FIRST YEAR LABORATORY MANUAL

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FIRST YEAR LABORATORY MANUAL

PHY 110 & PHY 111: BASIC PHYSICS 1&II

2015

@Maera John

STUDENT DATA

NAME: ____REG NO: ________________

GROUP NAME: ____

GROUP MEMBERS:

SNO	NAME	REG NO
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EXP NO:	EXPERIMENT TITLE	DATE DONE	MARKS /10	Signature

Student's signature: ____________________________________

Table of Contents

NOTE TO LABORORY SUPERVISOR

This laboratory manual has been designed for first year students taking practical physics course at the proposed to be Maasai Mara University.
The aim of the laboratory sessions cannot simply be to demonstrate what has been learnt in the lectures. Most laboratory classes have neither the time, nor sufficient equipment to do this instead, the emphasis is on laboratory techniques, data analysis and the interpretation of results. This will then provide a solid basis for laboratory work in subsequent years.

AIMS OF THE COURSE

1. How to use *various m*easuring instruments and to estimate their reading errors.
2. How to reduce/eliminate errors.
3. How to calculate errors.
4. How to use various common instruments.
5. Methods of analysis and how to draw and interpret linear and curved graphs.
6. To discuss results and draw intelligent COC1US1OflS.
7. Laboratory techniques and laboratory safety.

Each experiment is designed so that it can be completed within a three hour session, including written work. Students will be expected to fill in during the course of the experiments. The worksheets include blank data tables, spaces for data manipulation and error calculation, questions on the experiments and spaces for discussion and conclusion. All written *work*, including rough graphs, is to be handed in at the end of each practical session. Late work is not acceptable under any circumstances.

Cooperation from the students is required. Students will be told in advance *which* experiment they will be doing. They must read the script before coming to the class. They should be able to plan their own time order to set up the apparatus, do the experiment do the analysis, and discuss it. The format will make marking easier and faster. It is regretted that the students will not get much practice in report writing, but these skills will be taught in the second and later years.
Before students are admitted to the laboratory, it would be helpful to conduct perhaps two tutorial Sessions in the lecture theater:

1. Laboratory conduct, safety, units, significant figures, how to draw graphs, how to interpret graphs - students to do examples in class.

2. Errors - different types, how to estimate reading error how to reduce or eliminate errors, calculation of errors. Again, students to do examples in class.
   First laboratory session every student will do a Common experiment designed to introduce them to various types of common measuring instruments, simple error analysis, etc.
   Subsequent laboratory sessions- a series of experiments designed to introduce the students to laboratory techniques, analysis, different types of equipment, .

INTRODUCTLON TO THE STUDENT

This manual contains all the experimental scripts and worksheets that you will need for the first year practical course in physics. You will also find information on graphical analysis and error analysis which form an important part of the course.

The aim of the course is not simply to demonstrate practically the physics principles learnt in the lectures. It is just not possible to provide the equipment for all of you, for example, to experiment with lenses in the laboratory class after learning about lenses in a lecture. There may be only one or two sets of apparatus, or the experiment may be too difficult or too dangerous to be performed by a student in class.

Instead, the major objective of the course is to enable you to lean laboratory technique and discipline. You will learn how to take measurements and estimate reading errors; how to analyze and interpret data; how to discuss your results and draw intelligent conclusions from them. There will be exposure to different types of equipment, illustrating different laboratory and analytic techniques. And of course you will also be learning some physics!
Remember that "Without Observations and Experiments our natural Philosophy [Physics] could only be a Science of Terms and a unintelligible jargon" (J.T Desaguliers, 1683-1744).

LABORATORY RULES

Students are required to attend all laboratory sessions and to hand completed work at the end of each session. This means that you should plan your time so that all experimental work and all written work is finish within the three hours of the laboratory class. *Work handed* in *late will not be marked.*
Students *who* come to the laboratory late may not be admitted. Students *who* are absent because of illness *must* provide satisfactory evidence if this is be taken into consideration.
Students should come to the laboratory class prepared. You will need:

a pad of graph paper,

Calculator, pen, pencil etc.

You will be told in advance which experiments you will be doing, and this should be read before coming to the class.

For each experiment, fill in the data sheet (s) provided with *the actual observations made during the* experiment. The data sheets must be fill using ink -data sheets and reports written in pencil are not acceptable.
Plot rough graphs during the experiment itself. That way you will be able spot any measurements that may have to be repeated. These rough graphs must be handed in at the end of the class. Do all calculations, including error calculations, and draw any graphs required. Answer any questions posed.
After experiments have been marked and returned, keep this manual safe. It must all be handed in at the end of the year.

Note on completing worksheets

1. Discussion- discuss the sources of error in the experiment and whether they are acceptable. How does your final answer compare with theory or with accepted values***?*** What is the significance of your results? Can you explain any unexpected findings? Are there ways of improving the experiment?
   Writing a satisfactory discussion requires you to think about the experiment in all its aspects. Be brief

2. Conclusion - this is where you sum up and justify your results. The conclusion should always relate to the original objectives of the experiment.

DATA ANALYSIS

Units

Where relevant, units should always be quoted, e.g. in headings of tables, axes of graphs and in the statement of results. All units must be S.I. or derived SI units.

Significant Figures

Since you will be using calculators, the calculation of quantities usually yields more figures in the results than are warranted by the precision of the measurements made. Care should be taken not to include these figures in further calculations or in the statement of results. For example:
g =9.7937126 m/s^2 would not represent the accuracy with which laboratory measurements are made. The correct figure would be g = 9.8 m/s2.

Graphs

Graphs must be drawn on graph paper, and they must have a title. Use crosses or circles to mark points on the graphs. Choose sensible scales, drawing the graph as large as possible, preferably. filling the page..
(i) A graph can disclose information not apparent from looking at a table of observations. For example, in Boyle's law experiment, the intercept on the vertical negative axis gives the atmospheric pressure. One could not deduce this from a table of figures easily.

(ii) You can deduce the relation between two physical quantities, e.g. in Boyle's law experiment, that P and 1/V are linearly related,
(iii***)*** You can interpolate (reading between observed points) or extrapolate (producing the graph beyond the region of. observation). However, care is needed in extrapolating curves as it is difficult to judge. 'how the curve will continue.

(iv) You can deduce important data from discontinuities maxima and minima, or gradients.
In all cases, plot a rough graph *while the experiment is running.* Then it is easy to see if there are any erroneous measurements and to redo them if necessary..

In plotting graphs

Important . use a sharp pencil for plotting graphs, making crosses or circles for marking the points.

The graph should be headed with a brief title, for example, in the experiment about the simple pendulum, the title could read:

period, T^2 versus length L. Horizontal axis - plot the physical quantity which is varied in consciously controlled steps (e.g. pendulum length), Vertical axis - plot the physical quantity which is then measured (e.g. period of the pendulum).

For a linear graph of the form $y = ax + b$, y is the measured variable and is plotted on the vertical axis. x is *the* controlled variable and is plotted on the horizontal axis.

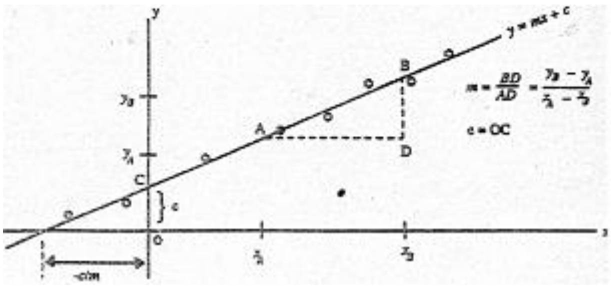
Drawing curved graphs

Consider the experiment on Newton's law of cooling. When plotted, the data points indicate a curve. Draw a smooth curve through the points. It does not matter if some points lie outside the curve. Never join up the dots to give a linked line.

Slopes

Always choose the largest possible triangle from which to calculate the slopes. The larger the values of the sides of the triangle, the smaller the percentage error in them. Remember - the vertical and horizontal values must be measured in the units of the scales of the graph, NOT in cm or 'squares'.

For an equation of the form $y = mx + c$, a straight line graph on an *x-y* Coordinate frame can be drawn, as shown below:



When a straight line graph is used as a source of information, the slope or the intercept or both are usually measured. To measure the slope of a line, select two points, A and B, on the line drawn - *observational points* - which are *well* separated. Record from the graph thevalues of YA and XA(at A),and of YB andX3 (at B).The

the slope is: $$\frac{Y_B - Y_A}{X_B - X_A}$$

N.B: BD and AD represent measurements along the scales of the Y and x axes.
This form of graphical analysis for straight line graphs is not the best way of obtaining information from your data. It is not objective because you cannot be certain that the line you have drawn truly gives the best fit to the data points. In fact learn how to analyze graph objectively using the least squares method.

If the graph is curved, then its slope at any point is the slope of the tangent to that point. To draw the tangent, place *a* plane mirror so that the reflecting surface is perpendicular to the curve (see Fig. 2). Turn the mirror about until the curve and their reflections appear as one Continuous curve, The reflecting surface of the mirror is then normal to the Curve. Rule a line along its base. The tangent will then be at right angles to the line.

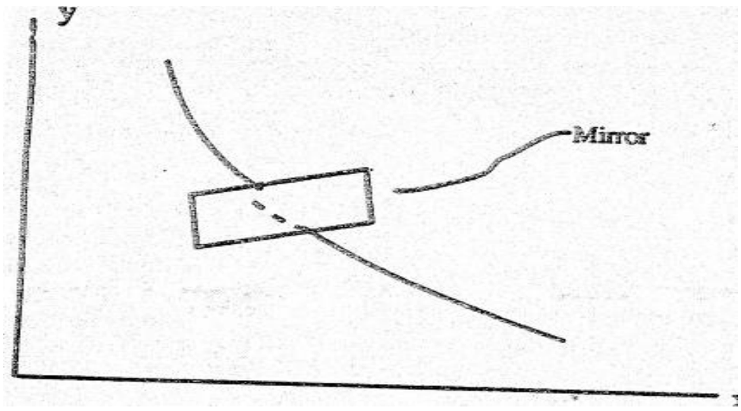


Fig 2.

NB: Graphical analysis is the roost accurate method of obtaining your final result. It is more accurate than doing a calculation for each individual pair of results and then averaging, However, the accuracy of the graph can be destroyed by two easily avoidable mistakes:

(1) Choosing the scales so that the slope is either close to infinity or close to zero. Either way, measurement of the shorter side *of* the triangle will have a large percentage error compared to the measurement of the longer side. The most accurate slope measurement is made from a line inclined approximately 45^0 to the axis.

(ii) Assuming that the origin is the most accurate point on the graph. The origin is frequently not a very reliable point due to, for example, instrument error or inaccurate zero adjustment.

Errors

The term error, when used in physics, has a meaning different from its everyday meaning. In layman's terms an error is a mistake. In physics, an error in an observational reading is a way of indicating the range of uncertainty of the reading. Mistakes of course do occur in physics, so it is important when writing reports to distinguish clearly between the mistake you might make and the error that can occur in a reading. There are a number of different types of error, which are discussed below.

(a) Random errors

If a measurement is repeated a number of times, the values obtained do not always agree. This variation is due to random errors which arise from a number of factors.

(i) Errors of judgment - estimates of a fraction of the smallest division of a scale on an instrument may vary in a series of measurements.
(ii) Fluctuating conditions - important factors in a given experiment, such as temperature, pressure or voltage, may vary during the measurements, affecting the results.
(iii) Small disturbances - for example, small mechanical vibrations, the pick-up of spurious electrical signals.
(iv) Lack of definition in the quantity measured for example, measurements of the thickness of a steel plate having non-uniform surfaces using a micrometer will in general not be reproducible.

(v) Randomness in the quantity measured for example, repeated measurements of the number of disintegrations per second in a radioactive source will give different values because radioactive disintegrations occur randomly in time.

Thus when random errors are present, deviations of measured values from the true value will vary in a series of repeated measurement

(b) Systematic errors

If Systematic errors are present in a measurement the deviations of the measurement values from the true value will be constant in a series of repeated measurement For example, a systematic error will be present in a set of measurements if the measuring instrument is not correctly calibrated or is improperly used, This could be a Stop-watch running fast or slowly, or a micrometer screw gauge with an undetected zero error, This type of error cannot, in general**,** be determined except by checking out the apparatus against other standards**.**

Precision and accuracy

A measurement is said to be accurate if the measured values cluster closely about *the* true value. An experiment with little or no systematic errors as well as small random errors is regarded as *having* high accuracy.

A measurement is said to be precise if the spread of measured values is small, a precise measurement can be very precise but not accurate if the systematic error(s) are large. Precision and accuracy are both *limited* by the sensitivity of the measuring devices. For example, the sensitivity of a meter rule subdivided in *mm* is I mm.

Reading error

In general, the reading error is *plus* or minus the smallest division on the measuring scale. For a meter rule subdivided into mm, the reading error L ± 1 mm. However if the division is large, then one may estimate to the nearest half-division. For example, the thermometer in common use in the laboratory has a scale subdivided into degrees, but as the divisions are large, one can estimate to the nearest half-degree, and the reading error is ± 0.5 degrees.

Progation of errors

In most experiments, the initial readings are used to calculate out some quantity. To calculate the error in this quantity, the reading errors of the individual measurements must be combined. The final error may be quoted in a number of different ways:

(a) As the actual error *dx* of the quantity x. This will have the same units as the quantity itself.

(b) As the fractional error, *dx/x.* This will have no units.

(c) As the percentage error, = **fractional** error x 100%

The combination of the original reading errors **is quite** simple if a number **of** simple rules are followed:

(1) Addition or *subtraction*

$x = a + b + c$; then $dx = da + db + dc$

$x = a - b$ then $dx = da + db$

In both cases the reading errors are added together.

Length L (4.5 ±0.l) cm + (3.6±O1) cm
Error in length is then 0.1+0.1= O.2 crn
Thus ‘we write for the length, *L* = (8.1± O.2) cm

or
Length L= (5.4 ±0 1) - (3 2 ±) cm
The error will again be (0.1 + 0.1) = 0.2cm
Therefore the length will be L = (2.2 ± 0.2) cm
In both cases, the error is added.
(ii) Quotient or product

$$x = ab \text{ or } \frac{a}{b}$$

In both cases divide the reading error by the actual value of that measurement for each value in the equation. Then the fractional error in the final quantity is equal to the sum of the individual fractional errors:

$$\frac{dx}{x} = \frac{da}{a} + \frac{db}{b}$$

The mass per unit length of a wire is given by (5.6±0.1) divided by *(50.0* ± 0.1) cm. The fractional error is given by:

$$\frac{0.1}{5.6} + \frac{0.1}{50} = 0.0178.... + 0.002 = 0.0198$$

The actual error is then obtained by multiplying the fractional error by the result, i.e
11.2 g/m x 0.0198 = 0.2 gm
Note that the error has the same number of decimal places as the actual value.

(iii) Powers

Errors in square or higher powers magnify rapidly $x = a^n \; \frac{dx}{x} = n\frac{da}{a}$ for example, if

T^2 = (1.2 ± 0.2) seccds, then

. error in T^2 is $\frac{2dT}{T}$; $i.e. \frac{2 \times 0.2}{1.2} = 0.33$; $i.e. T = (1.44 \pm 0.33) \sec onds$

(iv) *Error in logarithmic functions*

If $x=e^2$ then $\frac{dx}{x} = dz$; if x = $\log_e Z$ then $dx = dzlz$

Least squares analysis for linear graphs
Calculating the error on a quantity derived from a formula involves applying the error calculation rules correctly. But what do you do if some of the information in that formula has been derived from a graph?
Consider a linear graph of variable x versus variable y. x and y represent measurements you have taken so there will be a reading error associated with each *x* value and each y value.

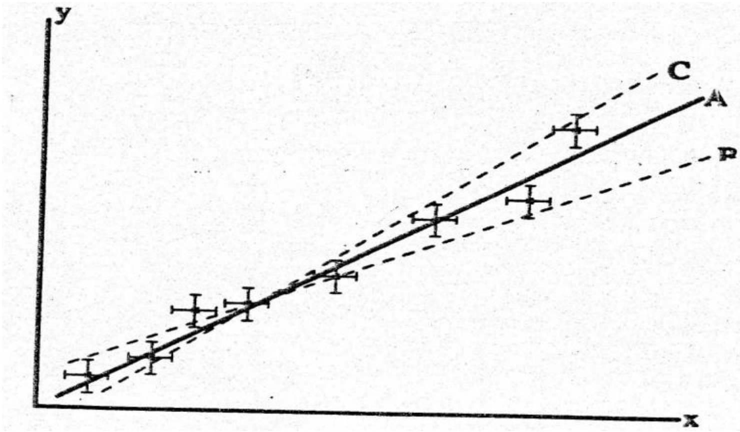


Fig. 3

The points are plotted on the graph represented by the crosses. The reading errors may be marked with error bars, the length of the bar being the size of the error according to your scales. A horizontal bar denotes the reading error in *x, a* vertical bar, that in y. The crosses are positioned in the diagram above such that they seem to form a straight line. However, given the errors on each point, it is difficult to draw the actual graph. If you wish to obtain the value of the slope or intercept, you will see that a big error may be introduced. Where do you draw the line to minimize the error?
Fortunately, there is a *way* of finding the slope and intercept with minimum error. It is called least squares analysis.

The equation of a straight line is: $y = a + bx$

x and y represent the horizontal and vertical axes respectively. *a* is the intercepted on the y axis and *b* is the slope of the line. The slope, *b,* may be calculated according to the formula:

$$b = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sum x^2 - \frac{(\sum x)^2}{n}} \; ;$$ where *n* is the total number of points.

[If you *wish* to know where the formula came from, consult any text book on experimental errors.]

The intercept is then: $a = \bar{y} - b\bar{x}$

The bars over x and y denote the averages of all the x values and all the y values.
If you have a scientific calculator, you should be able to calculate the sum and averages easily. You can then use the calculated values of a and *b* to draw the line on the graph if you wish.
Note that the slope and intercept thus calculated, plus the resulting line on the graph, are objective solutions in graphical analysis. A line drawn by estimating it by eye is *not* objective. Also, note that you will not be tempted to draw the line through the origin if you think it is meant to go there. Why should the origin be the most accurate place on the graph if you haven't even made a measurement at that point?
Calculating the line will force you to find reasons as to why the graph does not behave as you expect (e.g does not go through the origin) instead of fudging the results to obtain what you want.
Example *of an experiment*
In the Ohm's law experiment, the value of an unknown resistance may be found by measuring different values of the current flowing through the resistor as the voltage across it is changed.

V, volts	I x 10^{-3}, amps				
0.5	1.1				
1.0	1.9				
1.5	3.2				
2.0	3.9				
2.5	4.9				
3.0	6.2				
3.5	6.7				
4.0	8.1				
4.5	9.3				
5.0	10.0				

Calculate the slope and the intercept from these values letting *V* form the y Coordinates and I form the x coordinates. You should find that the slope, *b,* is 494.4, i.e the resistance is 494.4 Ohms, The intercept, *a,* turns out to be a value other than zero, i.e 0.13. Find a reason for this,

We can find the error in the slope and intercept by calculating the standard errors in the slope and intercept using the appropriate formulae,

Let S_y be the standard error in y

S_a be the standard error in the intercept, a

S_b be the standard error in the slope, *b*

$$Then: S_y = \left[\frac{\sum y^2 - a\sum y - c\sum xy}{n-2}\right]^{1/2}, S_a = S_y\left[\frac{\sum x^2}{n\left[\sum x^2 - (\sum x)^2/n\right]}\right]^{1/2}, S_b = S_y\left[\frac{1}{\left[\sum x^2 - (\sum x)^2/n\right]^{1/2}}\right]$$

Calculate the standard errors in the slope and intercept using the Ohm's law data.

Note: (important) - the standard errors you have calculated arise, from the statistical analysis; they do not include the reading errors. Strictly speaking for accuracy, these errors should be included, i.e weighted measurement should be used. However, since the number of readings in your experiment is usually small (10 readings 'or less), the standard error will partly) compensate for the neglect of reading errors. In any case, the use of weighted measurements complicates and lengthens the analysis to an extend unnecessary at this juncture.

If the slope and/or intercept is subsequently used in a formula to calculate some value, then the standard errors are used in the error calculations in the same way as you would use a reading error.

Note that this procedure is only useful for linear graphs. It cannot be applied to curved graphs such as the cooling curve drawn in the Newton's Law *of* cooling experiment.

Reference: A more detailed discussion of least squares analysis using a scientific calculator is given in "Introduction to First Year Experiments Physics at Kenyatta University by Father P. 'Gouin, July 1983.

RESISTOR COLOUR CODE

Colour	1st digit multiplier	2nd digit	
Silver			10^{-2}
Gold			10^{-1}
Black		0	10^{0}
Brown	1	1	10^{1}

Red	2	2	10^2
Orange	3	3	10^3
Yellow	4	4	10^4
Green	5	5	10^5
Blue	6	6	10^6
Violet	7	7	10^7
Grey	8	8	10^8
White	9	9	10^9

***Tolerance* :** Gold ±*5% ;* Silver ±10% ; No band ±20%. ; Salmon ± 20%

Examples

Ist Colour	***2nd Colour***	***3rd Colour***	***4th Colour***	***R***
brown	Violet	Red	Gold	$17 \times 10^2 \pm 5\%$
gray	Black	Orange	Silver	$80 \times 10^3 \pm 10\%$
yellow	Green	Brown		$45 \times 10 \pm 20\%$

Introductory Experiment: PRECISION MEASUREMENTS

Objectives
To study some of the instruments and methods used in precision measurements, and to compute the volume and density of various items.

Apparatus
Metre rule, vernier calipers, micrometer screw gauge, electronic balance and travelling microscope. Such items as a copper cylinder, steel ball and glass capillary tube are also supplied.

Method
The experiment comprises the measurement of the various objects supplied with the appropriate instruments. Where feasible, at least two instruments should be used for each measurement and the precision obtained in each case compared. In this way, the volume and density of at least two metal object should be deduced and the capacity of the capillary tube determined. All weighing should be done on the electronic balance.
in the second part of the experiment, some electrical circuits have been set up for you to measure the current. Measure the current using an ammeter, milliammeter and a microammeter,and estimate the reading errors in each case.
N.B. In all cases an estimate of the precision obtained should be given, i.e note the reading errors on all measurements. Where appropriate, note the zero error.
Record the data in Worksheet 1, working out any calculations asked for Answer the questions posed on the sheet.

Worksheet 1
N.B You must include in the table the units of any measurements you take

Items	*Measurement*			
	Mete rule	Vernier calipers	Micrometer screw gauge	Balance
Zero error				
Reading error				
Copper cylinder: Height			.	.
:Diarneter		.		
Steel ball				
Copper wire:				
Diarneter				
Capillary tube: Length				

Internal diameter **of** capillary tube using travelling microscope =

	Volume	*Density*
Copper cylinder		
Steel bail		
Capillary tube	(internal volume)	

Errors

Now work out the errors in volume and densities calculated above by using the reading errors of the appropriate instruments. Refer to the section on errors in this manual for instructions on how to calculate errors.

	Volume	*Density*
Copper cylinder		
Steel bail		
Capillary tube		(internal volume)

Measurement of current

Instrument	Measurement	Error	Unit
Ammeter			
Milliammeter			
Microammeter			

Questions

1. Why is it appropriate to use the metre rule for measuring the length of the copper we but the micrometer screw gauge for the diameter?

2. What is the difference between accuracy and precision?

Conclusion

The volume of the copper cylinder *was* found to be ______ +__________ (units), and its density was found to be _______+ _________ _______(units).

Write similar conclusions for the steel ball and capillary tube, and give the correct values for the densities of copper and steel. The values may be found in the reference book *Tables of Physical and Chemical Constants 15th* Edition, G.W.C. Kaye and Labye (Longman *1986).*

PARTA: MECHANICS

Experiment I: PARALLELOGRAM AND TRIANGLE OF FORCE THEOREMS

Objective
To verify the Parallelogram and Triangle Theorems.

Apparatus
Force board (A), pulleys *(B),* sheet of paper (C), string (D), selection of weights (W).

T_1 and T_2 represent tensions in the string.

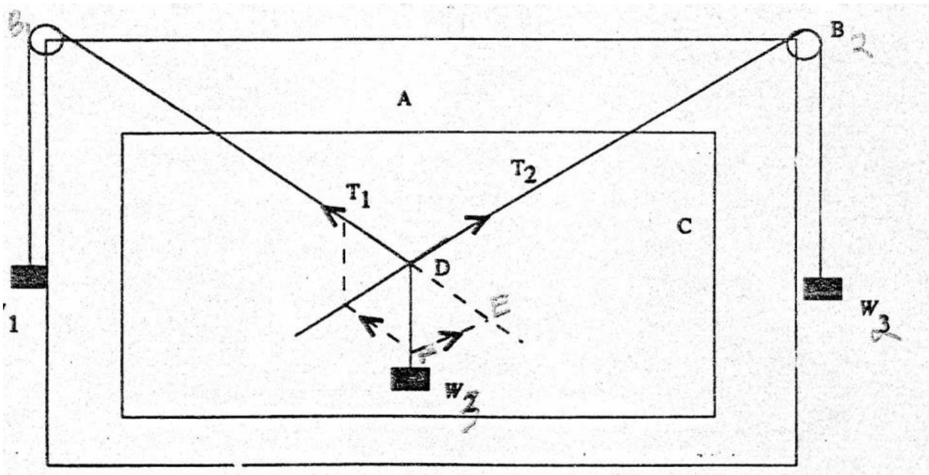


Fig. 4

Theory
Parallelogram Theorem. If two concurrent coplanar forces are represented in magnitude and direction by the sides of a parallelogram, drawn from one angular point, then their resultant is represented in magnitude and direction by the diagonal of the parallelogram drawn from the same point.
Triangle Theorem. If three concurrent coplanar forces are in equilibrium then their magnitudes and directions may be represented by the sides of a triangle.

Method

1. Set up the apparatus as shown in Fig. *4.*

2. Adjust the three weights, W_1 , W_2 and W_3 to produce equilibrium. Arrange such that B, D DW, and BD,are fairly central on the sheet of paper.

3. Transfer the directions of T_1 , T_2 and W_2 carefully to the sheet of paper and note the values of W_1 ,W_2 and W_3.
4 Remove the sheet of paper from the force board.
5 Using a suitable scale, mark lengths along DB_1 and DW_3 to represent the forces T_1 (i.e. W_1) and W_3 respectively.
Parallelogram Theorem. Complete the parallelogram and draw the diagonal from the point D. This diagonal should be collinear with DB_2 (the direction ofT_1), act in the opposite direction and

be equal in magnitude to T_2 sinceT_2 is the equilibrant of T_1 and W_3. This verifies the parallelogram theorem.

Triangle Theorem. Produce BD towards E Using a suitable scale mark off lengths along DE and DF to represent the forceT_1 (i.e. *W_1)* and W_3
Join the ends of these lengths with FE The line FE should bepara1lel to DB_2 , and have a length which represents T2 (i.e. W_2 according to the scale used. This verifies the triangle theorem.
Complete the data table given below and answer the questions that follow.

Worksheet 2

Units	*Mass (Kg)*	*Mass (N)*
W_1		
W_2		
W_3		

Questions

1. How do you convert kilograrns to newtons?
2. Comment on your drawings and state whether or not you have verified the theorems.
3. What are the sources of error in this experiment?

Conclusion

Experiment 2: THE SIMPLE PENDULUM

Objective
To determine acceleration due to gravity using a simple pendulum.

Apparatus
Pendulum bob, thread, clarnp and stand, stopwatch.

Theory
The time period, T, of a simple pendulum oscillating with amplitudes
(less than 10°) is given by the expression: $T = 2\pi\sqrt{\frac{L}{g}}$

where L= length of pendulum thread and ***g*** = acceleration due to gravity.

Method
1. Set the pendulum d 50 cm and set the pendulum swinging with small oscillations.
2. Time 50 oscillations

3. Repeat for a number of different pendulum between 50 and 100cm.
4. Note the reading errors in time and length.
5. Draw a graph and deduce the acceleration due to gravity from the graph. Indicate error bar on the
graph. Estimate the error in *g*.
6. Answer the questions in the worksheet.

Worksheet 3

Length	Time	? (You decide)

Units: Length: Time:

Reading error: Length: Time:

(i) Plot a suitable graph.

(ii) Indicate the error bars.

(iii) From the graph, deduce the value of g.

(iv) Estimate the error in g.

Questions
1. Why are *50* oscillations timed instead of only one?

2. Why must the size of amplitude be small?

3. Compare the value of g obtained with the standard value for Narok.

Conclusion

Experiment 3: PRINCIPLES OF EQUILIBRIUM

Objective
To verify the principles of equilibrium using a simply supported beam.

Apparatus
A beam resting on *two* supports attached to weighing scales R_1 and R_2. The scales can be adjusted to zero before loading. Loads can be placed at selected positions on the beam. A metre rule stick is used *for* position measurements since the scale is graduated in centirnetres.

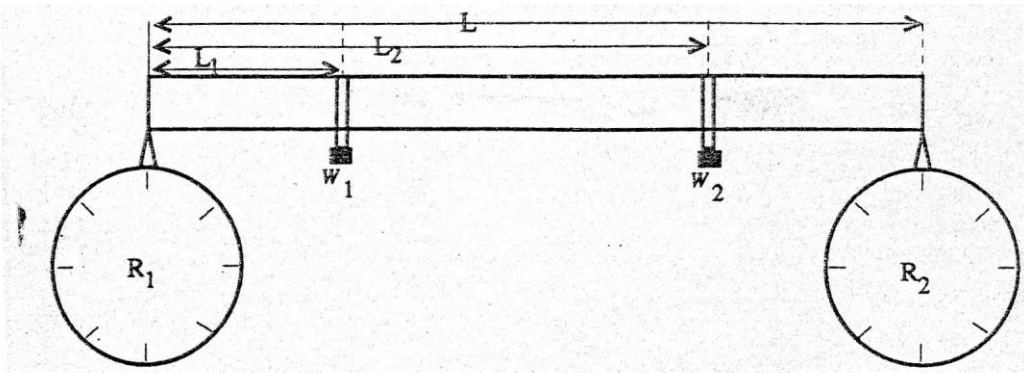


Fig. ***5***

Theory
For equilibrium:
(i) The sum of the forces on the beam must be zero.
(ii) The sum of the moments on the beam must be zero.

Method
1. Place loads W_1 and W_2 or more on the beam and note the readings on the scales R1 and R2. Note the lengths L- L_1 and L-L_2.
2. Complete the work sheet and answer the questions that follow.

Analysis
1. R_1+R_2 should equal W_I + W_2
2. Taking moments about the left hand support;

R_1 x L=[W_1xL_1]+[W_2 xL_2]

Therefore $R_1 = \frac{W_1L_1 + W_2L_2}{L}$

Check that the calculated value = scale reading for R_1
Similarly take moments about the right hand support to find R_2 using L-L_2, and L - L_2 as the distances of the loads from the support. (NB: Check all units carefully.)
Total length of beam (between supports), L =

Worksheet 4

	First try		Second try	
	Value	Units	Value	Units
W				
W				
L				
L				
R				
R				

	First try	Second try
$R_1 + R_2$		
$W_1 + W_2$		

R_1 scale:
R_2 calculation:

R_2 scale:

R_3 calculation:

Questions
1. State the reading errors in:
(i) mass =
(ii) length=
(iii) scale reading of R=

What is the error in $R_1 + R_2$?
What is the error in W_1+W_2?
What other sources of error are there in this experiment?

2. What would you expect if one of the loads *was* directly over the support?

3. What would happen if W acted upwards?

Conclusion

Make a statement as to whether or not the principles of equilibrium were verified in your experiment.

Experiment 4: DETERMINATION OF 'g' BY FREE FALL

Objective
To determine the value of the acceleration of a falling body.

Apparatus
A steel ball suspended from *a* solenoid magnet powered via a clack timer.
(When the *sweep* hand of the clock passes zero the solenoid is de-energised 2nd the ball starts top)
A gate switch connected to the timer is positioned some distance below.
(When the ball strikes the flap, the circuit is broken and the timer stops.)

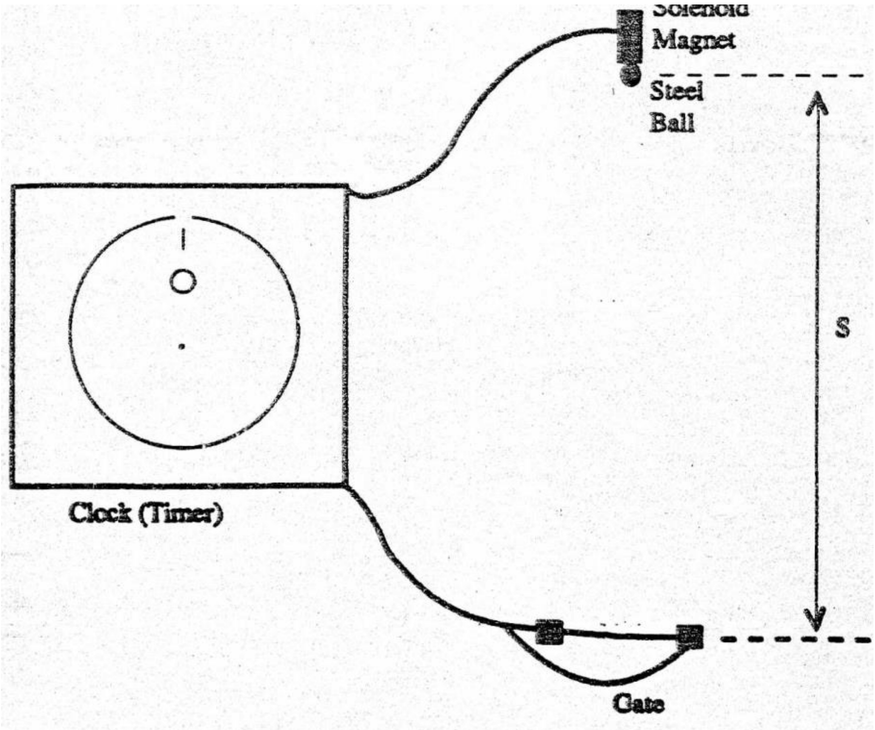


Fig. 6

Theory
The distance traavelled by the fall is measured and the time elapsed noted.
Then:

$$S = \frac{1}{2} g t^2 \ \ and \ \ g = \frac{2S}{t^2}$$

Method

1. Adjust the plug at the open end of the gate switch so that the hinged steel plate is just held in the closed position by the small inset permanent magnet. Place the steel ball in the lower end of the core of the e1ecomagnet and then adjust the core position by means of the threaded ring at its upper end so that the ball is just held by the magnetized core. This is to ensure the prompt release of the ball when the clock is switched on.

2. Now adjust the positions of the electromagnet and gate switch so that when the ball is released, it falls on the steel plate near its free end and opens the gate.

3. Set the clock in the timer to zero, Then switch it on. At that instant the steel ball will be released.

4. When the ball strikes open the gate, the circuit will be broken, thus switching off the clock. The clock thus records the time of fall of the ball.

5. Measure and record the distances as marked in the diagram.

6. Repeat the measurement over a range of distance, *s*, until 10 sets of readings have been recorded.

Analysis

Plot a graph of *s* against *t2*. A straight line graph, through the origin, confirms that g is a constant acceleration over the range of distances used. g may be found from the slope, where: Slope = g/2

Worksheet 5

Distance, s	Time of fall, t	Errors in t	t^2	Error in t^2	Unit

Questions

1. In the graph of *s* against t^2 include error bars for t^2.

2. Slope of graph + error in slope =

3. Acceleration due to gravity, g + error = unit of g =

Conclusion

Experiment 5: VARIABLE INERTIA BAR

Objectives
(i) To show that the angular acceleration of a rotating system is proportional to the applied torque.
(ii) To show that the moment of inertia of the system varies with square of the distance of the rotating mass from the centre of rotation.

Apparatus
A light bar with sliding masses *M* rotating about a central spindle. A cord wrapped around the spindle and a weight suspended from the free end.

(When the assembly is released, the weight descends a distance *h* metres giving the inertia bar an angular acceleration, α and per second. A stopwatch is used to time the descent)

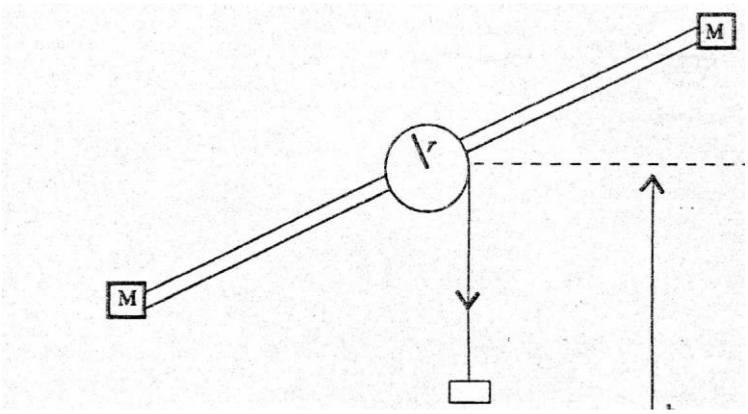


Fig. 7

Theory I

$T = I \times \alpha$ (to be demonstrated)

Where T = applied torque
I = moment of inertia
α = angular acceleration

Now, $Wr = T$ and $a = \dfrac{2h}{t}$

where W = mass at end of suing
r = radius of spindle
a = acceleration of mass W
h = height descended
t = time of descent

Also $\alpha = a/r$

$$then\; Wr = I \times \frac{2h}{t^2 r}; \qquad W = \frac{2hI}{t^2 r^2} = \qquad W = \frac{K}{t^2} \quad where\;\; K = \frac{2hl}{r^2}$$

Method I

1. Cut a length of cord just sufficient to allow the falling mass to reach the floor. Knot one end and thread the cord through the small hole in the spindle. Attach the free end to the weight carrier.
2. Rotate the spindle thus winding on the cord, ensuring that the adjacent turns are evenly arranged. Use a metre stick to check when the bottom of the carrier is exactly one metre from the floor.
3, Release the inertia bar and start the stopwatch simultaneously. Stop the watch when the weight strikes the floor, Note the time t and return the weight to its former height by winding *in the same direction as before.*
4. Repeat the process with five or six different weights.
5. Plot a graph of W against $1/t^2$

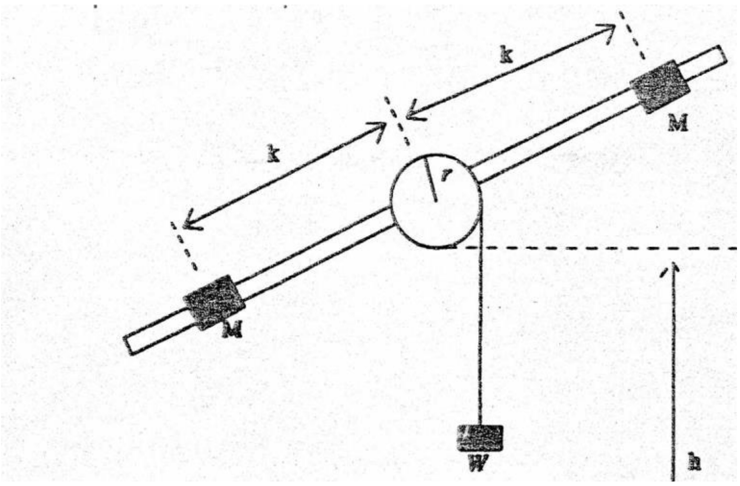


Fig8: Variable inertia

Data table (i)

Worksheet 6

Theory II
$I = Mk$ (to be demonstrated) where M is the mass on the bar
Now $T = I\alpha$; a $(2h, t^2)$; $\alpha = a/r$ *and* $Wr = T$

From these we have $\frac{2h}{t^2 r} = \frac{Wr}{Mk}$ *where h, r, W,* and *M* are constants; therefore $1/t^2$ is proportional to 1/k.

Method II
(In general the same as for Method I)

1. Using a fixed weight but varying the position of the masses, *M*, from the centre, obtain a set of values of time of fall, t, for each value of k, the distance of the mass, *M*, from the centre.

2. Plot a graph of t^2 against k.

Data table (i)

Weight, W	**Time, t**	**$1/t^2$**

Plot a graph of *W* against $1/t^2$ inc1uding error bars on $1/t^2$

Time, t	t^2	Distance, k

Plot a graph of t^2 against k including error bars on t^2.

Comment on your two graphs and state whether or not the objectives of the experiments have been achieved.

Reading error in t^2 =

Reading error in k =

Assume no error in W. What other errors are found in this experiment?

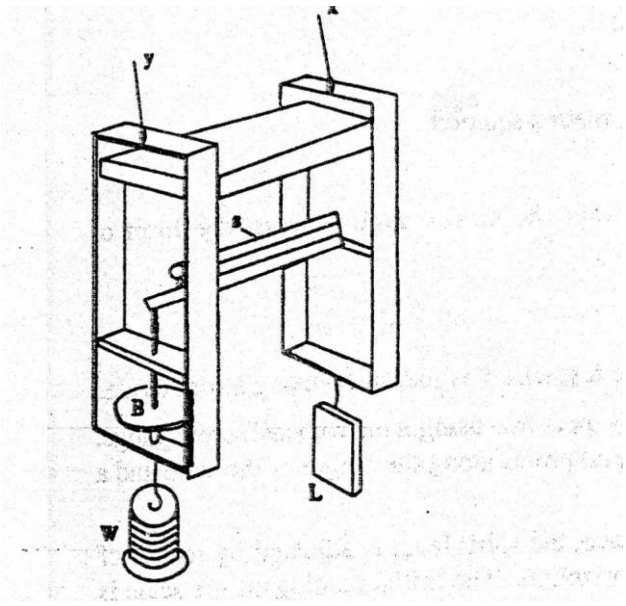
Conclusion

B. PROPERTIES OF MATTER

Experiment 6: YOUNG'S MODULUS OF ELASTICITY

Objective
To determine Young's Modulus (E) for a wire.

Apparatus
Two long wires of *the* material X and Y suspended side by side from the same support. The ends of the two wires are attached to two frames connected by a spirit level S, one end of which rests on a screw *C* operated by a graduated wheel *B.* The movement of B can be measured on a fixed scale graduated in mm. The heavy weight *W* and the inia1 loading *L* ensures that the wires are taut and free from kinks. The overall arrangement (due to C.F.Searle), avoids any errors due to temperature changes or yielding of the support.



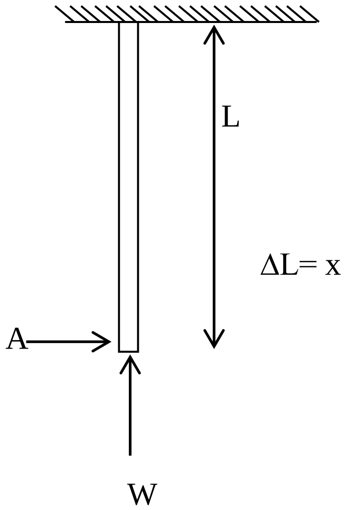


Fig.9(a) Fig 9(b)

Theory

$$\text{Young's modulus, E} = \frac{\text{elongatory stress}}{\text{elongatory strain}} = E = \frac{Mg.x}{\frac{1}{4}d^2} N^2 \quad = \frac{4gLM}{d^2 x}$$

Where M = mass hanging on wire
g = acceleration due to gravity
d = diameter of wire
w = weight (in newtons)
L = length, metres
A = cross sectional area, metres squared.
x = extension, metres

This equation applies only within the elastic region upto the limit of proportionality.

Method

1. The original length of the test wire Y is measured using a metre rule
2. The diameter of the wire is measured using a micrometer screw gauge. Readings are taken at several points along the length of the wire and a mean value calculated.
3. With the initial load in place, the spirit level is adjusted by means of the wheel so that it is horizontal. The initial reading on the scale is noted.
4. The extending load is added to the pan in steps up to a maximum total load of 3.5kg. After each step the spirit level is adjusted so that it is horizontal and the reading on the scale is noted.
5. The load is then removed step by step, and a note is made of the scale readings at each step as before.

Analysis

A graph of extending load (in newtons) versus extension (in metres) should *d2* x be a straight line through the origin. The slope of the graph is *w/x.*
Calculate the slope of the graph and the cross sectional area of the wire.
Determine the value of Young's modulus and the error in your value.

Errors

Original length of the wire L = ±m

Diameter of the wire = , , ±m
Mean diameter = ±m
Initial reading of scale A = ±

Worksheet 7

Extending Load	W (N)	Scale readings			Extension
W kg		Loading	Unloading	Mean	x m

Plot the graph of extending Load versus extension.

Slope of graph = *W/x* =
Cross-sectional area of wire = m^2
Therefore value of Young's Modulus = Nm^2

Error in calculation (i.e. error in E = (% error in L) + 2(% error in d) + (% error in slope)

Comment on your answer value and the error.

Questions

1. Why is it acceptable to use a metre rule to measure *L*, while a micrometer screw is used to measure d?

2. What is the yield strength?

3. Compare the calculated value of E with the accepted value for the material of the wire.

Conclusion

Experiment 7: VISCOSITY

Objective

To measure the coefficient of *viscosity* of water.

Apparatus

Aspirator, length of capillary tubing, stop watch, thermometer, beaker

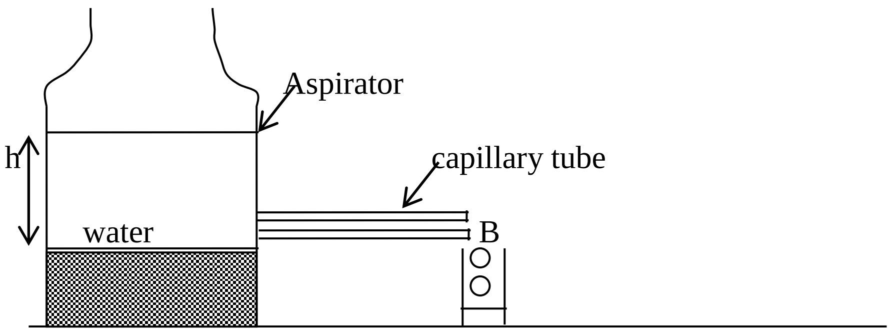


Fig. 10

Theory

When a fluid is forced through a tube of small bore, the flow is controlled entirely by viscosity.

Poiseiulle showed that the flow is given by the formula: $Q = \frac{\Delta P r^4 \pi}{8\eta L}$

Where η = coefficient of viscosity,

Q = volume of water flowing per second through the tube of length L and radius *r*. The flow is maintained by a pressure difference ΔP between the ends of the tube, where

$\Delta P = g\rho h$

g = acceleration due to gravity

ρ = density of the fluid.

h = height in metres as shown in fig. 10

Method

1. The apparatus is set up as shown in Fig. 10.

2. Adjust the rate of flow through the capillary tube so that water emerges slowly in drops from B. Smear a little vaseline under end B to prevent water running along the outside of the tube.

3. Weigh a clean dry beaker and record its mass.

4. Time the collection of about *50* ml of water and reweigh the beaker plus water.

5. Repeat the water collection several times, and note the room temperature at intervals.

6. Measure the length of the capillary tube. Measure the diameter of the capillary tube using the travelling microscope. Remember to level the microscope before use.

7. Fill the data into the tables provided and calculate the coefficient of viscosity of water.

Worksheet 8
Length of capillary tube, L = m

Travelling microscope measurements: ‘(To find internal radius of capillary tube).

First scale reading (m)	Second scale reading (m)	Difference (m)

Average diameter = m; Radius = m; Error in scale of microscope = m;

Error in radius = m; Density of liquid (water) = kg/m^3; Height, h = m

Mass of beaker = kg

Mass of beaker plus	Mass of water (Kg)	Time (s)	Volume flow per

From the data given above calculate the coefficient of viscosity for each volume of water timed.

The average coefficient of viscosity was found to be:
The unit of viscosity is: -
Now calculate the error in your value of viscosity using one set of data: -

What is the accepted value for the coefficient of viscosity?

Is your value within experimental error of this accepted value?

How does the coefficient of viscosity vary with temperature? Why

Conclusion

PART C: HEAT

Experiment 8: LINEAR EXPANSION

Objective

To measure the coefficient of linear expansion of copper.

Apparatus (see Fig. 11 below)

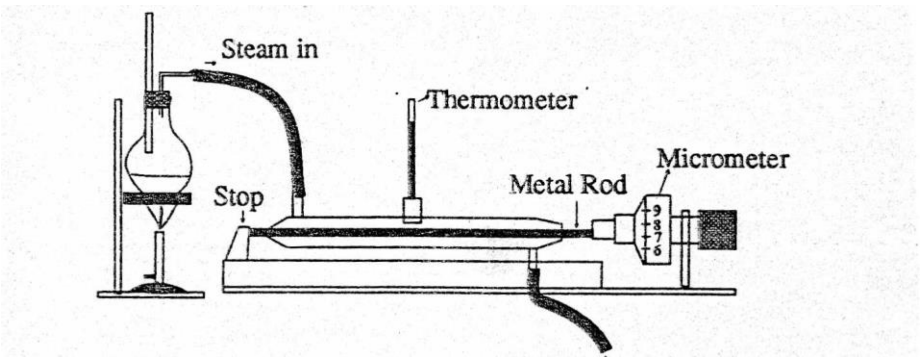


Fig. 11

Theory

If a solid bar of metal is heated, its length L at temperature T_1 °C and its length L_2 at temperature T_2 °C are connected by the relation: $L_2 = L_1 [1 + \alpha (T_2 - T_2)]$

where α is the *average* coefficient of linear expansion of the metal over the temperature range. Making α the subject of the formula:

$$\alpha = \frac{L_2 - L_1}{L_1(T_2 - T_1)}, \quad i.e.\ \alpha = \frac{\exp ansion of\ bar}{L_1(T_2 - T_1)}$$

Method

1. Remove the bar of metal from the steam jacket and measure its length L_1, and temperature T_1.

2. Replace the bar in its steam jacket and adjust the micrometer until j just tips the end of the bar. Record the micrometer reading.

3. Reset the micrometer back from the end of the bar to allow room for expansion of the bar.

4. Heat the water in the flask and allow steam to flow around the bar until the expansion is complete. This will take 10 to 15 minutes.

5. With steam still passing through the jacket record the new reading on the micrometer and the temperature of the steam.

Analysis
Calculate the coefficient of linear expansion of the copper and the error in this value.

Answer the questions in Worksheet 9 below.

***Worksheet* 9**

	Readings			Error	Unit
Initial length of bar, L_1					
Initial temperature of bar, T_1					
Final temperature of bar, T_2					
Initial micrometer setting, E_2					
Final micrometer setting, E_2					

Analysis
AverageE_1 =

Average E_2 =
Expansion of bar = E_2 - E_1 = (don't forget units)

Error in expansion of bar =
Temperature difference = T_2 - T_1 =
Error in temperature difference =

Substitute these values in the equation . $\alpha = \frac{Expansion}{L_1(T_2 - T_1)}$

Now calculate the error in α: $\frac{\Delta\alpha}{\alpha} = \frac{\Delta Expansion}{Expansion} + \frac{\Delta(L)}{L_1} + \frac{\Delta(T_2 - T_1)}{(T_2 - T_1)}$

This gives the fractional error. Multiply through by 100 to find the percentage error.

Questions

1. What would happen if the micrometer screw gauge was not reset back from the end of the bar?

3. Why is it necessary to measure the expansion with a micrometer screw gauge, whereas the initial length of the bar can be measured with a meter rule?

Conclusion

Experiment 9: SPECIFIC HEAT BY THE METHOD OF MIXTURES

Objective

To determine the specific heat of zinc by the method of mixture

Apparatus

Beaker, Water, Gauze, Bunsen burner, Thermometer, Cotton .

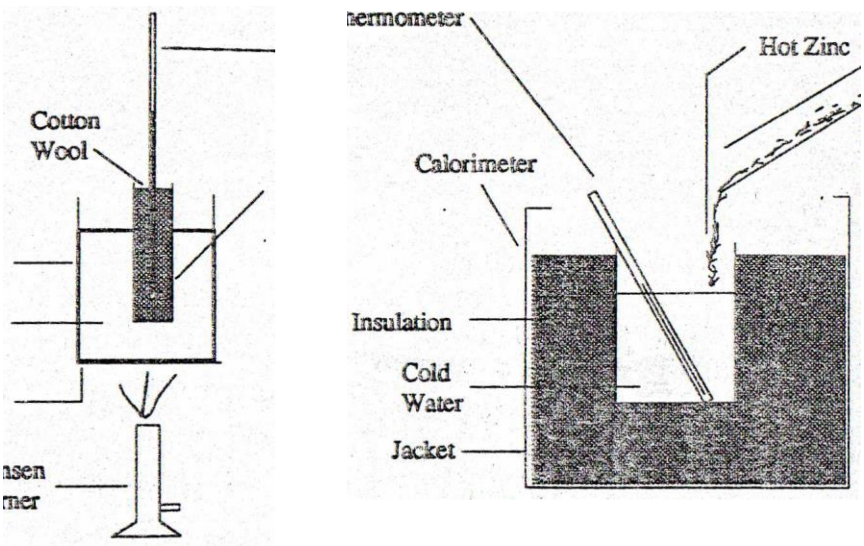


Fig. 12

Theory

If hot zinc is added to cold water in a calorimeter which is insulated, then:

Heat gained by water + calorimeter = Heat lost by zinc

$$(M_w\ C_w + M_c\ C_c)\ (T_2 - T_1) = M_{zn}\ \ C_{zn}\ (T_3\text{-}T_2)$$

Where M_w = mass of water
C_w= specific heat of water
M_w= mass of calorimeter
C_c = specific heat of calorimeter
T_2 = final temperature of mixture
T_1 = initial temperature of water and calorimeter
M_{zn} = mass of zinc
C_{zn} = specific heat of zinc
T_3 = temperature of hot zinc

Method

1. Put the thermometer into the boiling tube and put as much zinc as possible around the thermometer. Place some cotton wool on top.

2. Place the boiling tube in a beaker of water and heat to boiling. Keep the water boiling for at least *five* minutes.

3. Meanwhile, weigh the calorimeter empty and then add about 113 full of water.

4. Replace the calorimeter in its jacket. Record the temperature of the water.

5. Record the temperature of the hot zinc.

6. Remove the cotton wool and thermometer from the boiling tube, and immediately pour the zinc into the calorimeter.

7. Stir the contents of the calorimeter

8. Record the highest temperature reached, and then remove the thermometer.

9. Weigh the calorimeter and its contents.

10. Record the data on Worksheet 10 and evaluate the specific heat of the zinc.

Worksheet 10

	Reading	*Error in reading*	*units*
Mass of calorimeter M_o			
Mass of calorimeter + cold water M_1			
Temperature of cold water T_1			
Temperature of hot zinc T_2			
Temperature of mixture T_3			
Mass of calorimeter, water + zinc M_2			

Analysis

	Value	*Error in value*	*Unit*
Mass of cold water $M_w=M_1-M_c$			
Mass of zinc $M_{zn}=M_2-M_1$			
Increase in temperature of water +			
Decrease in temperature of			

Specific heat capacity of water = 4186 J/g deg C

Specific heat capacity of copper = 380 J/kg deg C

From these values, substitute into the equation *given* above and calculate a value for the specific heat of zinc.

Calculate a value for the error in the specific heat of zinc

Questions

1. What are the sources of error in this experiment?

2. Why is water the medium used in so many heat exchange processes?

3. Compare and contrast the specific heat for zinc obtained in this experiment with the standard value.

Conclusion

Experiment 10: THERMAL CONDUCTIVITY - SEARLE'S BAR

Objective

To measure the thermal conductivity coefficient of copper using Searle's apparatus.

Apparatus

AB is a solid copper bar which is heated at end A by steam. At end B, a coil carrying water is wrapped around the bar. Thermometers T_1, T_2, T_3 andT_4
are inserted as shown. The apparatus is well lagged and is enclosed in a wooden box.

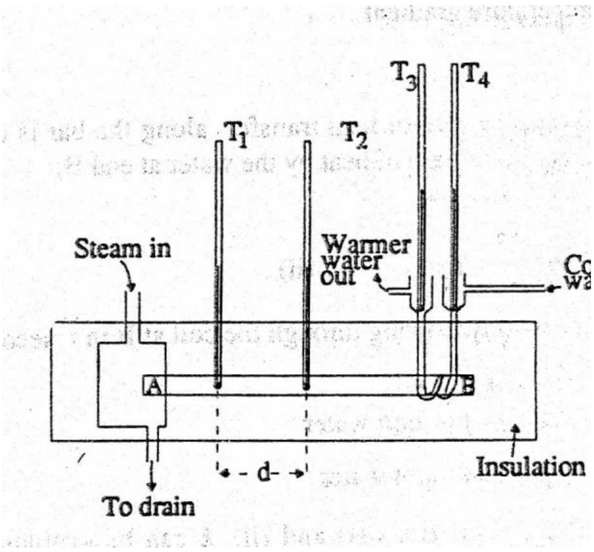


Fig. 13

Theory

The rate of flow of heat by conduction along the copper bar is given by:

$$\frac{Q}{t} = k.A.\frac{(T_1 - T_2)}{d} \text{..........................} (i)$$

where k=coefficient to thermal conductivity and *A* = cross sectional area of bar

$\frac{T_1 - T_2}{d}$ = temperature. Gradient

If it is assumed *that* rate of heat transfer along the bar is constant, this rate is equal to the rate of gain of heat by the water at end B;

where m = mass of water flowing through they coil at B in t seconds

C = specific heat of water

T_3 = temperature of output water

T_4=temperature of input water

Combining Q/t from equations (i) and (ii), k can be evaluated from the equation:

$$\frac{Q}{t} = k.A.\frac{(T_1 - T_2)}{d} = \frac{m}{t}C.(T_3 - T_4) \text{..} (iii)$$

Method

1. Take several readings of the diameter of the copper bar using the vernier calipers provided. Record all readings and get their average.

2. Measure and record the distance *d* between the thermometers T_1 and T_2.

3. Close up the wooden box and heat the water in the steam generator.

4. Adjust the constant head device to give a small rate of flow of water through the coil at the end B. Loosen thermometers T_3 and T_4

momentarily to eliminate air pockets in the water jacket, then insert the stoppers securely so that there are no leaks.

5. While the steam is circulating around end A, record temperatures T_1, T_2, T_3 and T_4 every five minutes. The purpose of these readings is to enable you to ascertain easily when the steady state has been reached, i.e. that none of the temperatures is changing with time.

6. When this state has been reached, the temperature difference between thermometers T_3 and T_4 should be about 10°C. Adjust the water
flow if necessary.

7. Then record the mass of water collected from exit B in a beaker during a time of five minutes. If marked fluctuations appear in any of the temperatures during water collection, repeat this reading and take an average.

8. Record all data in Worksheet 11. Calculate the value for k and estimate its error.

Worksheet 11

			reading		*error*	*unit*
Bar diameter, D				*(average)*		
Cross sectional area of bar A						
Distance between thermometers T_1 and T_2						
Mass of water collected in 15 mins						
Average mass per second(m/t)						

Time, min	T_1	T_2	T_3	T_4	*Unit of temp*

Identify the steady state readings

Error in reading temperature= (don't forget units)

Specific heat of water=4200J/kg deg C

Substitute values into the equation:

$$\frac{Q}{t} = k.A.\frac{(T_1 - T_2)}{d} = \frac{m}{t}C.(T_3 - T_4)$$

Therefore, error-in (T_1 - T_2) =

Error in (T_3 - T_4) =

Calculate a value for *k.*

Calculate the error in your value of *k.* State the error arising from errors in measurement of temperatures.

The thermal conductivity of copper

Questions

1. Explain why this method is not a good one for poor thermal conductors.

2. Do you think that the accuracy of the experiment would be improved if a bar of a larger diameter was used?

3. By what percentage does your value of *k* deviate from the standard value of *k* for copper?

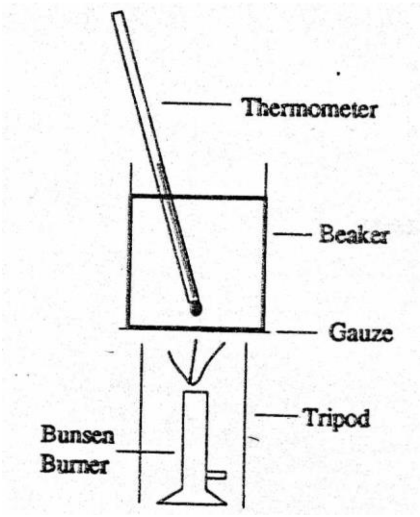
Conclusion

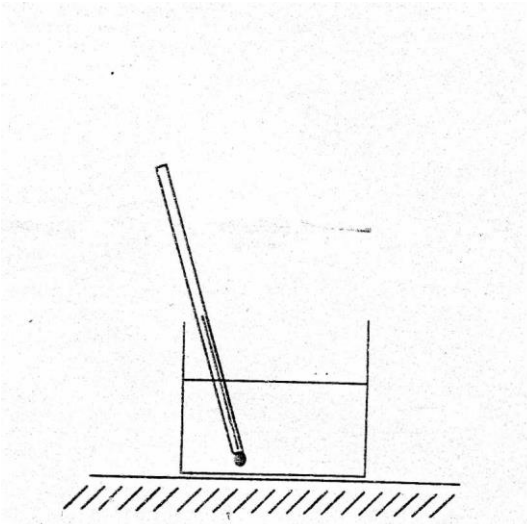
Experiment 11: NEWTON'S LAW OF COOLING

Objective

To investigate Newton's law of cooling.

Apparatus
Bunsen burner, tripod stand, gauze, beakers, thermometer, stopwatch





Theory

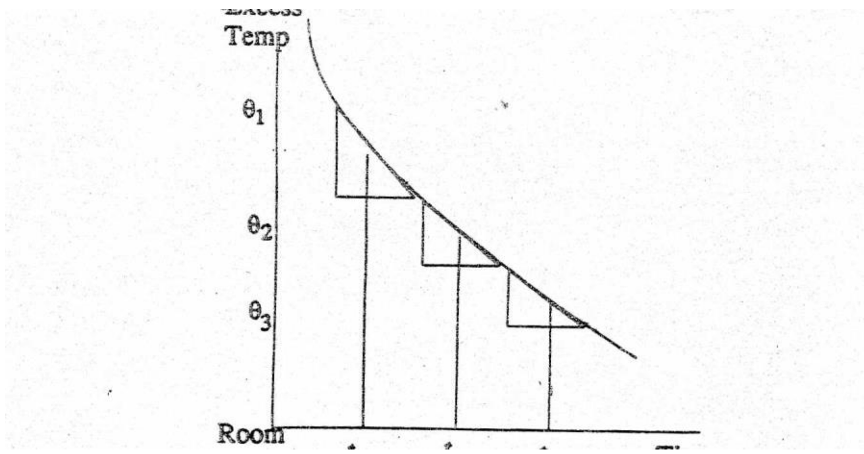
Newton's law of cooling states that in conditions of forced convection (i.e. a draught), the rate of heat loss from a body is directly proportional to the excess temperature of the body over that of its surroundings. Newton's law of cooling is an approximation which can be used only when a body cannot surround itself with a layer of warm air, i.e. in conditions of forced convection. In still air, the approximation can still be used provided that temperature differences do not exceed about 30K. We use the law to predict heat losses of a body at various temperatures so that we can design suitable heating systems or make corrections for any losses which may occur during measurements of heat First, we plot a cooling curve over a convenient range of temperatures (Fig. 15(a)). The rate of cooling at any instant is given by the corresponding slope, *j,* of the curve, which is proportional to the excess temperature at that instant:

$j_2 \propto \theta_1$; $j_2 \propto \theta_2$; etc.

or generally, $j = k\theta$

We obtain the rate of cooling at a particular excess temperature by

extrapolating a graph of temperature excess against j (Fig. 14(b)).



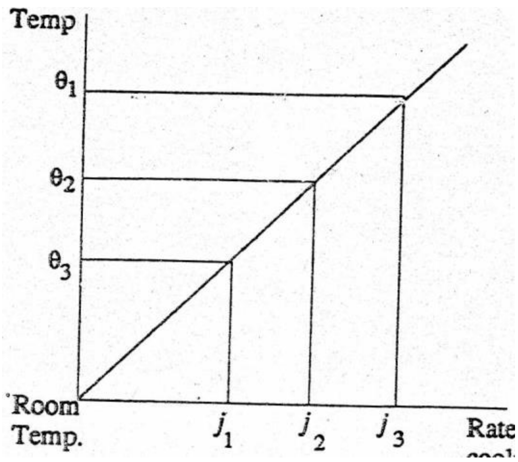


Fig.15 (b)

Method
I, Heat the liquid to a temperature close to 60^{o}C.
2. Withdraw the source of heat from the liquid.
3. Record the temperature of the liquid every minute, until the temperature reaches about 35^{o} c

Analysis
Plot a graph, using all the data, of temperature versus time, and a second graph of temperature excess *against* rate of cooling... (Refer to the introductory section on graphs for instructions on how to take slopes from a curved graph.)

Worksheet 12

Temperature (^{o}C)	*Time (min)*	*Temperature (^{o}C)*	*Time (min)*	*Temperature (^{o}C)*	*Time (min)*

Plot a graph of temperature against time.

Room temperature=

Temperature (^oC)	*Temperature excess (^oC)*	*Slope, j C/min*

Plot a graph of temperature excess against slope, j.

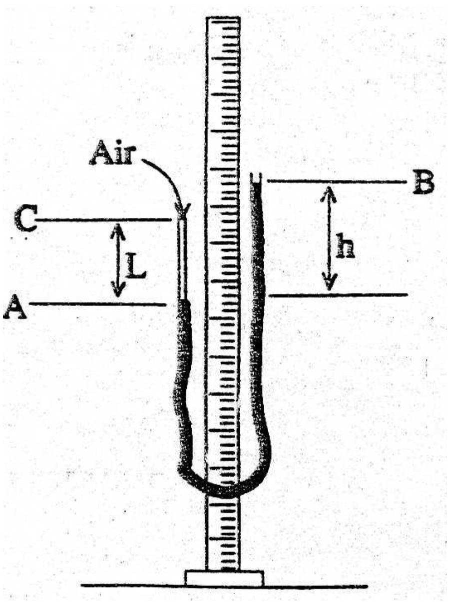
Comments

Conclusion

Experiment 12: BOYLE'S LAW

Objectives

(i) To verify Boyle's law
(ii) To determine atmospheric pressure graphically



Apparatus

Standard Boyle's law apparatus.
A volume of air enclosed in a length of tube, *L*.
(Pressure is supplied by the atmosphere and the column of mercury, *h*.)

Fig. 16

Theory

Boyle's *law* states that, at constant, temperature, the volume of a definite mass of gas is inversely proportional to its pressure.

$PV = k$ (at constant temperature)

Assuming that the tube AC is of uniform cross-section, the volume of air in AC will be V units. Pressure is *proportional* to *(H + h)* cm of mercury (Hg), where *H* is atmospheric pressure. Thus, in terms of these quantities,

Boyle's law becomes: $(H + h)\, L = k$ **(**at constant temperature).

Method

1. Adjust the apparatus so that the mercury level in tube B is at the highest feasible level and that in tube A it is at the lowest feasible level. Note these levels and also the level of C.
   NB Make these changes slowly in order to prevent temperature changes which might result due to compression.

2. Take these measurements for four settings with the mercury level in B above that in A, and four settings with A above B.

3. Tabulate your observations.

4. Read off the room temperature and atmospheric pressure from the barometer.

Analysis

The equation for Boyles *law*, $(H + h)\, L = k$ can be written in the form:

$$H + h = \frac{k}{l}; \quad and \quad h = k\frac{1}{L} - H$$

which is of the form *y=mx+c, with y=h and x= 1/L*. Hence if a graph of *h* against *1/L* is plotted, a straight line should result.
This would verify Boyle's law and also yield a value for *H* as the negative intercept on the y axis.

Worksheet 13

Level of A(cm)	Level of B (cm)	Level of C (cm)	h(cm)	L (cm)	1/L (cm)

Reading error in measuring the levels = cm
Room temperature = ° C
Pressure from barometer = mm Hg
Plot a graph of *h* versus *1/L*.
Intercept on y-axis = cm
Comment on your graph.

Compare the two values of atmospheric pressure (from barometer and from the graph).

What would be the effect on your results if the temperature was to charge during the course of the course of the experiment?

Conclusion

PART D: WAVE MOTION

Experiment 13: STANDING WAVES IN A TAUT STRING

Objective
To study the relationship between resonant frequency and the tension in a taut string.

Apparatus
A string of mass per unit length *m*, set up as shown, with an electrically driven vibrator and a set of weights.

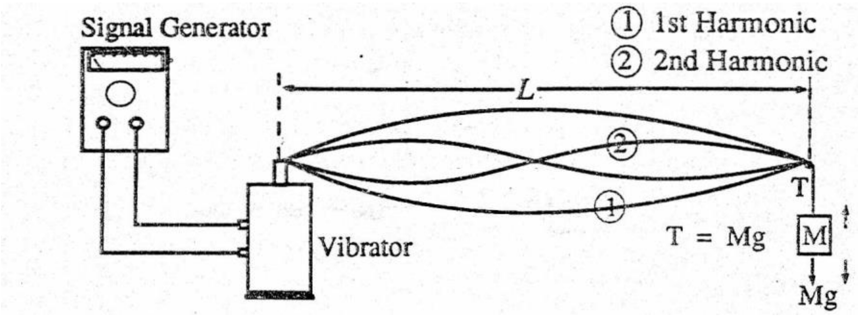


Fig. 17

Theory

When the applied frequency is equal to a natural frequency of the string it will resonate in one of its modes of vibration.

The frequency of the fundamental mode or first harmonic, $f_1 = \frac{1}{2L}\sqrt{\frac{T}{m}}$

The frequency of the first overtone or 2nd harmonic, $f_2 = \frac{2}{2L}\sqrt{\frac{T}{m}}$

The frequency of the nth harmonic, $f_n = \frac{n}{2L}\sqrt{\frac{T}{m}}$

$T = mg$; $\quad f_n = \frac{n}{2L}\sqrt{\frac{Mg}{m}}$ Hz

Method

1. The apparatus is set up as shown in *Fig.* 17 above. *L* should be between I and 1.5 metres.

2. A sample of string is used to measure *m*.

3. A mass of l50g is attached at M.

4. The signal generator is switched on and the frequency *(f)* varied slowly from zero Hz. When the string vibrates clear1y in its first harmonic, the corresponding value off is noted *(f_1).*

5. With the same mass, increase *f* to roughly twice this value and observe the second harmonic. *Note* the new value of $f\ (f_2)$.

6. Where possible, observe and record the frequencies of higher harmonics, f_n.

7. Repeat 4-6 for a range of values of M and tabulate the results as shown on Worksheet 14.

NB. Unwanted resonances originating in the vibrator itself may be observed. Be careful that the frequency readings refer to a consistent set of harmonics.

Analysis

For the first harmonic,

$$f_2 = \frac{2}{2L}\sqrt{\frac{Mg}{m}} \qquad (T = Mg); \qquad f_1^{\ 2} = \frac{1}{4L^2}.\frac{Mg}{m}; \qquad f_1^{\ 2} = \frac{g}{4L^2 m}.M$$

Hence if a graph of f_1^2 against *M* is plotted on a straight line through the origin of slope g/*4Lm* should result. Use the graph to calculate a value for *m* and compare this with the measured value.

Worksheet 14

Length of string, L=

Mass per unit length of string, *m* =

N.B. Remember to give the reading errors in these two values.

M (kg)	f_1 *(Hz)*	f_2 *(Hz)*	f_3 *(Hz)*	f_1^2 *(Hz)*

Plot a graph of f_1^2 against M, putting error bars on f_1^2.

Calculate the slope of the graph where slope = $g/4L^2m$

Questions

1. Are the two values of *m* within experimental error? Show by calculation.

2. How are the frequencies of the overtones related to that of the fundamental frequency? Does your data confirm this?

3. Give two examples of resonance which are of practical importance.

Conclusion

Experiment 14: RESONANCE TUBE

Objective

To determine the velocity of sound using a resonance tube.

Apparatus

Set of resonance tubes of varying lengths
Large tube nearly full of water
Retort stand and clamp to hold
Resonance tube
Set of tuning forks of frequency *256- 5l2Hz*

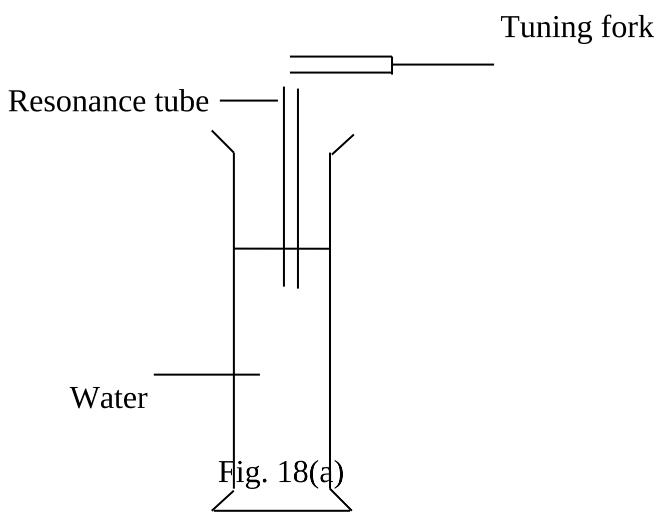


Fig. 18(a)

Theory

Longitudinal waves are set up as shown in Fig. 18(a), a node occurring at the closed end and an anti-node occurring at the open end.

Fig. 18(b) shows the conditions of vibration for the first two positions of resonance.

$L_1 + e = \frac{\lambda}{4}$

$L_2 + e = \frac{3\lambda}{4}$

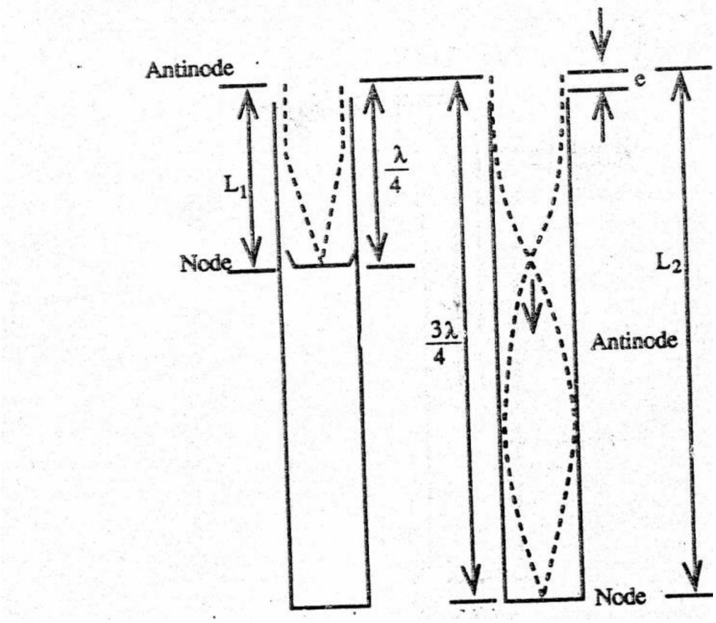


Fig. 18(b)

Therefore: $L_2 - L_1 = \frac{\lambda}{2}$

Velocity of sound $= V = f\lambda$

Note: e = end correction = distance of antinode above end of tube.

From the above equations, $e = ½ (L_2 - 3L_1)$; Alternatively, $e = \frac{1}{3}$ x diameter of tube

Method

1. Place the smallest resonance tube well down in the water.
2. Strike the tuning fork of highest frequency on a soft surface and hold it over the mouth of the resonance tube while gradually raising it.
3. When resonance occurs (i.e. when the note of the fork swells to the loudest volume), measure the length L of the tube above the water level.
4. Raise the tube further out of the water and find a second position of resonance, L_2.
5. Repeat the experiment using each of the forks in turn.

Analysis

From the theory above, $V = f\lambda$, and $L_1 + e = \frac{\lambda}{4}$

Combining these two equations: $\lambda. = \frac{v}{f} = 4\,(L_1 + e)$

Rearranging, we have $L_1 = \frac{v}{4} \cdot \frac{1}{f} - e$

A graph of L against $\frac{I}{f}$ should be a straight line with a gradient of $\frac{v}{4}$. The negative intercept on the vertical axis will yield a value for *e*.

Worksheet 15

Tuning fork frequency Hz	$\frac{l/}{f}$	Length,L_1 m	Length,L_2 m

Plot a graph of L_1 against $\frac{I}{f}$

Slope of graph = $\frac{v}{4}$ =

Velocity of sound =

End correction

Diameter of resonance tube =

1. $e = \frac{1}{3}$ x diameter of tube =

2. Negative intercept on graph =

3. e = ½ (L_2 - $3L_1$) =

Comment on, and compare, the three values you obtained for the end correction.

Reading error in length =

What are the other sources of error in this experiment?

Conclusion

E. OPTICS

Experiment 15: REFLECTION

Objectives

(i) To verify the laws of reflection.

(ii) To investigate some properties of spherical mirrors.

Laws of Reflection

A. Plane Mirror

Apparatus

In Fig**.** 19, BAC is a plane minor and P_1, P_2, P_3 and P_4 are pins on drawing board and paper.

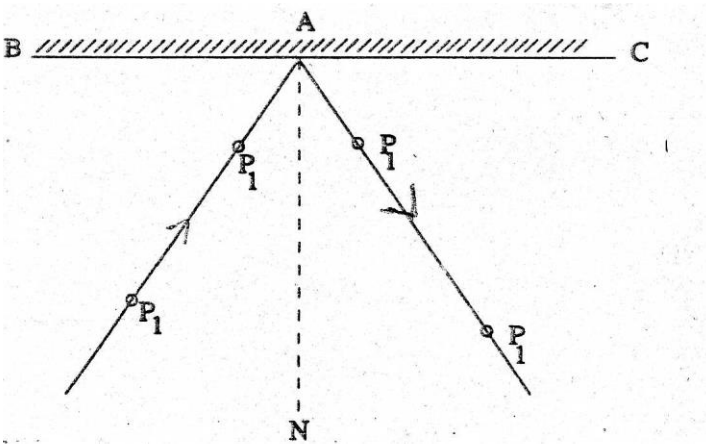


Fig. 19

Theory

A. Laws of Reflection *Analysis*

1. The incident ray, the reflected ray and the normal, at the point of, incidence, all lie in the same plane.

2. The angle of incidence is equal to the angle of reflection.

Method

1. Place the minor perpendicular to the drawing board and paper.
2. Insert pins P1 and P2 into the drawing board.

3. Look in along the direction P3 and P4 until pins P1 and P2 are seen the same line.
4. Insert pins P3 and P4 into the drawing board in line with the images P1 and P2,such that when looking into the mirror all the four pins appear to lie in line.
5. Draw a line on the drawing board to mark the reflecting surface of the mirror.
6. Remove the mirror and pins from the paper.
7. Draw AN (the normal) perpendicular to BAC.
8. Measure the angles of incidence and reflection**.**

Analysis

The data should show that the first and the second laws are verified.

B. Spherical Mirrors

Apparatus

Illuminated object, pins screen, concave and convex mirrors.

Theory

The distance of the object and the image from a spherical mirror are related to the focal length of the mirror by the formula:

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

Where , u = object distance; v = image distance; f = focal length

A ray of light from the object which enters the mirror parallel to the principal axis will be reflected back through the focus. The ray of light which enters the mirror through the center of curvature will be reflected back along the same path.

Method
1. Switch on the illuminated object.
2. Move the concave mirror slowly away from the illuminated object until it projects an image of the illuminated object onto itself. *Move* the mirror such that a good clear focus is obtained.
3. Measure the distance between the mirror and the object/image. Half this distance is the focal length.
4. Set the mirror at a distance greater than 2f away from the object.
5 Use the screen to locate the image and measure *v (2f> u <f and u = f).* (image distance).
6. Repeat this for 2f > *u* >f and u =f.
7. Use the method of no parallax to locate the virtual images in the concave and convex mirrors using the search pins provided.

Analysis
Calculate the focal length,f, in each case, thereby verifying the formula:

1/u + 1/v =1/f for the concave mirror.

Worksheet 16

A. Plane mirror

	Angle	Error
Angle of incidence, i		
Angle of reflection, r		

N.B. Hand in original ray diagrams

Are the two laws of reflecrion verified?

What sort of image is seen in a plane mirror?

What sort of image does the convex mirror produce?

Conclusion

Experiment 16: LAWS OF REFRACTION AND PROPERTIES OF LENSES

Objectives
(1) To verify the law of refraction
(ii) To investigate properties of lenses

A. **The Laws of Refraction**

Apparatus
ABCD is a rectangular glass **block.** P_1, P_2, P_3 **and** P_4 **are pins on a** drawing board and paper.

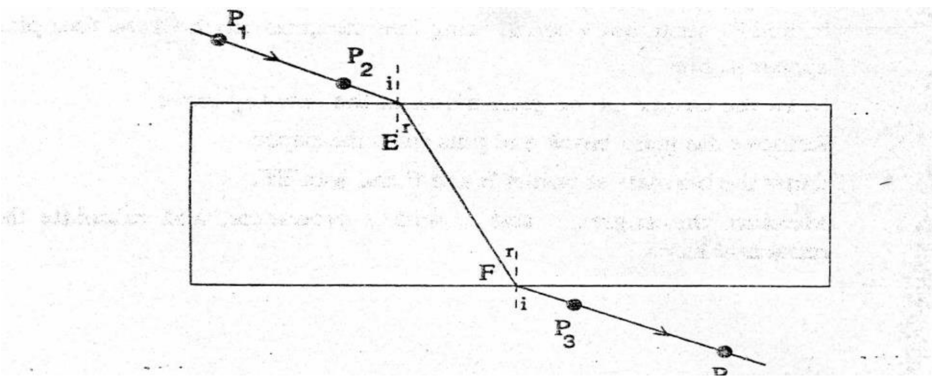


Fig. 20

Theory

1. The incident ray, the refracted ray and the normal,at the point of incidence, all **lie** in the same plane.

2. The *sine* of the angle of incidence divided by the *sine* **of** the angle **of** refraction is equal to a constant called the *refractive index* for the two media involved

Method

1. Place a rectangular glass block on a paper on the drawing board.
2. Insert pins P_1 and P_2 into the drawing board.
3. Look in along the direction P_3 and P_4 until the pins P_1 and P_2 are seen in line.
4. Insert pins P_3 and P_4 in the drawing board in line with the images of P_1 and P_2 such that when looking into the glass block all the four pins appear in line.
5. *Draw* the outline of the glass block on the drawing paper.
6. Remove the glass block and pins from the paper.
7. Draw the normal at point **E** and **F** and join **EF**
8. Measure the angles ***i*** and **r** with a protractor and calculate the refractive index.

Analysis

The data should show that the first and second laws of refraction have been verified.

Additional note

Device an experiment to show that: $\frac{\text{real depth}}{\text{apparent depth}} = n$

by using a glass block and a microscope. (Consult the lecturer in charge.)

B. **Lenses**

Apparatus

An illuminated object, pins, screen, concave and convex lenses,

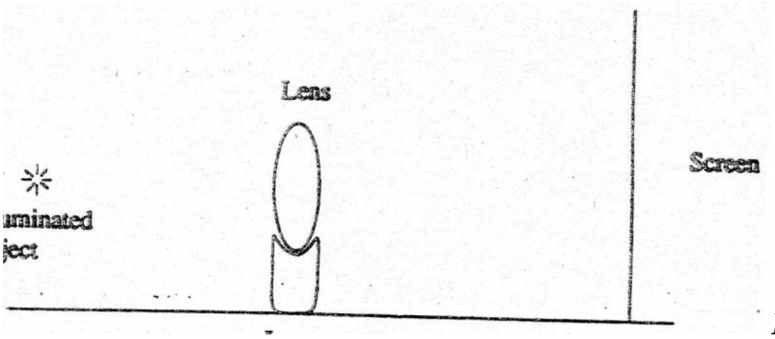


***Fig.* 21**

Theory

The location and type of image formed in a lens can be ascertained by drawing a ray diagram. The ray of light from the object which enters the lens parallel to the principal axis will be refracted through the focus. The ray of light which goes through the center of the lens will emerge undeviated. It can be shown that:

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

Where f = focal length from lens

u=distance of image from lens

v=distance of image from lens

Method

1.Establish a rough value for the focal length of the convex lens by focusing on a distant object (eg. window of laboratory) on the screen.
2. Switch on the illuminated object and place it at a position greater than 2*f* from the lens. Move the screen until a clear image is in focus on it.
3. Measure the distance from the object to the lens (*u*) and from the lens to the screen *(v).*
4. Calculate *f* using the above values of *u* and *v.*
5. Repeat the above steps for positions of the object:

$u=2f$; $2f>u>f$; $u=f$

6. Use the method of no parallax to locate virtual images in both the convex and the concave lenses using search pins provided.

Additional notes

The focal length of the concave lens can also be determined by combining the lens with a convex lens of shorter focal length than itself. The focal length of the combining (F) is given by:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

where f_1 = focal length of convex lens

f_2= focal lenth of concave lens

F is determined by using the combination lens to form a real image on a screen, whence:

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

f_1 is known and hence F can be calculated.

Worksheet 17

A. Laws of Refraction

i	**Sin *i***	***r***	**Sin *r***	***Refractive index, n***

B. Lenses

i. ***Convex lens***

	u	*v*	*f*	State if image is:		
units				*Real/virtual*	*Upright/inverted*	*Magnified/diminished*
u>2f						
u =2f						
2f>u>f						
u=f						
u<f						

Average *f*

ii. Concave lens

	Value	*Units*
u		
v		
f		

What kind of image does the concave mirror produce?

iii. Combination of lenses

Focal length of convex lens,f_1 (from above)

Combination:

	Value	*Units*
u		
v		
f		

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Calculate f_2

How does this answer correspond to that obtained in (ii) above?

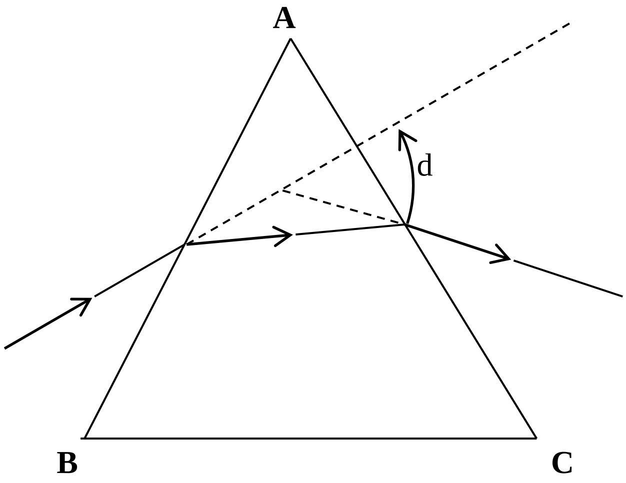
Conclusion

Experiment 17: THE SPECTROMETER REFRACIIVE INDEX

Objective
To measure the refractive index of the glass of *a* prism using monochromatic light from *a* sodium lamp

Apparatus
Spectrometer, glass prism, sodium lamp.

Theory
The refractive index of the glass of a prism may be found by measuring the angle of minimum deviation of the prism.
When a ray of light passes through a prism, it undergoes refraction, with the emergent ray bending towards the base of the prism as shown in Fig. 22. The emergent ray deviates from the direction of the incident ray by an angle *d*. This angle of deviation depends on the angle of incidence, and it is found that for a certain angle of incidence, the angle of deviation is a minimum.



Let D= angle of minimum deviation, and A= refracting angle of prism

Then the refractive angle of the glass of the prism is given by: $\boldsymbol{n}=\dfrac{\sin(\frac{A+D}{2})}{\sin\frac{A}{2}}$

If the prism is arranged so that light falls on the refracting corner as shown in Fig. 23, then it can be shown that the refracting angle is half the angle between the two emerging rays of light.

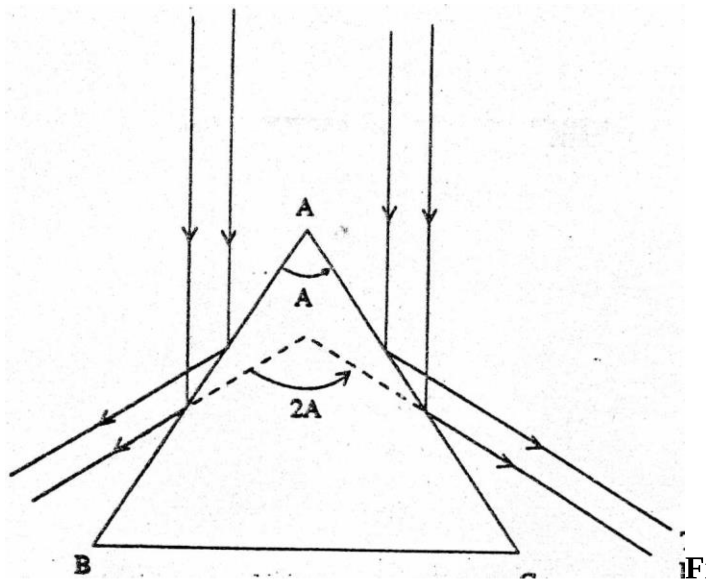


Fig.23

Both the refractive angle of the prism and the angle of minimum deviation may be found using the spectrometer.

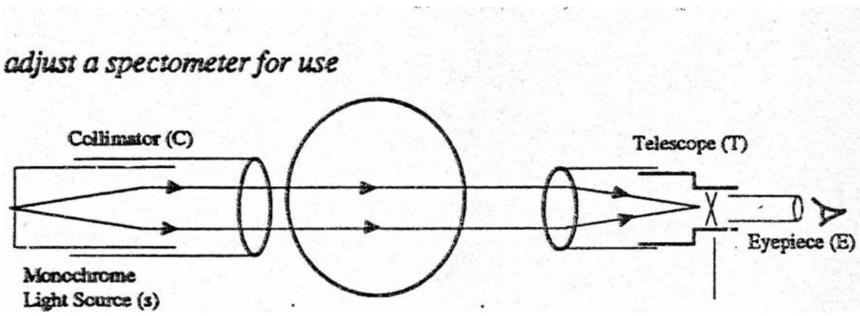


Fig.24

As the diagram above shows, the collimator has a slit at one end and a convex lens so arranged that the light passing through it from the slit issues almost as a parallel beam.
The telescope is of small magnifying power with cross-wires X in front of eyepiece E. The telescope can be turned in a horizontal plane and the angle through which it swings can be measured on a protractor engraved on the turntable.

To set up the spectrometer
(N.B: Carry out these adjustments in the order given and do not alter any adjustments which has already been completed.)

1. Point the telescope at any coloured surface and adjust the eyepiece until the cross-wires are seen clearly.
2. Point the telescope at a distant object, e.g. a house seen through a window, and adjust the focusing until the image (of the house) and the cross wire show no parallax. The telescope is now adjusted to focus parallel light on the cross wire.

3. Place the source of monochromatic light *a few* centimeters from the collimator slit.
4. If necessary, adjust the collimator (sliding tube) until the image of the slit shows no parallax with the crosswire. In this case the beam emerging from the collimator is a parallel beam.

To level the turntable

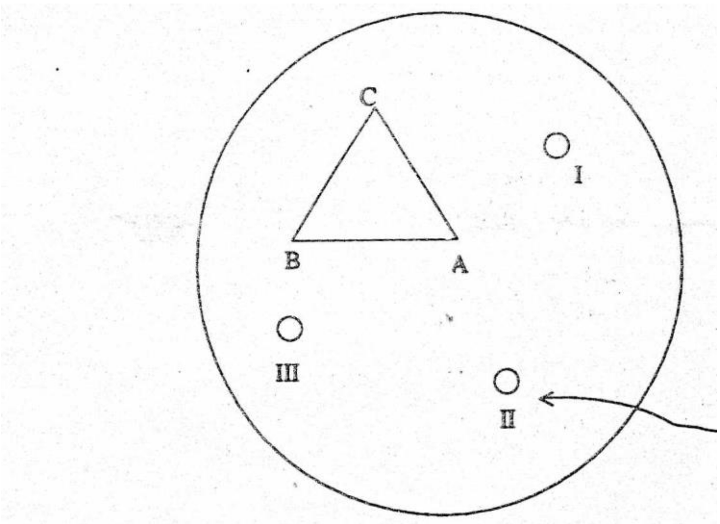


Fig. **25**

This is done optically by using a prism of refracting angle A, which is placed on the table such that face AB is perpendicular on the line between the two leveling screws **I** and **II**. A is close to the table center.

Turn the telescope close to the collimator and observe the reflection of light from the slit in face **AB.**
Adjust screw **I** until the image is vertical and its middle coincides with the crosswire.
Turn the table and now observe the reflection in the face AC**.** Screw **II** is then adjusted. Go back to check the first observation, repeating the adjustment if necessary.

The table is now level.

Method

1. Set up the spectrometer for use as given by the appendix**.** It's important to take time and care over this as accuracy depends on the correct adjustment of the spectrometer.

2. Ensure that the faces of the prisn1are clean.

Refracting angle of the prism

3. Mount the prism on the table as shown in ***Fig.* 23.** Light from the collimator must fall on *both* the reflecting faces **AB** and **AC.**
4. Rotate the telescope so that it receives reflected light from say face AB. Use the tangent screw to bring the centre of the image exactly on the center of the crosswire. Note the readings on both verniers.
5. Repeat the measurement for the telescope set to receive light from face **AC.**
6.Record the data on Worksheet 18 and deduce the refracting angle of prism.

Angle of minimum deviation

7. Mount the prism centrally on the table such that one of its reflecting faces, say AB, is perpendicular to the line joining the two leveling screws **P** and ***Q***. **(See Fig. 26)**

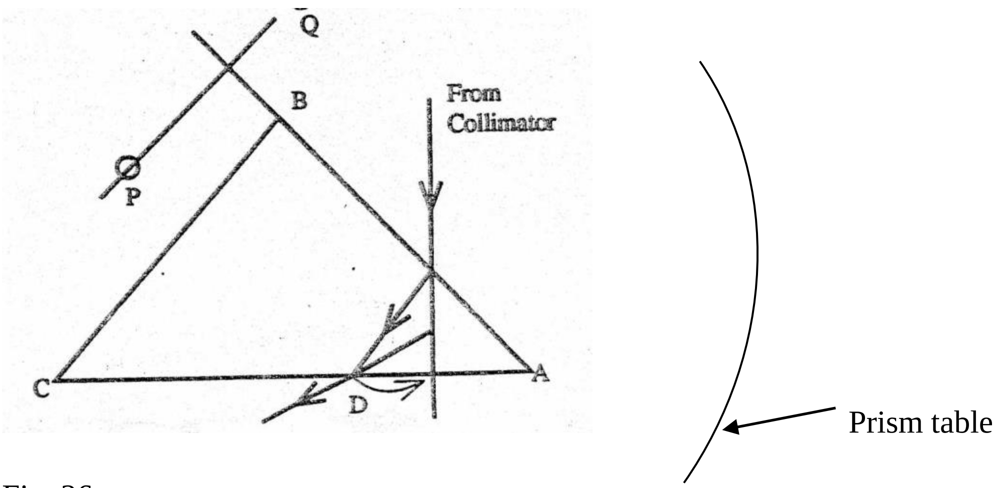


Fig. 26

8.Rotate the table so that light from the collimator is incident on face AB and after refraction emerges from face AC. Locate the face AC first with the naked eye to find the image, and then rotate the telescope to receive this image.
9. Rotate the prism table such that the telescope has to be rotated towards the line of the collimator ads in order to keep the image in the center of the field of view,
10. Note that as the table is rotated in this direction, the deviation decreases. At the position of minimum deviation, the image becomes stationary for a very small rotation of the table.(Further rotation of the table makes this image move in the opposite direction.)
11. Adjust the telescope until the image is at the center of the crosswire, and read both verniers.
12. Remove the prism. Bring the telescope in line with the collimator so that the image of the slit is viewed directly. Again, read the verniers.
13. Calculate the refractive index.

Worksheet 18

Refracting angle

Venier	*Telescope Left*	*Telescope Right*	*Difference*	*Angle of Prism A*
V(1)		:.		
V(2)				

Mean A= **;** **Error in A=**

N.B. When taking the difference angle, Θ, pay attention to what happens when the telescope is rotated through the 360 degree mark!

Angle of Minimum Deviation

Vernier *Readings*	*Prism* ***in*** *minimum deviation position* Θ_1	*Straight* ***through reading*** Θ_2	*Difference* Θ $\Theta_2 - \Theta_1 = D$
V(1)			
V (2)			

Mean D = ; Error in D: ; Refractive index:

N.B: Quote the value of n (and its error) to three decimal places since this is the minimum accuracy expected with the spectrometer. Error in Refractive Index:

Questions

1. Show how $n = \frac{\sin(A+B)/2}{\sin A/2}$ is derived

2. Why is the telescope adjusted for a distant object?

3. When will the maximum deviation occur in this experiment?

Conclusion

F. ELECTRICITY

Experiment 18: OHM'S LAW

Objective: To verify:

(a) Ohm's law for a metallic conductor
(b) $R = R_1 + R_2 + R_3$ for resistances in series
(c) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ for resistances in parallel
(d) Ohm's law is not obeyed by a semiconductor

Apparatus

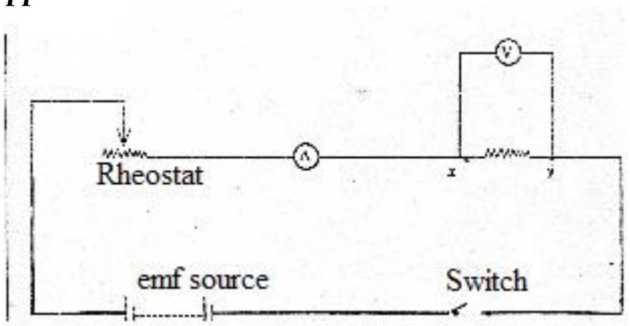


***Fig.* 27**

Theory

Ohm's law for a metal conductor states that V = RI at constant temperature, where V = voltage (volts), I = current (amps), R = resistance (ohms).

Method A

1. Connect the circuit as shown in *Fig.* 27.
2. Use the rheostat to adjust the current flowing through the unknown resistance R.
3. Record the ammeter and, voltmeter readings.
4. Repeat steps 2 and 3 until six readings are recorded
5. Reverse the terminals of the resistance, i.e. X and Y, and record another three readings.

Analysis A

Use your experimental values of V and I to plot a graph of V versus I. A straight line graph proves Ohms law. Find R from the slope of your graph.

Method B

1. Measure the resistances R_2 and R_3 separately.
2. Measure the resistance of R_1 , R_2 and R_3 in series.
3. Measure the resistance of the three resistors in parallel.
4. Record all values on the worksheet and test to see if the relationships for resistors in series and in parallel hold.

Method C

1.Repeat the first part of the experiment using a semiconductor and draw the graph of V against I. Remember to take a few readings with forward bias and a few with reverse bias

2. *A* graph other than a straight line shows that Ohm's Law is not obeyed.

Worksheet 10

(a) To verify Ohm's law

							Reversed connection	
V volts								
I amps								

Plot the graph of V versus I.

Slope of graph = R = (units?)

Combinations of resistors (b) and (c)

$\mathbf{R_2}$		$\mathbf{R_2}$		**Series**		**Parallel**	
V volts	*I* amps	*V* volts	*I* amps	*V* volts	*I* amps	*V* volts	*I* amps

Plot a graph to find R_2 and R_3.

	From graph	*From formula*	*Units*
R(series)			
R(parallel)			

R_1 = ; R_2 =

Compare your experimental results with those obtained using the formula.

Read the actual values of the resistors using the colour code and compare with your experimental values

Discuss the sources of error in these measurements on resistances. Is this the most accurate way of measuring resistance? If not, what would you use and why?

(d) Semiconductor

							Reversed connections	
V volts								
I amps								

.

Plot a graph of *V* versus *I*.

Comment on your graph. Is Ohms law verified?

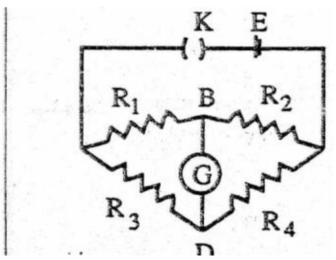
Use a resistance meter to check your values for R. Comment.

Conclusion

Experiment 19: THE THERMISTOR

Objective
To determine the resistance characteristics of a thermistor.
Apparatus
Metre-bridge, cell, standard resistance box (R), sensitive galvanometer switch (G), beaker of glycerine, bunsen burner
S = thermistor.

X=shunt



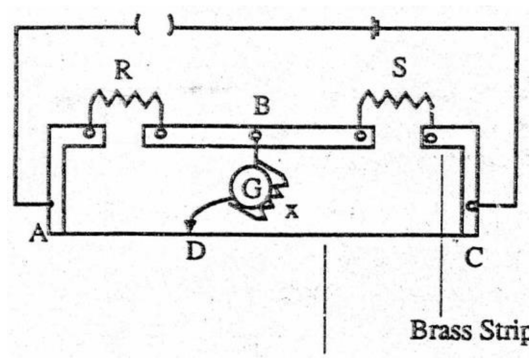


Fig. 28

Theory

The metre-bridge is a convenient form of the Wheatstone bridge arrangement (Fig. 28 (i)). When the switch K is closed and the resistances are such that when no current flows through the galvanometer G, then the bridge is balanced. It can be shown that: $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

The metre-bridge consists of a one meter length of uniform resistance wire AC (Fig. 28(11)) alongside a metre rule, and soldered at A and C using brass strips of negligible resistance. A third brass strip is arranged as shown in the figure. Since the resistance of a uniform wire is proportional to its length, then, if D is the balance point:

$$\frac{R}{S} = \frac{AD}{DC}$$

Method

1. Connect the metre bridge as shown in Fig. 28 (ii), with the thermistor S immersed in glycerine.
2. Check all connections with the laboratory demonstrator.
3. Heat the glycerine slowly and when a reading is taken, remove the burner, otherwise a large error will occur.
4. Close switch K. Move the sliding contact along the resistance wire until a point of balance is obtained, where the galvanometer reads zero. The shunt X should be on.
5. Turn the shunt 'off' to find the balance point more accurately.
6. Record the lengths L_1 L_2 and the temperature of the glycerine.
   7. the measurements at five or six different temperatures of the glycerine, taking a. wide range of temperature. (Consult the laboratory demonstrator for the temperature range appropriate for the thermistor you are using.)

Analysis

The resistance of the wire is directly proportional to its length. The resistance of the thermistor at each temperature may thus be calculated.

$$S = \frac{R.L_2}{L_1}$$

Plot a graph of the log of the resistance against the temperature.

Worksheet 20

Resistance of resistance box (ohm's)

Temperature ℃	L_1 (cm)	L_2 (cm)	S ohm	log S

Plot a graph of log *S* against temperature.

Comment on your results.

Questions

1. Why do you use a shunt on the galvanometer?

2. Why do you use a meter bridge for the measurements rather than a voltmeter and an ammeter?

3. Why is it simpler to plot the log of the resistance of the thermistor against temperature rather than the resistance against temperature?

4. State two applications of the thermistor.

Conclusion

Experiment 23: THE POTENTIOMETER

Objective

To compare the E.M.F.'s of two cells using **a** potentiometer.

Apparatus
Potentiometer *with* sliding contact, accumulator (driving voltage), Leclanche cell, Daniell cell, Standard reference cell

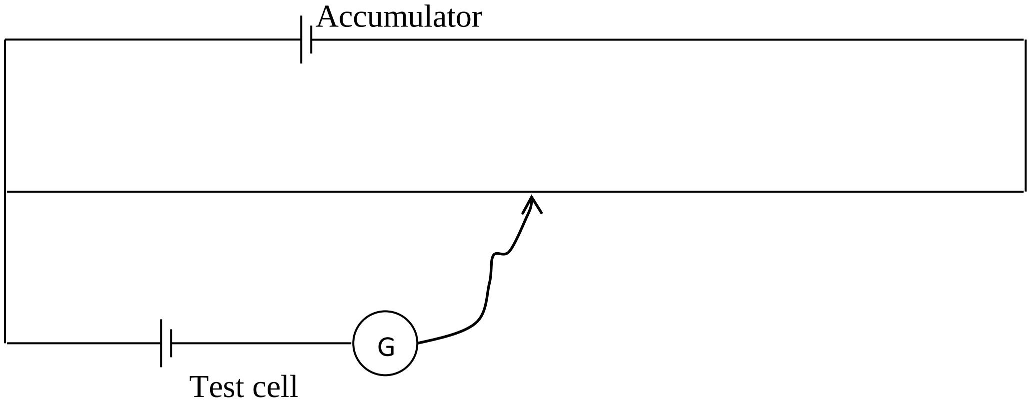


Fig. 29

Theory

The potential difference between the points A and C of the potentiometer wire,
V_{AC} = I × resistance of *AC*

$$V_{AC} = I \times \frac{\rho L}{A}$$

Where ρ = resistivity of wire

A= Area of cross section

L = Length AC

Hence V α L

Since *I, ρ and A* are constant along the wire.

$$Thus\, at\, balance, \quad E_1 = V_1 \,\alpha\, L_1; \quad E_2 = V_2 \,\alpha\, L_2; \; Therefore \quad \frac{E_1}{E_2} = \frac{L_1}{L_2}$$

If E_1 is known (as in the standard Western cell) then E_2, the E.M.F. of an unknown cell, may be found

Method

1. The circuit is connected up as shown in Fig. 29, with the standard cell in place. Be sure that the positive poles of both the accumulator and the standard cell are both connected to A.

2. Get the circuit checked by the lecturer in charge.

3. Adjust the position of the sliding contact along the wire until no current flows in the galvanometer. Note the length L.

4. Repeat this procedure for the Leclanche cell and then the Daniell cell, noting the lengths required to obtain the balance. You will need to assemble these cells and add the correct liquids to them.

5. Repeat all the measurements at least once to obtain mean values for the lengths.

Analysis
since the E.M.F. of the standard cell is known*;* the E.M.F.'s of the Leclanche and Daniell cells may be calculated.
Worksheet 21

Unit	*Reading 1*	*2*	*3*	*Error*
L_1 (standard cell)				
L_2 (Leclanche cell)				
L_3 (Daniell cell)				

Calculate E.M.F. of Leclanche cell:

Error in E.M.F.

Calculate the E.M.F. of Daniell cell:

Error in E.M.F.

Accepted value for E.M.F. of Leclanche cell

Accepted value for E.M.F. of Daniell Cell

Comment on your results

Questions
1. Why must the EM.F. of the driver cell be greater than that of the cell under test?

2. A potentiometer can be considered as a voltmeter with infinite resistance. Why?

3. What factors limit the accuracy of a potentiometer?

Conclusion

Experiment 21: THE OSCILLOSCOPE

Objectives
(i) To learn how to use the oscilloscope
(ii) To investigate some simple applications of the oscilloscope

Apparatus
Signal generator, dual beam oscilloscope, circuit boards containing RCL circuits with different values of R, and with variable capacitor and inductor.

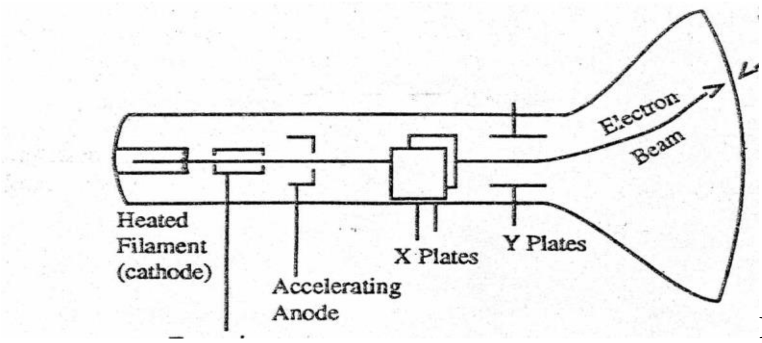


Fig. 30

NB. Disposition of controls varies depending on the make of the oscilloscope.

Operation of the Oscilloscope

The oscilloscope can be used to give an image of a repetitive signal as a function of time. The signal, as a voltage, is applied to the Y-plates (vertical movement) and internally generated wave sweeps the electron beam (seen as a spot on the screen) horizontally at some pre-determined rate. This rate is set using the “time/div” control.
The “time/div” control is calibrated such that when it is operating at 50 cps, 1 cycle occupies 20 ms. All the other ranges on the switch are direct multiples of this. The time calibration is only valid at the minimum setting of the “X pos ” control. The “X-shift” control moves the whole trace horizontally.
The trace may also be controlled vertically using the “volt/div” control. This switch inserts a series of resistances between the input socket and the vertical amplifier. It is used either to obtain a picture of convenient height or to obtain direct readings of the input voltage (provided the “Y-pos” control is at its minimum setting).
To take measurements, a steady trace is required, and the “trig. level” control may be adjusted. You will be using the internal trigger where the applied, i.e. unknown, signal is used to start the time base. The “trig. level” switch controls the signal level at which the time base is triggered.
The “d.c./a.c.” switch is normally set to the a.c. position. This inserts a blocking capacitor in series with the input of the vertical amplifier to remove d.c. component of the signal.

Method A

1. Connect the signal generator up to the oscilloscope. Set the generator to input sine waves at a frequency of 500Hz
2. You should see a steady sine wave on the screen. If not press in the trigger level button. Adjust the intensity and focus controls to give a sharp but not too bright, image.

3. Now try the effect of the following controls:
   X pos Y pos time/div   volts /div
4. Measure the wavelength of the wave seen on the screen and calculate the frequency of the wave.
5. Repeat for signal generator frequencies of 1000Hz and 1500Hz.
6. The oscilloscope can also be used to measure voltage. Set the voltage output of the generator to 1.
7. Measure the Voltage from the oscilloscope screen.
8. Repeat for settings 3 and 5.
9. Now set the generator to give out square waves at 500Hz and voltage output setting 3.
10. Measure the frequency and voltage of the wave.
11. Record all data on the worksheet. Comment and compare results from the sine and square waves.

Applications
Discharge of a capacitor in an RCL circuit.

Theory

A series circuits containing a resistance, capacitor and inductor will resonate with a frequency of ω under certain conditions. The signal generator charges and discharges the capacitor *twice* during one period causing oscillations in the circuit. The nature of the capacitor's discharge depends on the values of the circuit components according to the equation:

$$\frac{R}{2L} > \frac{1}{\sqrt{LC}}$$ (Aperiodic or smooth discharge)

$$\frac{R}{2L} < \frac{1}{\sqrt{LC}}$$ (oscillatory discharge)

Since the capacitor is being discharged, the amplitude of the oscillations in the second case decreases with time, i.e. damped oscillations.

Method B

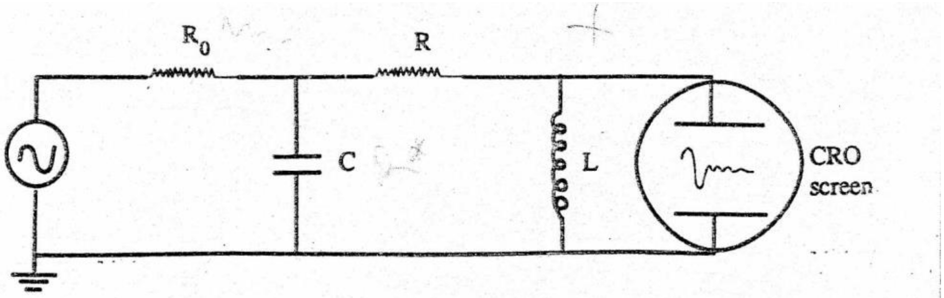


Fig. 31

1. Some RCL circuits have already been prepared on circuit boards. Choose the one with R 100 ohms. Connect the oscilloscope to the terminals,
2. Draw the curve seen on the oscilloscope screen.

3. Repeat for R = 1000 ohm and 10,000 ohm (or 100,000 ohm). (Use appropriate circuit boards).
4. Investigate what happens to the *curve* on the oscilloscope screen when C and L are changed.
5. Fill in the data sheets.

Worksheet 22

A. Oscilloscope controls

Sine Wave

Generator reqzeiwy Hz)	*Length on screen (cm)*	Time/div *(secs)*	*Time (secs*	*Osilloscope freqency(Hz)*
500				:
1000				
1500				

Voltage setting	Height on screen (cm)	Volts/div (volts)	Voltage (volts)
1			
3			
5			

Square wave

Generator frequency (Hz)	*Length on screen (cm)*	*Time/div (secs)*	*Time (sec)*	*Oscilloscope frequency (Hz)*
500				

Voltage setting	*Height on screen (cm)*	*Volt/div (volts)*	*Voltage (volts)*
3			

Comment on your results, comparing the two types of waves.

Discharge of a capacitor in an RCL circuit.
R= 10 ohms, C=4700pF, L=0.4H
Draw a diagram of what you see on the oscilloscope screen.

On a separate sheet of paper (to be handed in) draw the diagrams for R = 1000 ohms and R =10,000 ohms. Also draw the diagrams obtained when C and L are varied. In each case say whether the discharge is oscillatory or aperiodic. Is this borne out by theory? If not, why not?

The End