study the behaviour of a bar magnet in varying magnetic fields and to estimate the horizontal component of the Earth’s magnetic field</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>17*</td>
<td>Electronics</td>
<td>To understand the characteristics of an operational amplifier by measuring voltage gains and bandwidths</td>
<td>Stationed/ In groups of 5</td>
<td>At home</td>
</tr>
<tr>
<td>18</td>
<td>Geometrical Optics</td>
<td>To study the magnification of real image by a convex lens</td>
<td>Individual</td>
<td>In the lab</td>
</tr>
<tr>
<td>19*</td>
<td>Geometrical Optics</td>
<td>To determine the refractive index of glass using a concave mirror</td>
<td>Individual</td>
<td>At home</td>
</tr>
<tr>
<td>20*</td>
<td>Physical Optics</td>
<td>To study the diffraction pattern formed by a diffraction grating and to determine the wavelength of a laser beam</td>
<td>Stationed/ In groups of 5</td>
<td>At home</td>
</tr>
</tbody>
</table>

* Compulsory experiments to be carried out for assessment.

Note: Each of the experiments listed above, is allocated a duration of 1 hour and 20 minutes. For the experiments of which the reports are to be completed in the laboratory, the duration should not exceed an hour.
Experiment 1

**Topic:** Physical Quantities and Units

**Purpose:** To determine the density of

(i) PVC  
(ii) Steel  
(iii) Cooking oil

**Theory:**

The density of a substance is the mass per unit volume of the substance, i.e.

\[ \rho = \frac{M}{V} \]  ........ (1)

Before the density of a substance could be determined, it is necessary to measure the mass and volume of a sample of the substance. Using relationship (1), the density of the substance could be calculated.

**Apparatus:**

(i) PVC tube  
(ii) Steel wire (SWG 18) of approximate length 50 cm  
(iii) Any kind of cooking oil about 200 cm³  
(iv) Triple beam balance (to be shared)  
(v) A metre rule  
(vi) A pair of vernier calipers  
(vii) A 500 cm³ beaker  
(viii) A micrometer screw gauge  
(ix) A 250 cm³ measuring cylinder

**Procedure:**

(I) To determine the density of PVC

(a) Measure the external and internal diameters of a PVC tube at different parts of the tube. Determine the average external and internal diameters of the tube.

(b) Measure the length at different parts of the tube. Determine the average length.

(c) Weigh the tube using a triple beam balance.

(d) Calculate the density of PVC.
(II) To determine the density of steel

(a) Measure the length of a steel wire.

(b) Measure the diameter at different parts of the wire. Determine the average diameter.

(c) Weigh the wire using a triple beam balance.

(d) Calculate the density of steel.

(III) To determine the density of cooking oil

(a) Weigh an empty measuring cylinder.

(b) Measure 200 cm$^3$ of cooking oil using the measuring cylinder.

(c) Weigh the filled measuring cylinder.

(d) Calculate the density of the cooking oil.

Formulae that facilitate calculations

(i) Volume of PVC tube = cross-sectional area $\times$ length

$$ = \frac{\pi}{4} (a^2 - b^2) \times l$$

$\ a$ = external diameter, $b$ = internal diameter, and $l$ = length

(ii) Volume of steel wire = cross-sectional area $\times$ length

$$ = \frac{\pi}{4} a^2 l$$

$\ a$ = diameter, and $l$ = length

(iii) Mass of oil = $M_1 - M_2$

$M_1$ = mass of cylinder + cooking oil

$M_2$ = mass of cylinder
Experiment 2

Topic: Kinematics and Dynamics

Purpose: To verify the principle of conservation of linear momentum for a collision of two bodies of equal mass.

Theory: Figure 1 below shows the bob of a pendulum being released from P to Q.

If \( v \) is the velocity of the bob at Q and \( m \) is the mass of the bob, then,
\[
mgh = \frac{1}{2}mv^2 \quad \ldots \ldots \,(1)
\]
If \( z = \) horizontal displacement of bob from Q
\( L = \) length of pendulum
and \( \theta = \) angular displacement of the bob, then
\[
h = L(1 - \cos \theta)
= L \left( 2 \sin^2 \frac{\theta}{2} \right)
\]
For \( \theta \) smaller than 15\(^\circ\), \( \sin^2 \frac{\theta}{2} = \left( \frac{\theta}{2} \right)^2 ; \ z = L\theta \)
then,
\[
h = \frac{1}{2}L\theta^2 = \frac{1}{2} \frac{z^2}{L}
\]
from equation (1),
\[
v^2 = 2gh,
\]
then
\[
v^2 = \frac{z^2g}{L} \quad \text{and kinetic energy } E_k = \frac{1}{2}mv^2 = \frac{mgz^2}{2L}
\]
\[\therefore \ v \propto z \quad \text{and kinetic energy } E_k \propto z^2\]
Apparatus:

(i) Hooking plank
(ii) Two bobs equal mass
(iii) Two threads of length about 2 m
(iv) Two retort stands and clamps
(v) A metal wire as indicator
(vi) A screen to act as marker to the distance of collision
(vii) A metre rule
(viii) Plasticine
(ix) A pair of vernier calipers
(x) Blocks for raising the height of retort stands

Procedure:

(a) Set up the apparatus as shown in Figure 2.

(b) Using a pair of vernier calipers, measure the diameter of the pendulum bob.

(c) Hook the pendulum bob on the hooking plank as shown in the diagram above and make sure that the center of the two pendulum bobs rest at the same level and not less than 80 cm from the hooking plank.

(d) Place a metre rule below the bobs. Adjust the metre rule so that the 50 cm mark is just below the point of contact of the bobs.
(e) Move one of the bobs away, and determine the position of the centre of the other bob and record the corresponding reading on the metre rule as $X_{01}$. Repeat the process, and record the position of the centre of the other bob as $X_{02}$.

(f) Displace one of the bobs about 20 cm away. Record the position of the centre of the bob as $X_1$. Release the bob so as to make direct head-on collision with the other bob (The first bob should be almost at rest after the head-on collision).

(g) If it is a head-on collision, record the position of the screen that serves as a marker for the distance of collision. Repeat the process if the collision is not a head-on collision.

(h) Record the position of the centre of the second bob, $X_2$, if the collision is a head-on collision.

(i) Repeat steps (e) through (g) for displacements between 20 cm to 10 cm.

(j) Record all your readings, and tabulate $X_1 Z_1 = (X_1 - X_{01})$, $(Z_1)^2$, $X_2$, $Z_2 = (X_2 - X_{02})$, $(Z_2)^2$, and $\frac{Z_2}{Z_1}^2$.

(k) Stick a small lump of plasticine on one of the pendulum bobs and repeat steps (e) through (g). After the collision, both the pendulum bobs should move as one body.

(l) Record all your readings, and tabulate $X'_1$, $Z'_1 = (X'_1 - X'_{01})$, $(Z'_1)^2$, $X'_2$, $Z'_2 = (X'_2 - X'_{02})$, $(Z'_2)^2$, and $\frac{Z'_2}{Z'_1}^2$.

(m) From the results obtained, deduce a conclusion on the momentum and kinetic energy of the two systems.

State whether the collisions in the first and second systems are elastic or not.
Experiment 3

Topic: Rotational Motion of a Rigid Body

Purpose: To determine the moment of inertia of a flywheel.

Theory: Refer to Figure 3 below.

The load: \( mg - T = ma \)

\[ T = m(g - a) \]

The flywheel: \( TR - \tau = I\alpha \)

\[ \tau = \text{Torque from friction} \]
\[ \alpha = \text{Angular acceleration} \]

\[ \therefore \alpha = \left( \frac{R}{I} \right) T - \frac{\tau}{I} \]

\[ \therefore \text{graph of } \alpha \text{ against } T \text{ is a straight line} \]

The gradient, \( s = \frac{R}{I} \)

\[ \therefore \text{The moment of inertia of a flywheel, } I = \frac{R}{s} \]

Acceleration, \( a = \frac{2h}{t^2} \), and \( t = \text{the time taken for the load to reach the ground} \)

Angular acceleration, \( \alpha = \frac{a}{R} \)
Apparatus:

(i) A flywheel
(ii) A stopwatch
(iii) A set of slotted masses with a hanger that could turn the flywheel at a suitable speed
(iv) A metre rule
(v) A retort stand or ‘G’ clamp
(vi) Thread to hang the slotted masses to the flywheel
(vii) A soft board to absorb the impact when the slotted masses hit the ground

Procedure:

(a) The load is released from fixed height $h$ unwinding the thread around the axle.

(b) Record the time $t$ for the load to reach the ground.

(c) Vary $m$, and determine the corresponding value of $t$.

(d) Plot a graph of $\alpha$ against $T$.

(e) Calculate the moment of inertia of the flywheel.
Experiment 4

Topic: Statics

Purpose: To determine the coefficient of static friction between two surfaces

Theory:

A wooden block will slide down the inclined plane with acceleration if the angle of inclination $\theta$ exceeds a certain value. Figure 4 shows a wooden block of mass $m$ resting on an inclined plane with angle of inclination $\theta$. The wooden block is suspended from one end of a spring. The other end of the spring is being hooked onto a nail at the top of the inclined plane. If the wooden block is being displaced down the inclined plane, the wooden block will return to its original position when released because the net force up the plane exceeds the limiting friction down the plane. The downward displacement is being reduced gradually until a stage where the wooden block stays stationary when released. At this point, the net force up the plane equalised the limiting friction down the plane. If $T$ is the tension of the spring and $F$ is the limiting friction, then

$$T - mg \sin \theta = F$$

$$T - mg \sin \theta = \mu mg \cos \theta,$$

where $\mu = \text{The coefficient of static friction}$.

If $T = m'g$, where $m' = \text{mass equivalent to tension } T$, then

$$m' = m(\mu \cos \theta + \sin \theta)$$
Apparatus:

(i) A smooth plank as inclined plane
(ii) Six wooden blocks, one of which has a smooth surface and a hook
(iii) Triple beam balance (to be shared)
(iv) A soft spring
(v) A 50 g mass hanger
(vi) Five 100 g slotted masses
(vii) A retort stand and clamp
(viii) A weight for stabilising the retort stand
(ix) A protractor
(x) A pendulum bob
(xi) Thread
(xii) A half-metre rule
(xiii) Double-sided adhesive tape

Procedure:

Part I: To determine the relationship between the mass of load and the length of spring

(a) Hook one end of the spring on the retort stand and hang the 50 g mass hanger with a 100 g slotted mass at the other end of the spring. Measure the length \( \ell_1 \) of the spring. Record the mass \( m_1 \) (the mass hanger and the slotted mass).

(b) Increase the mass \( m_1 \) and measure the corresponding length \( \ell_1 \) of the spring.

(c) Tabulate \( \ell_1 \) and \( m_1 \).

(d) Plot a graph of \( \ell_1 \) against \( m_1 \).
Part II: To determine the coefficient of friction between two surfaces

(a) Weigh the mass of the wooden block having a smooth surface. Record down the mass.

(b) Adjusting the retort stand, the angle of inclination for the inclined plane could be changed. An angle of inclination is to be obtained such that the wooden block slide down freely with acceleration. Set up the apparatus as in figure 4. Measure and record the angle of inclination \( \theta \).

(c) Displace the wooden block downward and release, so that the wooden block will be pulled to move upward by tension in the spring.

(d) Repeat step (c) with smaller displacements until a stage that the wooden block stays stationary upon released. Measure and record the length \( \ell_2 \) of the spring.

(e) The mass of the wooden block could be increased by adding other wooden blocks on top of the first. Weigh and record the new combined weight \( m \) of the block. Repeat steps (c) and (d).

(f) Tabulate \( m, \ell_2, \) and \( m' \) where \( m' \) is the corresponding mass for the length \( \ell_2 \) from the graph \( \ell_1 \) against \( m_1 \).

(g) Plot a graph of \( m' \) against \( m \).

(h) Calculate the gradient of graph \( m' \) against \( m \) and hence determine the coefficient of static friction \( \mu \).
Experiment 5

Topic: Simple Harmonic Motion (SHM)

Purpose: To determine the acceleration due to gravity using a simple pendulum and to investigate the effect of large amplitude oscillations.

Theory:

The oscillation of a simple pendulum is a simple harmonic motion if

(i) the bob of the pendulum is a point mass,
(ii) thread is having negligible mass,
(iii) the amplitude of oscillation is small (< 10°).

From the theory of SHM, the period of oscillation of a simple pendulum is given by

\[ T = 2\pi \sqrt{\frac{l}{g}}. \]

\( l \) = length of pendulum
\( g \) = acceleration due to gravity

\( g \) could be calculated if \( T \) and corresponding \( l \) were known. If a set of values of \( T \) and \( l \) are measured, a graphical method could be used by plotting \( T^2 \) against \( l \) and the average value of \( g \) is obtained from the gradient \( s \) of the graph, i.e.

\[ s = \frac{4\pi^2}{g} \]

Apparatus:

(i) Thread of length about 150 cm
(ii) A pendulum bob
(iii) Two flat pieces of wood/cork to hold the thread
(iv) A retort stand and clamp
(v) A stopwatch
(vi) A metre rule
(vii) A weight for stabilising the retort stand
(viii) A protractor or semicircle card with an angle of 70° marked
Procedure:

(a) Set up the pendulum as in Figure 5 above.

(b) Measure the length \( l \) of the pendulum.

(c) Oscillate the pendulum and the time for proper number of oscillations is measured. Repeat this measurement, so that an average time is obtained and hence the corresponding period \( T \) is calculated.

Repeat the above procedure for other values of \( l \). Obtain a minimum of 6 sets of readings for \( l \) and \( T \).

(d) Plot a graph of \( T^2 \) against \( l \).

(e) From the graph, determine the value of \( g \).
(f) Fix the length $l$ of the pendulum at 120 cm and displace the bob by $70^\circ$ from the vertical and release.

Measure the time for 5 oscillations and calculate the period $T$.

(g) Calculate the value of $g$, using the values of $l$ and $T$ in (f) using

$$T = 2\pi \sqrt{\frac{l}{g}} \left(1 + \frac{1}{4} \sin^2 \frac{\theta}{2}\right).$$

(h) Calculate $g$ from $T = 2\pi \sqrt{\frac{l}{g}}$.

(i) Compare the values of $g$ obtained in (g) and (h). Give your comment.
Experiment 6

Topic: Oscillation

Purpose: To study the damped oscillation of a spring-mass system in the air

Apparatus:

(i) A retort stand with two clamps and weights to stabilise the retort stand
(ii) A metre rule
(iii) A 2 inch nail
(iv) Two small pieces of wood/cork to hold the nail
(v) A cellophane tape
(vi) A 100 g slotted mass
(vii) A 20 g mass hanger
(viii) An optic pin
(ix) A stopwatch
(x) A soft spring

Procedure:

(a) Set up the apparatus as shown in Figure 6 below. Make sure that the indicator pin is secured firmly on the load.

![Diagram of experiment setup](image-url)
(b) Record the total mass \( m \) of load on the spring. Record the reading \( y_o \) on the metre rule as indicated by the indicator pin during equilibrium.

(c) Determine \( T \), when the system oscillates with small amplitude.

(d) Now, displace the load downward by 6.0 cm from the equilibrium position and release. When the amplitude \( A \) of the oscillation reaches 5.0 cm, start counting number of oscillation.

Record the corresponding reading \( y \) on the metre rule as indicated by the indicator pin after each 20 oscillations until the number of oscillations \( N = 200 \).

Record all your readings, and tabulate \( N, y, A = |y_o - y| \) and \( \ln (A/cm) \).

(e) Plot a graph of \( \ln A \) against \( N \).

(f) From the graph, determine

(i) the gradient \( k = \frac{\Delta \ln (A/cm)}{\Delta N} \)

(ii) interception \( c \) on the vertical axis, i.e. \( N = 0 \).

(g) Calculate

(i) the value of \( b \), i.e. the damping factor for the spring-mass system, from

\[
b = \frac{2mk}{T},
\]

(ii) the value of \( \tau \), i.e. the time taken for the amplitude of oscillation to reduce to half of the original value, from

\[
\tau = \frac{2m \ln 2}{b}.
\]
Experiment 7

Topic: Stationary Waves

Purpose: To study stationary waves in a string and to determine the mass per unit length of the string.

Theory:

\[ f' = \frac{1}{2l} \sqrt{\frac{T}{m}} \]

where \( f' \) = oscillation frequency

\( T \) = tension in the string

\( m \) = mass per unit length

\( l \) = distance between two successive nodes

Apparatus:

(i) A 'G' clamp
(ii) A reel of insulated copper wire
(iii) A.c. power supply (2 – 12 V)
(iv) A metal rod
(v) Two magnadur magnets
(vi) A magnet holder
(vii) Thread
(viii) A pulley
(ix) A wooden wedge
(x) A plastic dish to hold the slotted masses
(xi) Slotted masses of combination of 2, 5, 10, and 20 g
(xii) A metre rule
(xiii) A fine V–shaped wire to serve as a “rider”

Note: Ticker timer can be used as a source of wave to replace items (i) to (vi) above.

Procedure:

(a) Set up the apparatus as in Figure 7 below.
(b) Connect the copper wire winding to the 2 V, 50 Hz power supply.

(c) Place the magnadur magnets above and below the metal rod.

(d) Tie one end of the thread to the metal rod and the other end to the plastic dish that carries the slotted masses. The length of the thread from the end of the rod to the pulley should not be less than 1.5 m.

(e) Switch on the power supply. Adjust the length of the metal rod so that it is vibrating at maximum amplitude. Clamp the metal rod firmly as shown in Figure 7.

(f) Place the wooden wedge below the thread and next to the pulley. Adjust the position of the wooden wedge so that a steady stationary wave is observed.

(g) Add extra masses to the plastic dish and observe the stationary wave in the string.

(h) Starts from 2 g of slotted mass and mass of dish as $M$, measure and record the distance $l$ between two successive nodes.

(i) Tabulate $l$ and $W$, where $W = Mg$.

(j) Plot a graph of $W$ against $l^2$.

(k) Calculate the gradient of the graph.

(l) Deduce the mass per unit length $m$ of the thread used if the frequency of the power supply is 50 Hz.
Experiment 8

**Topic:** Sound Waves

**Purpose:** To determine the velocity of sound using a resonance tube

**Theory:**

A column of air could be forced to vibrate by an external vibrating source if the natural frequency of the air is the same as the frequency of the vibrating source. Resonance is said to occur at that instant. Resonance could be produced by placing a vibrating tuning fork or any vibrating source at the opening of a column of air. Figure 8 shows the minimum length of the column of air that could resonate with the vibrating tuning fork. The stationary wave formed in the column of air is said to be at the fundamental.

![Figure 8](image)

If \( \ell \) is the length of air column that resonance at frequency \( f \) and \( \varepsilon \) is the end correction, therefore the vibration at the fundamental satisfies

\[
\ell + \varepsilon = \frac{1}{4} \lambda
\]

\[
= \frac{1}{4} \frac{v}{f},
\]

where \( v \) is the velocity of sound in air and \( \lambda \) the corresponding wavelength at the fundamental.

\[
\therefore \ell = \frac{1}{4} \frac{v}{f} - \varepsilon
\]
Apparatus:

(i) A 500 cm$^3$ measuring cylinder
(ii) An audio generator
(iii) A small speaker
(iv) A half-metre rule
(v) A retort stand and clamp

Procedure:

(a) Set up the apparatus as shown in Figure 9 below. Start the experiment with the length $\ell$ of air column of about 35.0 cm.

Figure 9

(b) Adjust the audio generator from zero Hz until the first resonance is heard. Record the length $\ell$ of air column and the corresponding resonance frequency $f$.

(c) Decrease $\ell$ gradually until $\ell = 10.0$ cm by adding water into the measuring cylinder and repeat step (b).

(d) Tabulate $\ell$, $f$, and $\frac{1}{f}$.

(e) Plot a graph of $\ell$ against $\frac{1}{f}$.

(f) From your graph, determine the velocity $v$ of sound in air and the end correction $\varepsilon$. 
Experiment 9

**Topic:** Deformation of Solids

**Purpose:** To determine Young’s modulus by cantilever method

**Theory:**

![Diagram of experiment setup](image)

$L = \text{length,}\n\nonumber
b = \text{width, and}\n\nonumber
\nonumber\nonumber\nonumber
\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonumber\nonu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Apparatus:

(i) A metre rule
(ii) A half-metre rule
(iii) A 'G' clamp
(iv) A retort stand and clamp
(v) Thread
(vi) A 50 g slotted mass hanger
(vii) A set of 20 g slotted masses
(viii) A wooden block
(ix) A pair of vernier calipers
(x) A micrometer screw gauge

Procedure:

(a) Determine the length $d$ for different values $M$ of slotted masses used.

(b) Plot a graph of $d$ against $M$.

(c) Calculate the Young modulus $E$ of wood of the metre rule.
Experiment 10

Topic: Kinetic Theory of Gases

Purpose: To verify Charles’ law using the air column trapped in a capillary tube

Theory:

Charles’ law: For a fixed mass of gas at constant pressure, it expands by $\frac{1}{273}$ of its original volume at 0 °C for every increase of temperature of 1 °C.

or $V = V_0(1 + \alpha \theta)$

$\alpha \approx 3.66 \times 10^{-3} \text{ °C}^{-1}$ for all gases at low pressure.

∴ The graph of $V$ against $\theta$ is a linear graph with

$$\frac{\text{Gradient}}{V_0} \approx 3.66 \times 10^{-3} \text{ °C}^{-1}.$$

Apparatus:

(i) A 1 liter beaker
(ii) A thermometer
(iii) A stirrer
(iv) A 30 cm wooden ruler
(v) Two rubber bands
(vi) Capillary tube with air trapped by column of concentrated sulphuric acid
(vii) Ice cubes and water (to be shared)
(viii) Boiling water
Procedure:

(a) Set up the apparatus as shown in Figure 11 below.

![Figure 11](image)

(b) Record the length \( l \) of the air column at different temperatures \( \theta \) in the range of \( 0 \, ^{\circ}\text{C} < \theta < 100 \, ^{\circ}\text{C} \).

(c) From the results obtained, plot a suitable graph, and thus verify Charles’ law.
Experiment 11

**Topic:** Thermal Conduction

**Purpose:** To determine the thermal conductivity of glass

**Theory:**

Thermal conductivity $k$ could be expressed in terms of the rate of flow of heat $\frac{dQ}{dt} = -k$ and $A \frac{dQ}{dx}$, where $\frac{dQ}{dt}$ = rate of heat conducted,

$A$ = tangential surface area for heat flow,

$\frac{dQ}{dx}$ = temperature gradient.

Relationship between temperature $\theta$ and time $t$ for this experiment is given by

$$\ln \theta_o - \ln \theta = \frac{kt}{Brx},$$

where $\theta$ = temperature in °C at time $t$ in s,

$\theta_o = 20$ °C,

$B = 4.84 \times 10^6$ J m$^{-3}$ K$^{-1}$,

$r$ = average radius of the boiling tube, and

$x$ = thickness of the wall of the boiling tube.

**Apparatus:**

(i) A boiling tube
(ii) A thermometer (−10 °C − 110 °C)
(iii) A 1000 cm$^3$ beaker
(iv) Two stirrers
(v) A cork stopper
(vi) A stopwatch
(vii) A pair of vernier calipers
(viii) A retort stand and clamp
(ix) Ice cubes
(x) Hot water
Procedure:

(a) Measure the internal and external diameters of a boiling tube and hence calculate the average radius \( r \) and the thickness \( x \) of the wall of the boiling tube.

(b) Fill up a beaker with water and ice. Clamp the boiling tube on to a retort stand and lower the boiling tube into the beaker until the whole of the boiling tube almost submerge in the ice and water mixture.

(c) Pour hot water into the boiling tube until the water level inside the tube reaches about 1 cm below the ice-water level in the beaker. The temperature of the ice and water mixture inside the beaker should be 0 °C before the hot water is poured into the boiling tube.

(d) Insert the stirrer and thermometer through the cork stopper as shown in Figure 12.

(e) Record time \( t \) and the corresponding temperature \( \theta \) starting at temperature around 30 °C. Recording of time \( t \) and temperature \( \theta \) proceeds until the temperature in the boiling tube reaches about 3 °C. The ice-water mixture in the beaker and the warm water in the boiling tube should be constantly stirred throughout the experiment.

(f) Tabulate \( t \), \( \theta \), and \( \lg \theta \).

(g) Plot a graph of \( \lg \theta \) against \( t \).

(h) Calculate the gradient of the graph and hence determine the thermal conductivity of glass.
Experiment 12

Topic: Capacitors

Purpose: To determine the time constant and the capacitance of capacitors in R-C circuit.

Apparatus:

(i) A 6 V d.c. power supply
(ii) An on – off switch
(iii) A d.c. milliammeter
(iv) A stopwatch
(v) Resistor-pack
(vi) Two connecting wires with a crocodile clip at one end
(vii) Eight 50 cm connecting wires
(viii) A 10 cm connecting wire
(ix) A capacitor labelled $C_1$
(x) A capacitor labelled $C_2$

Procedure:

Caution: Before you start the experiment, the capacitor has to be fully discharged. This is done by short-circuiting the terminals.

(a) Connect up the circuit with switch S as shown in Figure 13. The connecting wires with crocodile clips are to be connected to points X and Y and are meant for connection to the resistor-pack for selections of $R$, where $R$ is the effective resistance across X and Y.

![Figure 13](image-url)
(b) Starting with $R = 6600 \, \Omega$, close switch S, and decrease $R$ in stages by proper selection of combination of resistors from the resistor-pack until the reading of current $I_o$ in the milliammeter is 1.0 mA or about 1.0 mA.

Record the value of $I_o$ and the corresponding resistance $R_o$.

(c) Open switch S and short-circuit the terminals of the capacitor with a short connecting wire to fully discharge it.

(d) Close switch S again to charge the capacitor until the reading of the milliammeter shows $I_o$.

(e) Then open switch S and simultaneously start the stopwatch, and observe the reading of the milliammeter. Stop the stopwatch when the current reaches a certain value of $I$. Record the time $t$ and the corresponding value of $I$ of the milliammeter.

(f) Repeat the steps (d) and (e) to obtain a new set of $I$ and $t$.

Record all your readings and tabulate $I$, $t$, $\frac{I_o}{I}$, and $\ln\left(\frac{I_o}{I}\right)$.

(g) Now, add a capacitor $C_2$ to the circuit as in Figure 14. The value of $R$, i.e. the total resistance across X and Y, is to be fixed at $R_o$.

![Figure 14](image)

(h) Repeat steps (c), (d), (e), and (f) to obtain milliammeter reading $I'$ for the corresponding time $t'$.

Record all your readings and tabulate $I'$, $t'$, $\frac{I_o}{I'}$, and $\ln\left(\frac{I_o}{I'}\right)$. 

33
(i) Plot a graph of $\ln \left( \frac{I_0}{I} \right)$ against $t$ and a graph of $\ln \left( \frac{I_0}{I'} \right)$ against $t'$ using the same axes.

(j) From your graphs, determine

(i) gradient $k = \frac{\Delta \ln \left( \frac{I_0}{I} \right)}{\Delta t}$,

(ii) gradient $k' = \frac{\Delta \ln \left( \frac{I_0}{I'} \right)}{\Delta t'}$.

(k) Calculate the time constants $\tau$ and $\tau'$ for the respective $R-C$ circuits using $\tau = \frac{1}{k}$ and $\tau' = \frac{1}{k'}$.

(l) Calculate capacitance $C_1$ and the net capacitance $C'$ for the respective $R-C$ circuits using equations $\tau = R_0 C_1$ and $\tau' = R_0 C'$.

(m) Write down the relationship between $C_1$, $C_2$, and $C'$, and hence calculate the capacitance $C_2$.

(n) From the graph of $\ln \left( \frac{I_0}{I} \right)$ against $t$, deduce an expression for current $I$ as a function of time $t$. 
Experiment 13

Topic: Electric Current

Purpose: To study Ohm’s law and to determine the total resistance of resistors in series and parallel

Apparatus:

(i) D.c. supply from 3 dry cells/power-pack
(ii) Three carbon resistors of the same resistance
(iii) An ammeter
(iv) A voltmeter
(v) A rheostat (0 – 20 Ω)
(vi) An on – off switch
(vii) Six 50 cm connecting wires
(viii) Two connectors for connecting resistors
(ix) A small screw driver

Procedure:

(a) Set up the circuit as shown in Figure 15 below. Connect the three resistors in series.

(b) Use the circuit to study the variation of $V$ with $I$, where $V$ is the reading of the voltmeter and $I$ is the reading of the ammeter.
(c) From your graph, deduce the total resistance of resistors in series in the circuit.

(d) Connect up the circuit as shown in Figure 16.

(e) Repeat steps (b) and (c).

(f) From your graph, determine the total resistance of resistors in parallel in the circuit.
Experiment 14

Topic: Wheatstone Bridge

Purpose: To determine the resistivity of the material of a wire using a Wheatstone bridge

Theory:

Resistance $R$ of a wire of length $l$ and cross-sectional area $A$ is given by

$$R = \rho \frac{l}{A}$$

where $\rho$ represents the characteristic of the material of the wire known as resistivity.

To determine $\rho$, it is necessary to determine $R$, $l$, and $A$ for the wire.

$R$ could be determined using a Wheatstone bridge. When the Wheatstone bridge has reached a balance point, the resistances $x$ and $y$ on one side of the balance point give the same ratio as the resistances $r_1$ and $r_2$ on the other side.

i.e. $\frac{x}{y} = \frac{r_1}{r_2}$.

If the slide wire is uniform, then the expression above could be written as $\frac{r_1}{r_2} = \frac{l_1}{l_2}$, i.e. in terms of the lengths of the slide wire on the two sides of the balance point

Apparatus:

(i) A Wheatstone bridge
(ii) A 5 $\Omega$ standard resistor
(iii) A dry cell
(iv) A switch
(v) A resistance wire
(vi) A micrometer screw gauge
(vii) A metre rule
(viii) A galvanometer
(ix) A jockey
Procedure:

(a) Set up the apparatus as in Figure 17 below.

(b) Using about 50 cm of SWG 36 constantan wire as resistor X and make sure no criss-crossing of the wire. P is a standard resistor and determine the balance point. The balance point should be around 35 cm to 66 cm of the slide wire or otherwise adjust the length of X until the balance point falls in the range.

Record the values for P, $a_1$, and $b_1$.

(c) Reverse the terminals of the cell, and obtain the values of $a_2$ and $b_2$ for the second balance point. After that, interchange X and P and that will be the third balance point and record the values for $a_3$ and $b_3$. Then, reverse the terminals of the cell to obtain the fourth balance point, and record the values for $a_4$ and $b_4$.

(d) Determine $l_1$, where $l_1$ is the mean for $a_1$, $a_2$, $b_3$, and $b_4$, and also determine $l_2$, where $l_2$ is the mean for $b_1$, $b_2$, $a_3$, and $a_4$.

(e) Calculate the resistance of X using $\frac{R}{P} = \frac{l_1}{l_2}$.

(f) Measure the length $x$ of wire X between terminals C and D and the diameter.

(g) Calculate the resistivity of the material of the wire using

$$\rho = \frac{RA}{x},$$

where $A = \text{cross-sectional area of the wire}$. 
Experiment 15

Topic: Potentiometer

Purpose: To determine the internal resistance of a cell using a potentiometer

Theory:

E.m.f. of the cell = $\varepsilon$
Internal resistance of the cell = $r$

With switch $S_1$ closed while switch $S_2$ open, obtain the balance length $l_0$.

With both $S_1$ and $S_2$ closed, obtain the balance length $l$.

Then,

$$\varepsilon = V + Ir$$
$$r = \frac{\varepsilon - V}{I}$$
$$r = \frac{\varepsilon - V}{R}$$

$$r = \left(\frac{\varepsilon}{V} - 1\right)R$$
$$r = \left(\frac{l_0}{l} - 1\right)R$$

$$\frac{l_0}{l} = r \left(\frac{1}{R}\right) + 1$$

Graph of $\frac{l_0}{l}$ against $\frac{1}{R}$ should be linear and the gradient is $r$. 

Figure 18
Apparatus:

(i) A potentiometer
(ii) A resistor-pack
(iii) Two on-off switches
(iv) A jockey
(v) A 2 V accumulator
(vi) A 1.5 V dry cell
(vii) A centre-zero galvanometer

Procedure:

(a) With S1 closed and S2 open, determine the balance length \( l_0 \).

(b) With both S1 and S2 closed, determine the balance length \( l \) for various values of \( R \).

(c) Plot a graph of \( \frac{l_0}{l} \) against \( \frac{1}{R} \).

(d) Calculate the internal resistance \( r \) of the cell.
Experiment 16

Topic:  Magnetic Fields

Purpose:  To study the behavior of a bar magnet in varying magnetic fields at the end of a solenoid and hence estimate the horizontal component $B_H$ of the Earth’s magnetic fields.

Apparatus:

(i) A retort stand and two clamps  
(ii) A cork and an optical pin  
(iii) A set of small bar magnet fixed with a pair of optical pins  
(iv) A plane mirror attached to a protractor  
(v) Thread of length about 40 cm  
(vi) A test-tube wound with copper wires  
(vii) A 2 V accumulator or any other stable power supply  
(viii) A 0 – 1 A d.c. ammeter  
(ix) An on – off switch and three connecting wires  
(x) A rheostat  
(xi) A pair of vernier calipers  
(xii) A micrometer screw gauge

Procedure:

(a) Clamp the cork with a pin to the retort stand and hang the bar magnet from the pin using the thread supplied, so that the magnet stays at a height of about 5 cm above the table. Keep all magnetic materials away including the ammeter. Allow the magnet to stay stationary. Place the mirror with the protractor directly below the magnet and the 0° – 180° axis parallel to the pins on the magnet.

(b) Using the other clamp, hold the solenoid in a horizontal position at the same level with the magnet. Adjust the orientation of the solenoid so that its axis is perpendicular to the axis of the magnet and one end of the solenoid is at 3.0 cm from the axis of the magnet. Connect a rheostat, ammeter, power supply and switch to the solenoid in series. The ammeter should be kept at least 50 cm from the magnet. The arrangement of apparatus should look as in Figure 19.
(c) Adjust the rheostat to maximum resistance and close the switch. Record the reading $I$ of the ammeter and obtain the average deflection $\theta$ of the magnet from the $0^\circ - 180^\circ$ axis.

Decrease the value of the resistance of the rheostat in stages so as to change the value of $I$ and then measure the corresponding value of $\theta$.

Record all measurements for $I$, $\theta$, and $\tan \theta$.

(d) Plot a graph of $\tan \theta$ against $I$.

(e) At the point where $I = 0.20$ A, find the gradient $s$ of the graph of $\tan \theta$ against $I$.

(f) Remove the solenoid and measure
   (i) the internal diameter $D$ of the solenoid,
   (ii) average diameter $d$ of the wire used in the solenoid,
   (iii) length $L$ of the solenoid.
(g) Use the values of $d$ and $L$ to estimate the number of turns $N$ in the solenoid.

(h) Calculate the value of the horizontal component $B_H$ of the Earth’s magnetic field using the following estimation

$$B_H \approx \frac{\mu_0 N}{2 l s} \left[ 1 - \frac{l}{\sqrt{l^2 + \left(\frac{D^2}{4}\right)}} \right]$$

where $\mu_0 = 4\pi \times 10^{-7}$ H m$^{-1}$ and $l = 0.030$ m.
Experiment 17

Topic: Electronics

Purpose: To understand the characteristics of an operational amplifier by measuring the voltage gains and the bandwidths.

Introduction

Operational amplifier is a linear direct-coupled differential amplifier with high gain that depends on the feedback from the output to the input that determines the characteristics. Operational amplifier was originally used in analogue computer to perform mathematical operations such as addition, subtraction, multiplication, differentiation and integration. This amplifier can perform the operations with great accuracy and reliability.

Theory

Basically, operational amplifier is used to detect the difference in the potential of two signals connected respectively to the two inputs, i.e. \((V_2-V_1)\), which is multiplied by a factor \(A\) and will produce a voltage \(A(V_2-V_1)\), as the output.

An ideal operational amplifier generally has the following characteristics:

- Very high gain
- Very high input impedance (regards as infinity)
- Very low output impedance (regards as zero)

![Figure 20](image)

Figure 20 shows the universal symbol representing the operational amplifier, where (+) stands for the non-inverting input and (−) stands for the inverting input. Inverting input means that the output will be negative if the potential at the inverting input is greater than the potential at the non-inverting input and vice versa. Therefore the signs (+) and (−) does not mean that (+) input is more positive than (−) input.
Normally the operational amplifier is used with the negative feedback. There are two kinds of amplifiers with negative feedback, i.e. inverting amplifier and non-inverting amplifier. For the case of inverting amplifier, as in Figure 21, the non-inverting input is grounded and output voltage is given by \[ V_o = -\left( \frac{R_o}{R_i} \right) V_i. \] Take note that resistor \( R_o \) joins the output to the inverting input, and this setup is called negative feedback. The equations relating to the gain is given by \[ \text{Gain } A = \frac{V_o}{V_i} = \frac{R_o}{R_i}. \]

Figure 21

Figure 22 shows a non-inverting amplifier where the output voltage is given by \[ V_o = \left( 1 + \frac{R_o}{R_i} \right) V_i \] and the gain \( A = 1 + \frac{R_o}{R_i}. \)

Figure 22
OP-AMP 741 (Mini DIP 8 pins) and the terminals is as shown in Figure 23.

Apparatus:

(i) A 2.2 k\(\Omega\) resistor (red-red-red)
(ii) A 22 k\(\Omega\) resistor (red-red-orange)
(iii) An OP-AMP 741 IC
(iv) An OP-AMP 741 socket
(v) A signal generator
(vi) A circuit board 6.5 cm \(\times\) 6.5 cm
(vii) A digital multimeter
(viii) A rheostat
(ix) Two new 9 V dry cells
(x) Two 1.5 V dry cells with the holder
(xi) Connecting wires
Procedure:

**Part I:** Gain of inverting amplifier with d.c. voltage input.

(a) Set up the circuit as shown in Figure 24.

![Figure 24](image)

(b) Close switch A and open switch B. Adjust rheostat until digital multimeter reads $V_i = 0.1$ V. Record $V_i$. Open switch A and close switch B. Record digital multimeter reading $V_o$.

(c) Repeat step (b) with $V_i$ increasing in stages until $V_i = 1.2$ V.

(d) Tabulate $V_i$ and $V_o$.

(e) Plot a graph of $V_o$ against $V_i$.

(f) Calculate the voltage gain from the graph.
Part II: Gain and bandwidth of frequency response of inverting amplifier with ac voltage input (sinusoidal)

(a) Remove the rheostat and 3 V cell from terminal PQ and replace it with a signal generator.

(b) Set the digital multimeter knob to alternating current. Adjust the frequency $f$ of the signal generator to 1 kHz.

(c) Open switch B and close switch A. Adjust input voltage $V_i$ of the signal generator so that the digital multimeter reads between 0.100 V and 0.150 V. Record $V_i$ and $f$.

(d) Open switch A and close switch B. Record the output voltage $V_o$ on the digital multimeter.

(e) Repeat steps (b), (c), and (d) by increasing the frequency $f$ of the signal generator in stages until 30 kHz.

(f) Tabulate $f$, $V_i$, $V_o$, and $A = \left( \frac{V_o}{V_i} \right)$.

(g) Plot a graph of $A$ against $f$.

(h) From the graph $A$ against $f$, estimate the gain and bandwidth of frequency response of the inverting amplifier.
Experiment 18

**Topic:** Geometrical Optics

**Purpose:** To study the magnification of real image by a convex lens

**Theory:**

From lens equation \( \frac{1}{u} + \frac{1}{v} = \frac{1}{f} \)

\[ \frac{v}{u} + 1 = \frac{v}{f} \]

\[ m = \frac{v}{f} - 1 \]

where \( m = \frac{v}{u}, \)

\( m = \) linear magnification.

∴ The graph of \( m \) against \( v \) is a straight line.

Equation also shows that \( m \) increases with \( v \).

\( m = 1 \) when \( v = 2f \).

**Apparatus:**

(i) A convex lens
(ii) A short transparent ruler
(iii) A card with a square hole at the centre
(iv) A screen
(v) A bulb as light source
(vi) A metre rule
(vii) Plasticine
Procedure:

(a) Estimate the focal length of the convex lens.

(b) Set up the apparatus as in Figure 25.

(c) Choose a length of 2 cm on the scale of the transparent ruler as object. Therefore, the size of the object $h = 2.0$ cm.

(d) Vary the position of the object. Determine $v$ and the size $H$ of the image on the screen.

(e) Calculate the linear magnification $m$, and plot a graph of $m$ against $v$.

(f) From the graph, determine the focal length $f$ of the lens.
Experiment 19

Topic: Geometrical Optics

Purpose: To determine the refractive index of glass using a concave mirror

Theory:

When an object is placed at the centre O of a concave mirror, a real, inverted image, of the same size as the object is formed at that point as shown in Figure 26 below.

![Figure 26](image)

When one or more glass blocks of thickness $t$ are placed in between the object and the mirror, the position of the object need to be adjusted in order to obtain a real and inverted image of the same size as the object as illustrated in Figure 28.

If $m$ is the number of glass blocks used and $t$ is the average thickness of the glass blocks, then

$$h - h_0 = mt \left(1 - \frac{1}{n_k}\right),$$

where $n_k = \text{refractive index of glass}$. 


Apparatus:

(i) A retort stand and clamp
(ii) A half-metre rule
(iii) Vernier calipers (to be shared)
(iv) A 6 V bulb and the holder with connecting wires of length ≈ 0.5 m
(v) Four 1.5 V dry cells in the holder.
(vi) A concave mirror of focal length \( f = 10.0 \text{ cm} \)
(vii) Six glass blocks
(viii) Two wooden blocks

Procedure:

(a) Measure and record the thickness of the glass blocks.

(b) Place the concave mirror in between the two wooden blocks on the table. Clamp the bulb on the retort stand so that the filament of the bulb is vertically above the centre of the concave mirror as shown in Figure 27 below.

(c) Using non-parallax method, adjust the position of the bulb until the image coincides with the bulb. Measure and record the height \( h \) of the bulb above the table.
(d) Place a glass block on the wooden block as shown in Figure 28 and repeat step (c).

(e) Add the glass blocks one by one and repeat step (c) to obtain the corresponding height $h$.

(f) Tabulate the number of glass blocks $m$ and the corresponding height $h$.

(g) Plot a graph of $h$ against $m$.

(h) From the graph, determine the refractive index $n_k$ of glass.
Experiment 20

Topic: Physical Optics

Purpose: To study the diffraction pattern formed by a diffraction grating and to determine the wavelength of a laser beam.

Theory:

When a narrow parallel beam of light from a monochromatic light source is directed to a diffraction grating, a diffraction pattern consisting of a linear series of bright spots is observed on the screen.

\[ \sin \theta_n = \frac{n \lambda}{d} \]

where \( d \) is the separation of the grating. If \( N = \) number of lines per metre, then \( N = \frac{1}{d} \). Therefore \( \sin \theta_n = Nn \lambda \).

By measuring \( \theta_n \), and \( d \) is given, \( \lambda \) could be determined.
Apparatus:

(i) A laser pointer
(ii) Two retort stands and clamps
(iii) A metre rule
(iv) A screen
(v) Two diffraction gratings

Procedure:

Precautions:
It is important to take note that

(i) the incident ray should be normal to the diffraction grating,
(ii) the screen must be parallel to the plane of the diffraction grating,
(iii) the diffraction grating and screen must be exactly vertical.

(a) Set up the apparatus as shown in Figure 30. The incident ray from the laser pointer should be normal to the diffraction grating. The distance $D$ between the diffraction grating and the screen should be well adjusted to give the bright spots maximum possible separation.

(b) Using the diffraction grating with $(80 - 100)$ lines/mm, determine $l_1, l_2, l_3 \ldots$ for $1^{\text{st}}, 2^{\text{nd}}, 3^{\text{rd}} \ldots$ order interference.
To determine \( l_1, l_2, l_3 \ldots \) you may use a ruler to measure the distance between the respective bright spots on opposite sides of the zeroth order, and this distance should be divided by 2 to obtain the respective values for \( l_1, l_2, l_3 \ldots \)

\((c)\) Measure the distance \( D \) between the diffraction grating and the screen

\((d)\) Thus, determine the value of \( \sin \theta_n \) for \( n = 1, 2, 3, \ldots \), using \( \sin \theta_n = \frac{l}{\sqrt{l^2 + D^2}} \).

\((e)\) Plot a graph of \( \sin \theta \) against \( n \), where \( n = 1, 2, 3, \ldots \)

\((f)\) From the graph, determine the wavelength \( \lambda \) of the laser beam.

\((g)\) Replace the original diffraction grating with another diffraction grating, and repeat procedures \((a)\), \((b)\), \((c)\), and \((d)\).

\((h)\) Using the value of \( \lambda \) from \((f)\), calculate, by finding the average value of \( N \), the number of lines per mm for the second diffraction grating.

\((i)\) Compare the value of \( N \) calculated with the value of \( N \) marked on the second diffraction grating. Give your comments.

\((j)\) The bright spots have certain diameters. How could you ensure that the separation \( l \) between two bright spots are measured accurately?