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General Physics 101 lab

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Introduction

Important notes about the lab:

1 – Experiments were designed so that the student can complete all the requirements of any experiment during time period of three lectures, thus the student hands over the results of his work at the end of this period to lab supervisors. The student who does not submit his laboratory at the end of the specified period will be recorded for Degree (zero) in that experiment.
2 - In many experiments the results must be represented graphically, so the student should interest in review his former information on the drawing of graphs, the results must be presented on the chart carefully, the student should care about accuracy when representing the results graphically and show an appropriate manner should use a pencil for drawing and writing the definition of the drawing axes.
3 - When performing any experiment, errors in the results have to be calculated, this book has included a brief note on the errors and how to be calculated.
4 - The student is required to prepare the experiment before attending the lab in order to facilitate his task within the laboratory and the preparation of a complete report during the lab and on the student's knowledge of the required experiment in the next week to be reviewed before coming to the lab.
5 - What you should do in the lab is to ensure the integrity of hardware between your hands for each experiment and use them to achieve their primary purpose. Student and you have to write a short report about the experiment reflects his understanding of the experiment, in addition to the results includes lines from the theory of experiment and action steps through dealings with the experiment as it is not copying of the note.
6 - All students should bring the necessary tools for the lab: a transparent ruler, pencil, sharpener, eraser, calculator ... etc. any student isn't not allowed to borrow these tools from his colleagues in order not to disable the occupancy of his colleagues.
7 - The mark of the lab 25% of the decision marks, of which 15 is the rate of weekly reports and 10 marks on the final test of the lab, involved within the assessment class to the weekly report: The behavior of the student in the lab and his preoccupation with his own experiment, students prepare for the experiment or not and found that the supervisor when discussing to the student within the lab. As well as his organization of the report required.
8 - Students should take the opportunity to learn and acquire skill in experimentation and not rely on the results of others who preceded him in the implementation of this experiment. When discovery of any case based on the results of a previous class, record of that experiment will be (zero).
9 - Any student who misses more than four experiments will be deprived from the final test of the lab.

The purpose of the practical physics:

1 – To clarify the ideas in theoretical physics, a scientific explanation and hopes for interaction between theory and experiment.
2 - Definition of devices and get used to it.
3 - practicing on how to conduct experiments and gain skill in observation and conclusion is the main purpose of studying the physics of the process is that the practicing:
A - develop a plan to fit the purpose of accuracy.
B - a clear idea about the errors of the system (routine) in methods and devices, and how to get rid of them.
C - Analysis of the results and draw valid conclusions from them.

D - Set precision in the final result.
E - Recording measurements accurately, clearly and concisely.

The concept of measurement:
The linguistic meaning of the measure is an estimate or learn something by comparing the value of a recognized standard, the thing may be measured by weight or volume or space or degree or a time ... etc.. This means therefore that the measurement process of comparison between the measured and the thing to be something between last known value in all places and times and circumstances, and concentrated mainly on the measurement of the following:
1 - The well-known measurements on the basis of which various quantities are measured.
2 – Standards that are physically met by those units.
3 - Equipment and instruments to compare the quantities to be measured by the standards.
4 - The measurement method and conditions. Arithmetic mean: is the total number of readings divided on their numbers.

Errors in measurement:
Errors mean differences between the value measured in the experiment and the real value (or exact) and can be divided according to the nature of the errors to:

1 - Systematic errors (monotonous or regular):
The mistakes that are repeated on a regular basis no matter how many times this measurement and examples to be ruler of measurement are scaled irregularly or have a capillary tube of the thermometer with a diameter that varies from one section to another, or that the index does not stop the device at zero when it is not in the case of measurement. It is possible in most cases to get rid of systematic errors either in the calculating entered in the form of patches or devices used for calibration of standard devices.

2- Emergency or random errors:
Are errors arising from a number of reasons, the independent affect differently at each measurement, and stop these errors for the lack of accuracy of the device and on the incompleteness of our human senses and on the changing air continued to external circumstances (such as changing the temperature - pressure - humidity - etc.).

Errors Calculation:
1 - Absolute Error (ΔX): The difference between the value measured experimentally ($Xexp.$) and the theoretical value ($Xtheo.$) is the correct value.

$$\Delta X = Xtheo. - Xexp.$$

The reference to determine whether the meter under test gives an error in the reading of an increase or decrease.

2 - The Relative Error: is the ratio between the absolute error between the real value of the measured quantity that is:

$$relative\ error = \frac{\Delta X}{X_{theo}} = \frac{X_{theo} - X_{exp.}}{X_{theo}}$$

3 - Percentile Error: the relative error is multiplied by one hundred, ie: 100 %

$$percentage\ error = \frac{\Delta X}{X_{theo}} \times 100\ (\%) = \frac{X_{theo} - X_{exp.}}{X_{theo}} \times 100\ (\%)$$

Experiment 1

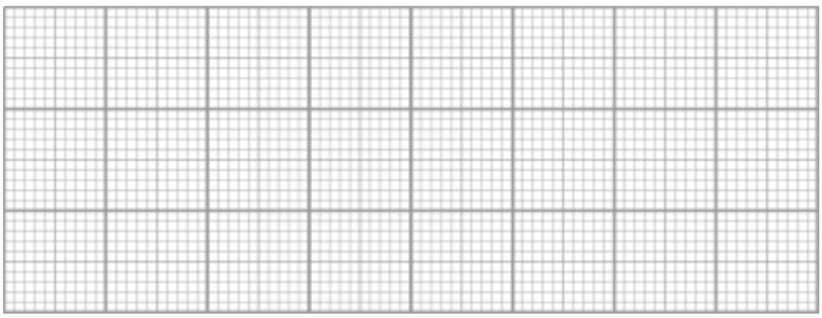
Graphing

Objective:
1. Plotting data.
2. Determination of the slope.

Theory:
plotting a graph:
Graphing is a photographic way of representing relationships between various quantities, parameters, or measurable variables in nature. A graph basically summarizes how one quantity changes if another quantity that is related to it also changes. It is a very important and useful technique in experimental physics because they can summarize a LOT of information into one picture.

Steps for plotting a graph:

1) <u>Kind of paper :</u>
we have many kind of paper graph for example millimeter paper , loglog paper and semi-log paper . In our lab we used only millimeter paper which has 10 squares per centimeter as shown in the figure



2) <u>The Axes</u>
☒ Any plot or graph that has two axes is an x-y plot. One axis (generally, the horizontal one) is the "x-axis" and the other (the vertical one) is considered the "y-axis".
☒ The independent variable always belongs on the horizontal axis (x-axis) and the dependent variables (the part of the experiment under observation) always belongs on the vertical axis (y-axis)

3) <u>The Scale</u>
The scale for a variable is the amount of this variable which is presented in each centimeters of length of the graph paper.
The scale should be chosen so that:
☒ It is convenient to you to locate the data points that you need to put in the graph.
☒ It is convenient for the reader to visualize the coordinates of each point in the graph.
☒ You nearly use the whole graph paper to plot your graph.

- ☒ The best way to choose a suitable scale is demonstrated in the example below. Suppose you have done an experiment to measure distance L versus time t, and you have obtained this table:

T (sec)	1	2	3	4	5	6
L (m)	10	21	28	40	53	61

And also suppose that you want to plot your graph in an area (of the graph paper) which is 15 × 23 cm. This means that the dependent variable x will be plotted on a 20 cm-long axis, and the independent variable on a 15 cm-long axis. The first step is to find a "rough scale" from the equation:

$$\text{Rough scale}=\frac{\text{Largest value}}{\text{Number of centimeters}}$$

for the L, the largest value is 60 and the number of centimetres (or boxes) in graph paper is 23
so the

$$Rough\ scale\ for\ L = \frac{61}{20} = 3.05$$

This mean every 1cm in graph paper = 3.05 cm
This scale is hard to be used in plotting the data provided in the table. So, the result is approximated to higher values so that there is no loss in the number of readings. In our case that will be
4 is the suitable numbers. So, if we choose 4 for example the scale in y axis (4, 8, 12, 16, 20 , 24………)
Now, if we want to find the rough scale of t, we repeat the same steps that we did for L.
the largest value is 6 and the number of centimeters in graph paper is 15

$$Rough\ scale\ for\ t = \frac{6}{15} = 0.4$$

which is a suitable scale, so we use it directly. the scale in x - axis (0.4, 0.8, 1.2 , 1.6, 2 , 2.4 ……)

<u>Partial reading:</u> is the small scale of 1 mm (the small square). for I cm = 10 mm

$$Partial\ reading = \frac{Rough\ suitable\ scale}{10}$$

In the example above

$$Partial\ reading\ for\ L\ = \frac{4}{10} = \ 0.4$$

(0.4, 0.8 , 1.2 , 1.6, 2 , 2.4 ……)

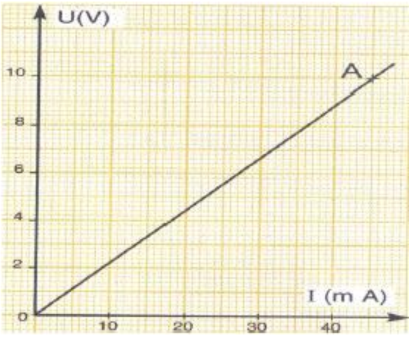
$$Partial\ reading\ for\ t = \frac{0.4}{10} = \ 0.04$$

(0.04, 0.08 , 0.12 , 0.16, 0.2 , 0.24 ……)
Another example: From the graph the rough scale in x-axis is 10

The partial reading equal $\frac{10}{10} = 0.1$ i.e every small square equal 0.1

From the graph the rough scale in y-axis is 2

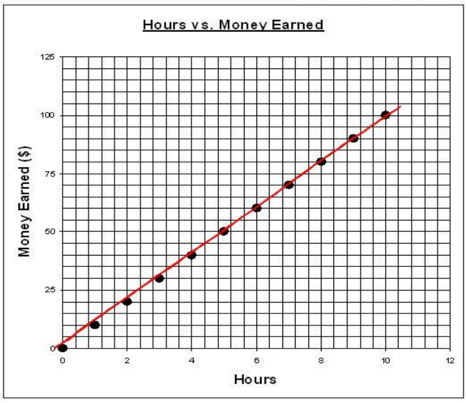
The partial reading equal $\frac{2}{10} = 0.2$ i.e every small square equal 0.2



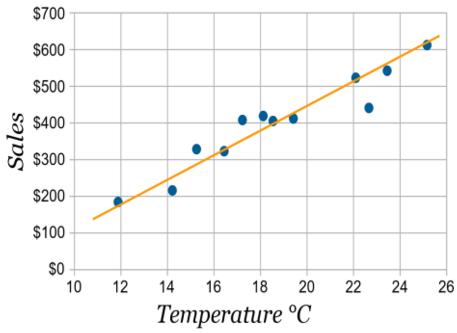
4) <u>Find each data point in your graph:</u>
Simply find each point in the graph by using the coordinates from the table of data. It is recommended to label your point by a dot inside a circle ⊙.

5) <u>Drawing a straight line through the data points:</u>
When the data fall on a straight line (or expected theoretically to do so), a ruler may be used to draw a straight line through the points.

☒ The line is drawn to match the data trend.



☒ For data with some scatter, balancing about an equal number of points above and below the line like a figure



6) Graphical analysis:

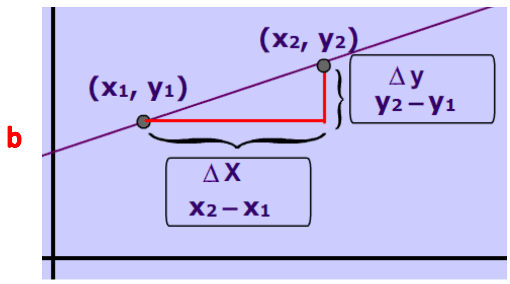
all the graphs should yield straight lines. As you may know that the general form of a straight line is

$$Y = mx + b$$

Where is m is the slope of the line, and b is intercept of $y - axis$

find the slope

We can find the slope by choosing any two points on the line itself (remember do not take any point from the table or your date) them use the equation.



$$slope\ m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

Slope direction

The slope of a line can positive or negative

Positive slope

Here, y increases as x increases, so the line slopes upwards to the right. The slope will be a positive number.

Negative slope

Here, y decreases as x increases, so the line slopes downwards to the right. The slope will be a negative number.

Procedure:

Example 1: A student hangs various masses M from spring and records the resulting the spring has stretched X as see in the table blew to study Hook's law (F = - K X)

M (kg)	0.12	0.15	0.22	0.27	0.35	0.40
X (m)	0.30	0.45	0.67	1.09	1.15	1.4
F = Mg (N)						

1) Calculate the force by using the equation F = Mg where g is the acceleration of gravity and equal 9.8 $m/s^{2.}$
2) Plot the relation between X and F (F as the vertical axis and X as the horizontal axis)
3) calculate the spring constant K where the spring constant is the slope of the line. Find the percentage error if the theoretical value of spring constant is 4.5 N/m

Example 2: The data set given in Table below is expected to obey a linear relation $v = v_o + at.$

Plot the relation between v and t, and from your analysis of the graph find the acceleration a and initial velocity v_o?

T (sec)	1	2	3	4	5	6	7	8	9
V(m/sec)	0.6	0.7	0.82	0.96	1.08	1.16	1.26	1.34	1.5

Experiment 2

Accurate Measurements

Objective:

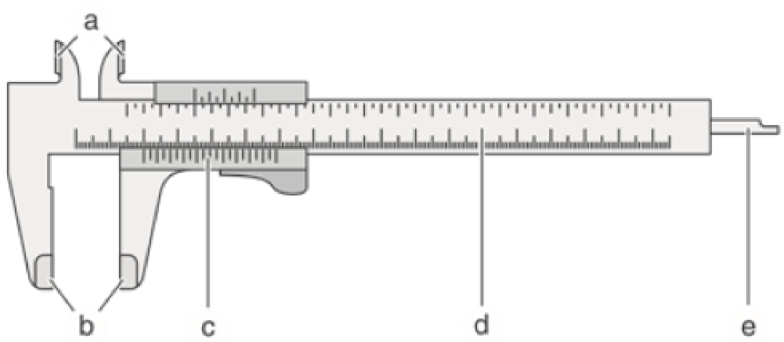
1. Determination of dimensions of cylinder by means of a Vernier Calipers
2. Measuring a diameter of thin wire and thickness of the slide by means Micrometer.
3.Improvement of the measuring accuracy by means of a Vernier and Micrometer.

Equipment

Vernier Calipers – Micrometer - Some objects (cylinder, thin wire and slide or sheet of wood)

Theory:

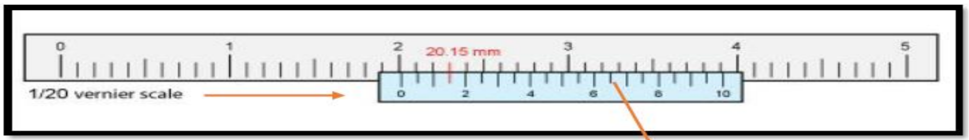
Vernier Calipers: it is a precision measuring tool.



Uses:
The length of a rod or any object: The diameter of a sphere - The internal and external diameter of a hollow cylinder - The depth of a small beaker

Consists of the following parts:
1. Main Scale (d) - The main scale is similar to that on a ruler, graduated in mm and cm on one side; inches on the other side.
2.Vernier Scale (c) – The vernier scale is a sliding scale. It slides parallel to the main scale and enables readings to be made to a fraction of a division on the main scale.
3.Screw -The vernier scale can be fixed at any position on the main scale with the help of a screw.
4.Jaws (a,b) : it has two jaws. (a)The upper (or short) jaws are called the inside jaws which are used to measure the internal diameter of a hollow cylinder or pipe. (b) The lower (or long) jaws are called outside jaws and they are used to measure the length of a rod, diameter of a sphere or the external diameter of a cylinder.
5. Tail (e)- The thin tail is used to measure the depth of the objects like beakers.

In our lab we have Vernier scale for this type section to 20 and it is less a reading of this type is 0.05 mm.



No. of divisions on Vernier scale = 20
Each small division on Vernier scale = 1/ 20 = 0.05

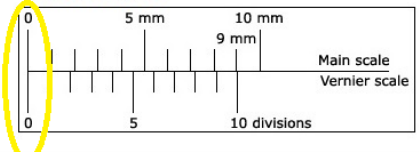
How to take reading:

Reading = Main scale+ Vernier scale + zero error

Zero error

When the two jaws are in contact, if the zero of the vernier coincides with the zero of the main scale, then the instrument has no error as show in the figure.

No Zero Error



zero error = 0 mm

Otherwise the instrument has zero error and correction should be applied to every measurement made with the instrument. This applicable decide the value of error and determine its direction so that added (if zero of varnier before the zero of main scale) or subtracted (If zero right the original zero) from any reading of the measurements were taken.

zero error = ± (the number of lines × 0.05)

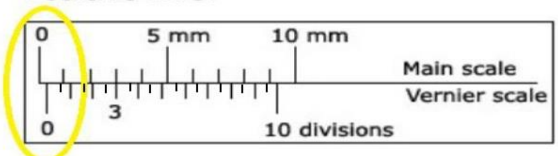
Zero error is of two types.

1. Positive error
2. Negative error

Positive error:

A positive zero error occur when the zero of the vernier scale is to the right of the zero of the main scale when the two jaws are in contact. Then calculate the number of lines of Vernier scale (the number of lines × 0.05 mm) with subtracting this value

Positive Error



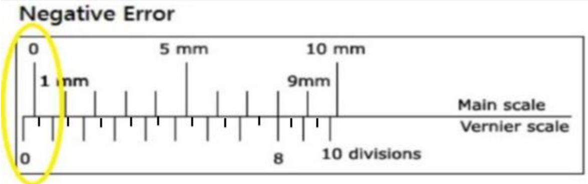
Here the number of lines is 6

zero error = - (6 × 0.05) = - 0.3 mm

Negative error:

A negative zero error occur when the zero of the vernier scale is to the left of the zero of the main scale when the two jaws are in contact. Then calculate the number of lines of Vernier scale (the number of lines × 0.05 mm) with adding this value

Negative Error



Here the number of lines is 16

zero error = + (16 × 0.05) = + 0.8 mm

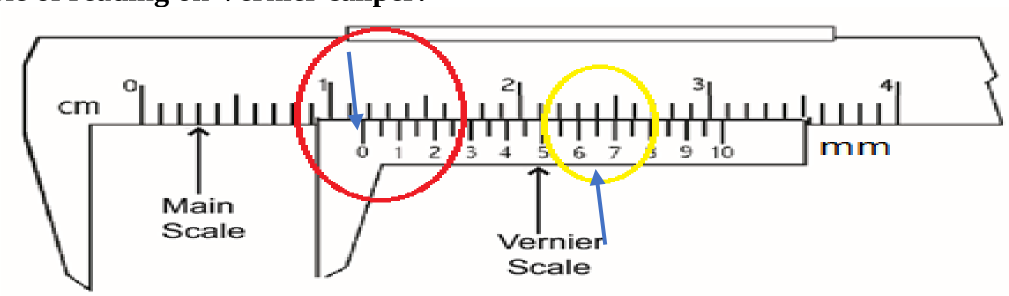
Main scale
Read the scale as the scale of the ruler perfectly. Each small division on the main scale is 0.1 cm. In main scale: read until the zero of Vernier scale cross the main scale then take the reading to covert the value from cm to mm by multiplying by 10 $\frac{mm}{cm}$.

$$(\text{reading } cm \times 10\frac{mm}{cm}) \;=\; \quad mm$$

Vernier scale
Search for a line of vernier scale to be fully applicable with main scale. Then calculate the number of lines of Vernier scale and multiplying by 0.05.

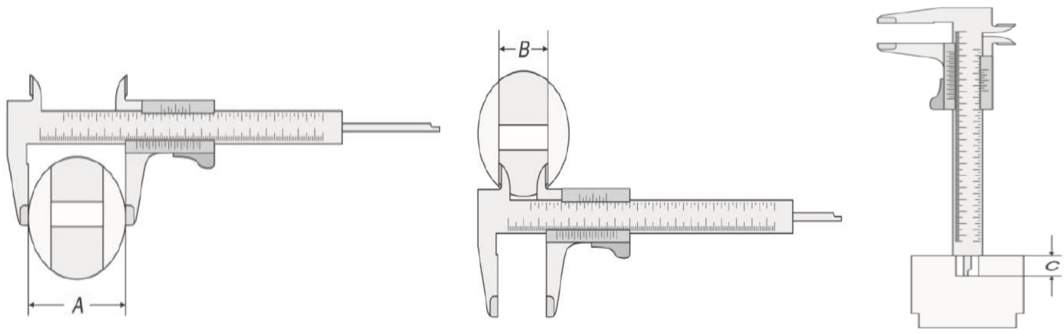
(the number of lines × 0.05 mm)

Example of reading on Vernier caliper:



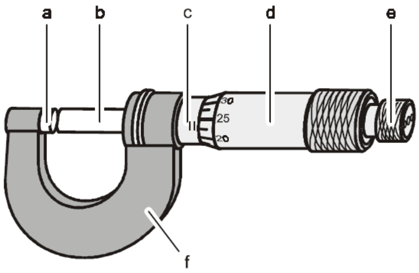
To measure the width for example above, you read the top and bottom scale as follows:
• Find where the 0 mark of the Vernier scale lines up on the main scale. In this case, it is between 1.1 and 1.2 cm. So, the first reading is 1.1 cm.
• Covert the value from cm to mm by multiplying by 10. In our case 1.1cm X 10 = 11 mm
• Find the mark on the Vernier scale that most closely lines up with one of the marks on the main scale. the number of lines of Vernier scale (13 × 0.05 mm)
• The total reading without zero error is: 11 mm + 0.65mm = 11.65 mm

Setup and carrying out the experiment
A) Determination of an outside dimension:
Loosen the catch of the gauge, bring the object to be measured between the long measuring jaws and push the measuring jaws into close contact without tilting.
B) Determination of an outside dimension:
Loosen the catch of the gauge. Guide the object to be measured over the short measuring jaws and slide the measuring jaws apart so that they ride up on the inside plane without tilting.
C) Determination of a depth:
Loosen the catch of the gauge. Set the ruler on the edge of the hole and by moving the slide lower the tail until it makes contact with the base.
D) Determination of a height:
Loosen the catch of the gauge, bring the object to be measured between the long measuring jaws and push the measuring jaws into close contact without tilting.



Micrometer

The micrometer is known for screw gauge because a calibrated screw is used for precise measurements. It is used to measure even smaller dimensions than the vernier callipers. The accuracy of the micrometer screw gauge is $0.01 = \frac{0.5}{50}$. This is very high accuracy compared to the vernier calliper accuracy.



Uses:

The thickness of a sheet or slid and the diameter of thine a wire are expressed in gauge number

Consists of the following parts:

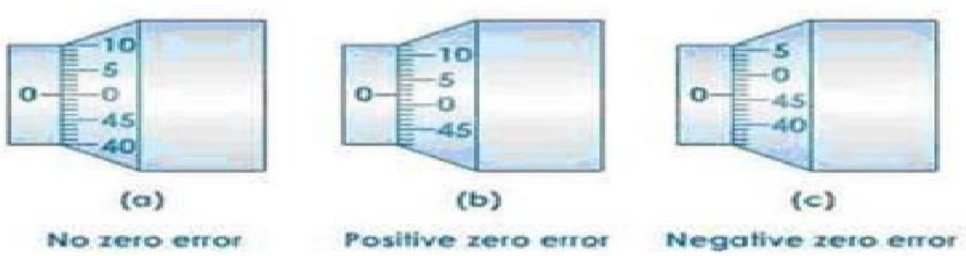
1. U-shaped Steel Frame or bow (f) : U shaped or C shaped frame will hold all the other parts together.
2. jaws (a, b): They were attached to the moving jaw and fixed jaw on the frame.
3. Lock Nut: The lock nut is to lock the moving jaw without altering the distance between the measuring jaws when the micrometer is at its correct reading.
4. Main Scale (c): This is having a 0.5 mm division length along the length of it.
5. Vernier Scale (d) or Thimble: it is having 50 divisions on its circumference. It will be moved over the barrel.
6. friction clutch (e): The jaws can be adjusted by rotating the thimble using the small clutch

How to take reading:

Reading = Main scale+ Vernier scale + zero error

Zero error: The scale of the error-free zero knowledge when you can touch the stem with a prominent part alone installer with the progressive application of a zero longitudinal and circular. If their application is said that there is zero error is determined by the number of parts (lines) on the scale ring confined between zero grading scale longitudinal line. Combines zero. error if the zero-ring staging goes to zero for the linear scale (ie, located to the left of zero longitudinal staging) and ask if the reverse occurs. This applicable decide the value of error and determine its direction so that added (if zero of varnier above the zero of main scale) or subtracted (If zero down the original zero) from any reading of the measurements were taken.

zero error = ± (the number of lines × 0.01)



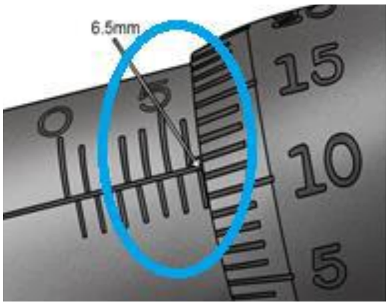
a) zero error = (0 × 0.01) = 0, b) zero error = + (2 × 0.01) = + 0.02mm
c) zero error = - (4× 0.01) = - 0.04 mm

Main scale:
Looking at sleeve scale, the value of the first significant figure of a measurement can be found on the sleeve scale. This will be the number immediately to the left of the thimble.
On a metric micrometer, this will be given in millimetres. Each minor increment on the sleeve scale represents 0.5mm. in main scale the reading above the line is 1 mm while the reading in below the line is 0.5 mm.

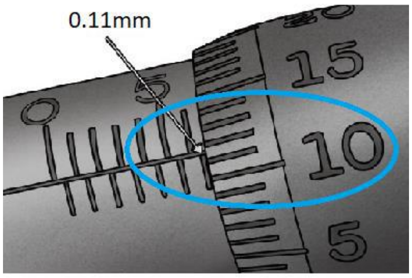
Vernier scale:
take the reading from vernier scale where the horizontal line of main scale applicable with vertical line of veriner scale, each line is 0.01 mm
Look at thimble scale ; Then, read the value shown on the thimble scale.
The thimble scale of a metric micrometer has a range of 0.5mm. The value is the lowest number that aligns best with the index line on the sleeve scale.

(the number of lines × 0.01)

Example of reading on Micrometer



Main scale



Vernier scale

In this example, the main reading is 6.5mm
The vernier reading on the thimble scale is showing = (11 × 0.01) = 0.11mm
To get your total reading, add the values from each of the scales together
(main scale + thimble or vernier scale = measured value) = 6.5mm + 0.11mm = 6.66 mm.

Procedure:
Part 1: measuring by Vernier Caliper

You are required to measure the external and internal diameter of the cylinder given to you, also measure height and depth for the same cylinder.
1 - write the accuracy of the scale you are using.
2 - Select the zero-error, if any, should be taken into calculating in all readings.
3- Measure the external diameter of the cylinder two times from different positions and record readings in the table prepared and then calculate the average.
4 - Measure the internal diameter of the cylinders of different positions and record readings with the calculated average.
5 - Measure the length of the cylinder from the outside two times from different positions and record readings with the calculated average.
6 - Use the tail of Vernier caliper in the measurement of the deep interior of the cylinder two times and record your results in the table.

Part 2: measuring by Micrometer
You are required to measure the diameter of a metal rod and measuring the thickness of the slide
1 - write the accuracy of the scale you are using.

2 - Select the amount of zero-error, if any, should be taken into calculating in all readings.
3 - Measure the diameter of the metal rod two times and record your measurements in the table prepared with a record average reading.
4 - Measure the thickness of the slide given two times from different positions and record your measurements with the calculated average

Experiment 3

Force table

Objective:

1. Using the force table to experimentally determine the force that balances two other forces.
2. Checking the result by arithmetically adding the Force vector components and graphically adding of them.

Equipment

Force table - Hanger set - A set of mass - Protractor - Ruler

Theory:

Physical quantities are of two types, scalar and vectors. Scalars quantities have only magnitude, while vectors have both magnitude and direction. Adding or subtracting vectors are different from adding or subtracting scalars. In this experiment we will add forces, which are vector quantities, experimentally using the force table. Then we will compare the results obtained with the theoretical methods of adding vectors.
The force table is an apparatus that allow us to add vectors by applying forces on a ring placed in the middle of the table. The forces can be adjusted in magnitude by changing the masses, or in direction by moving the pulleys. The goal is to keep the ring perfectly centered, in order to consider it to be in equilibrium and then apply Newton's law on it, which state that in equilibrium, all forces should add to zero. Therefore, we can find the sum of any two forces by knowing all the forces acting on the ring.

Vector can be collected in one of two methods:
1- Experimental Method
When an object is in equilibrium it has no acceleration, and therefore the sum of all forces acting on it equal zero,

$$\Sigma\vec{F} = 0$$

If two forces are acting on an object and a third force act in a way that bring the system to equilibrium. Then according to Newton's law, the sum of the three is zero,

$$\vec{F_1} + \vec{F_2} + \vec{F_b} = 0$$

Where F_b is the balancing force that brings the system to equilibrium.

$$\vec{F_1} + \vec{F_2} = -\vec{F_B}$$

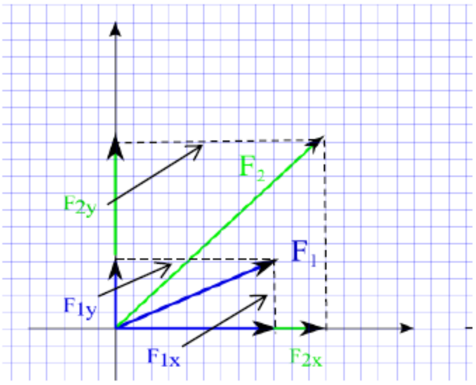
Therefore, the resultant force (F_R) is just the same magnitude as the balancing force but acts in the opposite direction.

$$\vec{F_R} = -\vec{F_B}$$

The force table is then can be used to find the resultant force of two forces by first applying the two forces on the ring. Then the third pulley is adjusted, and the masses are varied until the ring becomes perfectly centered. We know then that the resultant force is the same magnitudes as the third force but acts in the opposite direction.

2- Theoretical Method
A. Component method
B. Graphic representation (called a closed polygon method)

A. Component method
Forces cannot be added directly due to the difference in direction. However, if each force is resolved into a horizontal and a vertical component, these components may be just simply added to find the components of the resultant Force. Therefore, in order to use this method, we should first learn how to resolve each force to its component:



Compounds of force in the direction (x-direction) are:

$$F_{1x} = F_1 \cos\ \theta_1 \qquad\qquad F_{2x} = F_2 \cos\ \theta_2$$

Compounds of force in the direction (y-direction) are:

$$F_{1y} = F_1 \sin\ \theta_1 \qquad\qquad F_{2y} = F_2 \sin\ \theta_2$$

Total compounds of force in the (x-direction) be:

$$F_x = F_{1x} + F_{2x} = F_1\cos\theta_1 + F_2\cos\theta_2$$

Total compounds of force in the (y-direction) be:

$$F_y = F_{1y} + F_{2y} = F_1\sin\theta_1 + F_2\sin\theta_2$$

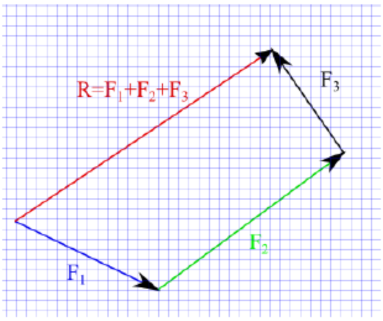
Amount collected is the following

$$F_R = \sqrt{F_x^2 + F_y^2}$$

The direction of the resultant force can be calculated through the following expression.

$$\theta_R = \tan^{-1}(Fy/Fx)$$

B. Graphical Method
As shown in the example above, draw a polygon with the three given vectors F_1, F_2, F_3 by placing the vectors, one after another, on a tail-to-tip basis. First draw F_1. Then from the tip of F_1, drawF_2. Next, from the tip of F_2, draw F_3. Finally, connect the tail of F_1 (the first one) to the tip of F_3 (the last one) to obtain the resultant ($R = F_1 + F_2 + F_3$) .



Procedure:
Part 1: Experimental Method

1. Choose two different forces (magnitude and direction). For the first force, at angle 50° mass (60 g). For the second force, at angle 330° mass (90 g). Attach suitable slotted masses with the thin strings to the center ring of the force table. Remember that:
2. Consider the direction of each force which is represented by the angle. The force table's edge will help you identify the angle accurately.
3. In order to balance the ring; a third force should be attached.
4. Record the magnitude and direction of the Balancing force in the following table.
5. Now find the resultant force which is equal and opposite to the equilibrium force. (F_R here is the F_{exp})

Part 2: Components method

1-Find the resultant force using the components method. By knowing F_1, F_2, θ_1 and θ_2, Find F_x and F_y then find F_R and θ_R

$\theta_R = \tan^{-1}\left(\frac{F_y}{F_x}\right)$, $F_R = \sqrt{F_x^2 + F_y^2}$

(F_R here is the F_{theor1})

2- Find the percentage error between $F_{exp.}$ and (F_{theor1})

$$\text{percentage error} = \frac{F_{exp} - F_{theor1}}{F_{theor1}} x\ 100$$

Part 3: Graphical Method

1- Find the resultant force using a polygon method.

2- Plot the forces on graphing paper by setting a drawing scale. (for example, 0.3 N = 1 cm).

3- Find the resultant force graphically. The magnitude of the force is represented by the length of the vector and should be converted using the scale you have chosen. (F_R here is the F_{theor1})

4-The direction is represented by the angle which you can measure using the protractor.

5- Find the percentage error between $F_{experiment}$ and (F_{theor2})

$$\text{percentage error} = \frac{F_{exp} - F_{theor2}}{F_{theor2}} x\ 100$$

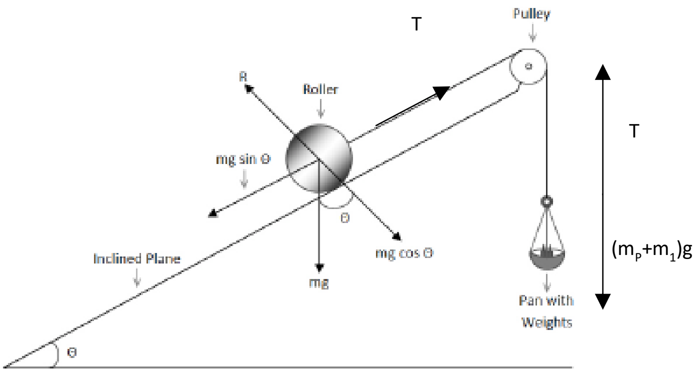
Experiment 4

Forces on an Inclined Plane

Objective:
To find the downward force acting on a roller along an inclined plane, due to gravitational pull of the earth and study its relationship with angle of inclination, θ.

Equipment
Inclined plane, Pulley, Metal Roller, Thread, Pan, Weights.

Theory:
The downward force acting on a roller along an inclined plane:



If we assume the inclined plane is a frictionless surface. From the figure the mass of roller is M, tension in the string or thread is T, the mass of pan is m_p and the mass on the pan m_1 or m_2.
By analyse the motion of the figure and Keep in mind that acceleration is zero because of constant velocity.

$$T - Mgsin\theta = 0$$
$$(m_1 + m_p)g - T = 0$$

If total weight $W_1 = M_1 g$ moves the roller up (which $M_1 = m_1 + m_p$) and total $W_2 = M_2 g$ moves the roller down(which $M_2 = m_2 + m_p$), then downward force acting on the roller along the inclined plane,
It is difficult to determine exact value of W. What we can do is we find tension W_1 (< W) at which the roller is just at the verge of rolling down and W_2 (> W) at which the roller is just at the verge of moving up. Then we can take

$$W = \frac{W_1 + W_2}{2} = \frac{(M_1 + M_2)g}{2}$$

This force W must be equal to $Mg \sin\theta$ i.e.

$$W = Mg \sin\theta$$

Where Mg is the weight of the roller.

Procedure:

1. Set up the inclined plane at 0 slope by ensuring that it is in horizontal plane.
2. Find the weight of the roller by balance and place it on the inclined plane.
3. Tie one end of a thread to the roller placed on the inclined plane and passes it over the pulley.
4. Find the weight of the pan by balance and tie it to free end of thread, keeping the thread free from board.
5. Raise the inclined plane and fix it at an angle of 20°. The roller may start rolling down with acceleration.
6. Put weights on the pan and increase them till the roller just starts moving upward with uniform velocity only on tapping. Note the total weights in pan.
7. Remove some small weights from weights in the pan till the roller just starts moving downward with uniform speed only on tapping. Note the total weights in pan.
8. Increase the angle of inclination in steps of 10° each, making it 30°, 40°, 50°...
9. Record your observations in Data Table
10. Wright the relation between downward force and angle of inclination of the plane.

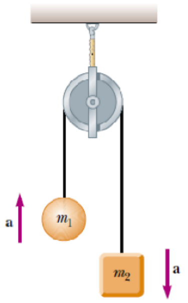
Experiment 5

Atwood Machine

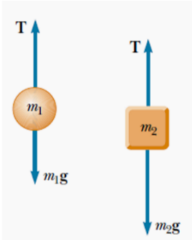
Objective:
1. Test Newton's 2nd Law of Motion by utilizing an Atwood machine apparatus.
2. Exploring the relationship between the acceleration, tension, and the masses in the apparatus.

Equipment
Atwood's machine consisting of two pulleys with string attached over pulley to two weight hangers; sets of gram-weights, meter stick and stopwatch.

Theory:
An Atwood's Machine consists of two objects of different masses hanging vertically over a friction-less pulley of negligible mass. When the system is released, the heavier mass accelerates downward while the lighter mass accelerates upward at the same rate. The masses are connected by a light string (also assumed to have negligible mass), so we assume the tension T is the same in each part of the string. The acceleration a, which is the same for both masses but in opposite directions, depends on the masses, m_1 and m_2, of the objects as well as the gravitational acceleration constant g.



To solve it, let's separate the system into two smaller subsystems, where each subsystem consists of one mass, and apply Newton's second law for each subsystem. Since the movement of each object is just in the vertical direction, we only need to calculate the net force in the y-direction for each object.
To determine a sign convention (which direction is positive, and which is negative) for this problem is important; and, since each object has its own separate subsystem, we can assign a different sign convention for each of them. The recommendation is always to pick the *positive direction as the direction of the acceleration in the system*. In this way, according to the previous figure, object 1 of mass m_1 has an upward acceleration, so that the reference is positive in the upward direction. Meanwhile, for object 2 of mass m_2, the reference is positive in the downward direction, because of its downward acceleration. Hence, the direction of the acceleration vector next to each mass in the diagram above indicates the positive direction for each subsystem.
Applying Newton's Second Law based on the free-body diagrams below, the force equations for masses 1 and 2 are:



$$\sum F_y = T - m_1 g = m_1 a_y \qquad (1)$$

$$\sum F_y = m_2 g - T = m_2 a_y \qquad (2)$$

Note that the tension and acceleration of the two systems are exactly the same, because they are connected through the same lightweight string and the pulley is friction-less and has a neglected mass.
Solving this system of equations, the expressions for the acceleration is:

$$T - m_1 g + m_2 g - T = m_1 a_y + m_2 a_y$$

$$(m_2 - m_1)g = (m_2 + m_1)a_y$$

$$a_y = \frac{m_2 - m_1}{m_2 + m_1}\, g \qquad (3)$$

It is also possible to determine the acceleration of the 2 masses by measuring the time it takes for the masses to descend a distance y to the floor, using the equation,

$$y - y_0 = v_0 + \frac{1}{2}\, a\, t^2$$
$$\Delta y = y - y_0 \quad and\ v_0 = 0$$

$$\Delta y = \frac{1}{2}\, a\, t^2$$

$$a = \frac{2\,(\Delta y)}{t^2}$$

$$t^2 = \frac{2}{a}\,\Delta y \qquad (4)$$

The equation above is given a straight line on the image y = mx. Where the variable x offset Δy and variable y offset t^2 and inclination.

$$m(slope) = \frac{2}{a}$$

$$a = \frac{2}{m(slope)} \qquad (5)$$

Procedure:

1. Loop your string over the pulley and connect masses on each side of the string while holding the wheel stationary. Set the masses to two weight hangers for example 30 g and 32 g. After hanging the masses, be sure the wire become stable (do not swinging).
2. Measure the y_0 which is the maximum height of heavier mass. This value will be used as a reference point.

3. Make the heavier mess follow a free fall to different distance y = (28, 31,34, 37, 40, 43) cm and record the time twice on the table in the report. Then, take the average of time.
4. Calculate $\Delta y = y - y_0$ and for each value t^2 on the table.
5. draw a relationship between Δy (on x-axis) and t^2 (on y – axis)
6. Calculate the slope of the straight line.
7. From equation 5, Calculate acceleration $a = \frac{2}{m(slope)}$ which the experimentally value.
8. Find the theoretically acceleration from equation 3, $a = \frac{m_2 - m_1}{m_2 + m_1}\, g$
9. Find the percentage error of acceleration

Experiment 6

ARCHIMEDES' PRINCIPLE

Objective:

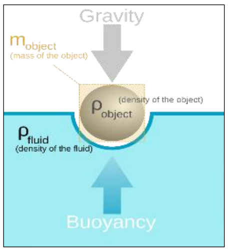
1. Study of forces and balance in fluids
2. Apply Archimedes Principle by measuring buoyant force and weight of water displaced.

Equipment:

Objects test (Plastic, aluminum and copper cylinders) + string ,Vertical long, rod, clamp , force sensor, beakers, and water.

Theory

Archimedes' principle states that a body wholly or partially submerged in a fluid is buoyed up by a force equal in magnitude to the weight of the fluid displaced by the body.



This force is given by:

$$F_B = F_g = m\, g = \rho\, V\, g$$

where ρ is the density of the fluid, V is the volume of fluid displaced and g is acceleration due to gravity.
F_B is the buoyant force that works to bounty up the objects while the objects weight drive them down, thus, when a body wholly or partially submerged in a fluid, there are some events that would happen which are summarized in the table below

density of water Vs. density of objects	buoyant force (F_B) Vs. objects weight (in air)	events
$\rho_{water} > \rho_{object}$	buoyant force (F_B) = the submerged part of object weight (in air)	Partially buoyed up
$\rho_{water} = \rho_{object}$ (regular objects)	buoyant force (F_B) = object weight (in air)	a body wholly submerged

$\rho_{water} = \rho_{object}$ (irregular objects)	buoyant force (F_B) = object weight (in air)	a body wholly submerged and rotation (spin) around the mass axe
$\rho_{water} < \rho_{object}$	buoyant force (F_B) <object weight (in air)	a body wholly submerged and rest in the ground

In this experiment, the buoyant force will be measured three ways and the results compared.

The first method is by the measurement of force. This method involves weighing an object first in air, then in water, and using the difference in weight as the buoyant force. Though the object's mass does not change, its apparent weight will change when measured while immersed in a fluid that is denser than air.

$$F_B = W_{air} - W_{water}$$

W_{air} is the weigh of the object in air and W_{water} is the weigh of the object in water.

The second method is the displaced volume method. The volume of fluid displaced by the object is measured and its weight calculated. The weight of the water displaced is equal to the buoyant force exerted on the object, by Archimedes' Principle.

The third method is by the buoyant force equation method. By measuring the dimensions (height and radius of each cylinder) of the object and calculating the volume, one can determine the buoyant force (by using Eq-1) that would be exerted on the object when it is submerged in a fluid of known density ρ .

Please note that for the third method, the volumes of interest are different for objects that float and objects that sink.

Procedure:
The first method (Buoyant Force)

1. Create a table as shown below. In the table W_{air} means the weight in air, and W_{water} means the weight in water, both with units of N. The last column contains a calculation.
2. Measure the weight of one of the cylinders in air and record in table at W_{air}
3. Suspend the object by a string tied into force sensor. Partially fill the beaker with water, then completely submerge the cylinder. Do not allow the cylinder to touch the sides of the container.
4. Measure its weight in water and record in table at W_{water}
5. The difference between the object's weight in air and its weight in water is the buoyant force on the object or $F_B = W_{air} - W_{water}$

The second method (Weight of fluid displaced)

1. From step 2 collect displaced water in measurement beaker and record the volume of displaced water (1ml = 1 x 10^{-6} m^3)
2. From the volume of displaced water find the mass by using
$$m = \rho_{water} \times V$$
3. Density of water = 1000 kg /m^3
4. Calculate the weight of displaced water from equation
$$W_{\text{displaced water}} = m_{\text{displaced water}} \times g$$
5. Compare the values obtained for buoyant force (from step 4)

The third method (Weight Method vs. Volume Method)

1. Measure the height and radius of each cylinder; calculate the volumes from equation ($V = \pi r^2 h$)
2. Using these volumes, the acceleration of gravity g and the density of water, calculate the respective buoyant forces using Eq-1.

$$(F_B = \rho V g)$$

Experiment 7

Viscosity

Objective:
Determining the viscosity of a liquid by using a falling ball (Stokes method).

Equipment
A clear tube filled with a viscous liquid (Glycerine), Micrometer, stopwatch and small balls (with various diameters).

Theory:
The viscosity of a liquid can be measured using a viscometer. A viscometer consists of a graduated glass cylinder filled with the liquid in in our case glycerine. Small steel spheres are dropped into the liquid from the top. After falling sufficiently, the spheres acquire terminal velocity.
For a spherical bodies Stokes derived the following formula:

$$F_d = 6\pi\eta r v$$

where η is the coefficient of viscosity, *r* is the radius of the sphere and *v* is the velocity of the sphere.

There are three forces acting on the sphere ball dropped into the liquid its weight W, an upward buoyant force F_b (Archimedes' Principle) and the drag force F_d (Stake's Law) as shown in figure

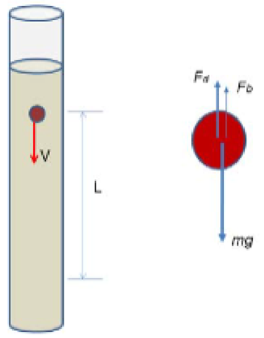


Figure 1 – A Falling Ball Viscometer.

1) The force of gravity

$$W = mg = Vg\rho$$

where V is the volume of the sphere ball, ρ is the density of the sphere ball and g is acceleration of gravity

2) Buoyancy force

$$F_b = Vg\rho_0$$

Where ρ_0 is the density of the liquid.

3) Viscous drag force

$$F_d = 6\pi\eta r v$$

By summing forces in the vertical direction, the following equation can be written:

$$W = F_b + F_d$$

or

$$Vg\rho = Vg\rho_0 + 6\pi\eta rv$$

The volume of a sphere is written as $V = \frac{4}{3}\pi r^3$.

Rearranging and regrouping the terms from the above equation the following relationship will be arrived the viscosity of glycerine

$$\eta = \frac{2r^2(\rho - \rho_0)g}{9v}$$

Where

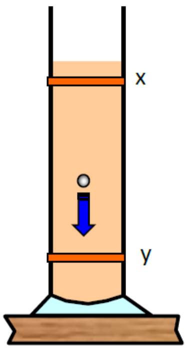
η is the viscosity of glycerine, ρ is the density of the sphere ball ($\rho = 7790$ kg / m^3), ρ_o is the density of glycerine ($\rho_o = 1260$ kg / m^3), g is the acceleration due to gravity (g = 9.8 m / s^2), r is the radius of the ball and υ is the velocity of the ball. The equation above is given a straight line on the image y = mx .where the variable x offset r^2 and variable y offset v and inclination.

$$m\,(slope) = \frac{2\;\;g\;\;(\rho - \rho_o)}{9\,\eta}$$

$$\eta = \frac{2\;\;g\;\;(\rho - \rho_o)}{9\;\;slope}$$

Procedure:

1) place two marks on the glass tube and measure the (L) where the distance between the two markers.
2) determine the radius r for each balls and record in the table
3) Drop the ball through the hole into the glass cylinder
4) Using the stopwatch to measure the time of the fall of each ball between the two markers.
5) Record the time for each ball in the table twice and take the average for the time to same ball size.
6) Compute the velocity for each ball by using the equation $\upsilon = L/t$
7) draw a relationship between r^2 (on x-axis) and υ (on y – axis)
8) Calculate the slope of the straight line.
9) Calculate viscosity of glycerine by using



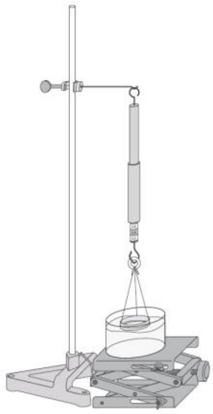
$$\eta = \frac{2\;\;g\;\;(\rho - \rho_o)}{9\;\;slope}$$

Experiment 8

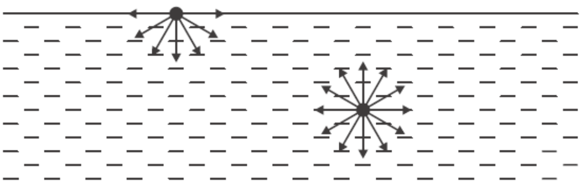
Surface tension

Objective:
1. Creating a liquid layer between the edge of a metal ring and the surface of the liquid.
2. Measuring the tensile force acting on the metal ring just before the liquid layer breaks away.
3. Determining the surface tension from the measured tensile force.

Equipment
Aluminium ring with a sharp-edged profile. Attached to it are three threads with a hook for hanging it on a dynamometer. String, Vertical long, rod, clamp, beakers, and water. Glycerine. Another liquid.



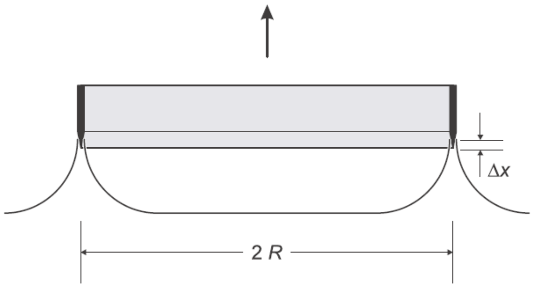
Theory:
The surface tension is due to the fact that a molecule on the surface of a liquid is acted upon by attractive forces from adjacent molecules towards one side only (see Fig. 2). The resultant force acting on the molecule points into the liquid and is perpendicular to the surface.



In order to enlarge the surface, i.e. to take more molecules to the surface, energy has to be supplied. The ratio of the energy ΔE supplied at a constant temperature and the change of the surface ΔA is called surface energy or surface tension of the liquid:

$$\sigma = \frac{\Delta E}{\Delta A} \qquad (1)$$

The surface tension can be measured, e.g., by means of a metal ring with a sharp edge which at first is immersed in the liquid so that it is completely wetted. If the ring is slowly taken out of the liquid, a thin liquid layer is pulled up (see Fig. 3).



The outside and inside surface of the liquid layer changes by

$$\Delta A = 4 \cdot \pi \cdot R \cdot \Delta x \qquad (2)$$

R: radius of the metal ring when the metal ring is lifted by Δx. Pulling up the ring requires the force

$$F = \frac{\Delta E}{\Delta x} \qquad (3)$$

to be applied. If this force is exceeded, the liquid layer breaks away. Because of Eqs. (1)-(3), the surface tension is

$$\sigma = \frac{F}{4\pi R} = \frac{F}{2\pi d} (4)$$

Procedure:

1. Determine the diameter of the metal ring.
2. Make the zero adjustment at the dynamometer using the movable tube and read the value …
3. Fill distilled water into the crystallization dish.
4. Lower the clamp with hook until the metal ring is completely immersed.
5. Cautiously lower the laboratory stand, always observing the tensile force at the dynamometer.
6. As soon as the edge of the metal ring emerges from the liquid, the liquid layer is formed. (When the tensile force does no longer increase although the laboratory stand is further lowered, the layer is just before breaking away).
7. Read the tensile force just before the layer breaks away and take it down.
8. Pour the distilled water out and dry the crystallization dish and the metal ring.
9. Repeat the measurement with glycerine.
10. Repeat the measurement with another liquid.
11. Find the percentage error of those liquids if you know (water at 20 C^0 is 72.8 mN/m , glycerine at 20 C^0 is 64 mN/m)

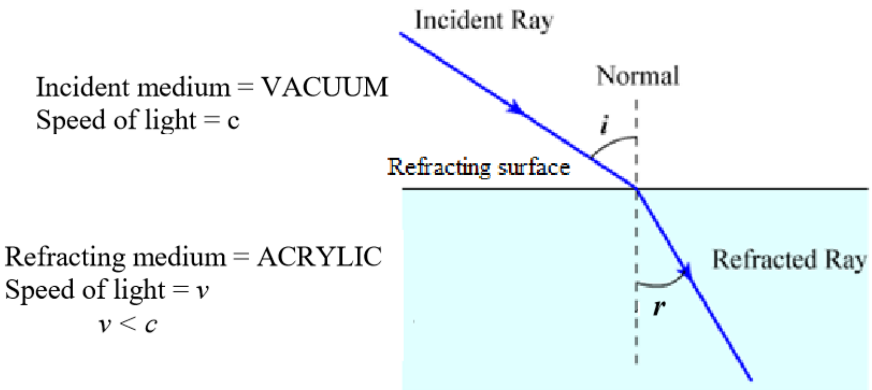
Experiment 9

Refractive Index of the Materials

Objective:
1. To study the refraction of light from plane surfaces.
2. To determine the index of refraction for Acrylic Rectangular and Prism.

Equipment
Rectangular Acrylic plate, Acrylic prism, protractor, ruler, Cork board, white paper, pins.

Theory:
When a ray of light passes from one medium into another one of different optical density, it undergoes a change of velocity and a consequent change in direction. Figure 1 is an example of refraction. The incident ray makes an angle with the normal to the refracting surface called the angle of incidence, i. The refracted ray makes an angle with the normal to the refracting surface called the angle of refraction, r.



In Figure, if the incident medium is vacuum or free space, the speed of light is c. (The speed of light in air is very nearly equal to that in vacuum.)

If the ray passes from vacuum (or air) to higher density medium as (glass or acrylic), then the speed of light in the refracting medium v is less than the speed of light in the incident medium, the refracted ray bends towards the normal so that angle r is less than angle i.

the refractive index n of a medium maybe defined as the ratio between the speed of light in vacuum c to the velocity of light through the medium v .

Generally, Snell's law for light travelling from incident medium which is a vacuum (or air, approximately) to other medium, can be written by;

$$n = \frac{c}{v} = \frac{\sin i}{\sin r}$$

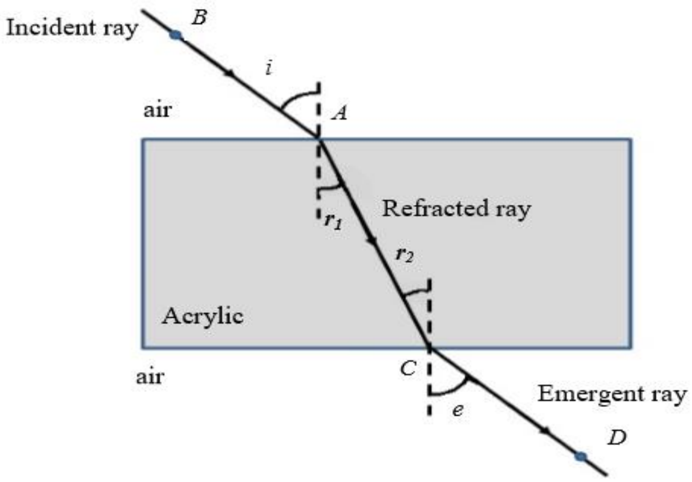
It is therefore possible to characterize a medium via its index of refraction by measuring the angles of incidence i and the angle of refraction r.

There are two parts to the experiment to study the refraction of light and determination of the index of refraction. In Part 1 we will use an acrylic slab and part 2 a prism.

Procedure:

First, Refraction by a rectangular acrylic plate:

1. Place a sheet of paper on the cork board, and on it the rectangular acrylic plate. Carefully trace out the outline of the plate.
2. Place the pins on the cork board. mark two points A and B along the incident beam, one near the plate and the other about 5 cm from it. See Figure. Do the same with the emergent line, points C and D. Point C is near the plate.



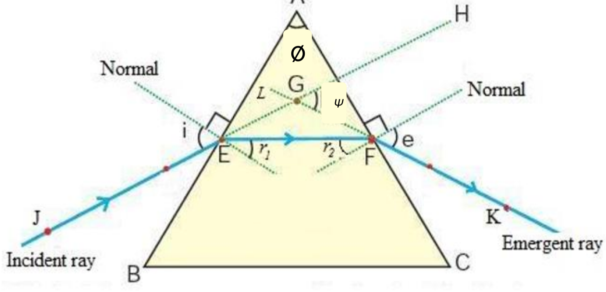
3. Now remove the plate from the paper. With the protractor, draw a perpendicular at points A and C. With the ruler, draw the incident, refracted and emergent beams. With the protractor, measure the angles i, r_1, r_2, eThen from Snell's Law, the index of refraction of the plate is

$$n = \frac{\sin i}{\sin r_1}$$

4. Calculate the percentage error

Second, Refraction by an acrylic prism:

1. Place the prism in the center of a sheet of paper on the cork board. Trace the outline of the prism. Mark off two points E and F on sides AB and AC of the prism that are equidistant from the vertex A. (See Figure)



2. Put the pin on the point E on side AB. Adjust the angle of incidence i of the beam such that the emergent ray emerges from point F on the side AC. Mark off two points J and K about 5 cm from points E and F along the incident and emergent beams, respectively.
5. Now remove the prism from the paper. With the protractor, draw a perpendicular at points E and F.
6. With the ruler, draw the incident, refracted and emergent beams. Extend the incident beam JE to H. Extend the emergent beam FK backwards to L.
7. With the protractor, measure the angles i, r_1, r_2, e the vertex angle α and the angle of minimum deviation Ψ.
8. As shown below, the index of refraction n as obtained from Snell's Law can also be expressed in terms of the angle of minimum deviation Ψ and the vertex angle Ø as

$$n = \frac{\sin i_1}{\sin r_1} = \frac{sin\frac{\Psi + Ø}{2}}{sin\frac{Ø}{2}}$$

Note:

The minimum deviation in an isosceles prism occurs when there is symmetric refraction,

EF parallel to BC because $r_1 = r_2$.

9. Calculate the percentage error

Experiment 10

Focal Length of Thin Lens

Objective:
To determine the focal length of a convex and concave lens by using the General Law of Lenses

Equipment
Light source (object) - Convex lens – Concave lens - white Screen

Theory:
The lens is understood as a curved and transparent piece of glass or plastic, which focuses and refracts light rays in a certain manner. They are used in spectacles, microscope and telescopes. There are two basic types of lens, converging and diverging.
Convex lenses (also called converging or positive lenses) are those with at least one convex surface, See Figure 1. They all focus distant images at a point on the side of the lens opposite from the light source (its "positive" focal length).

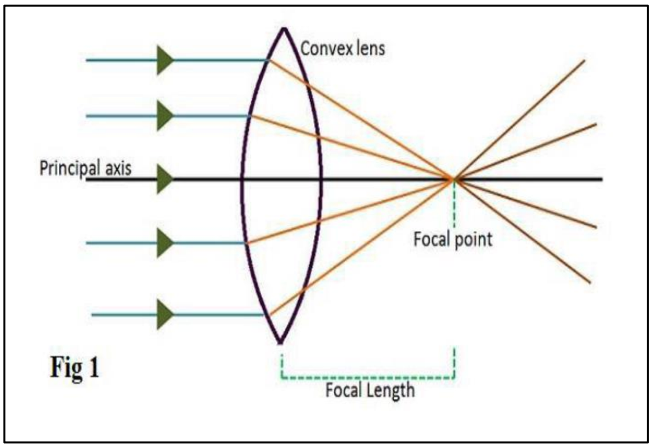


Fig 1

Concave lenses (also called diverging or negative lenses) are those, which have at least one concave surface, See Figure 2. They all focus distant objects so that for a viewer on the side of the lens opposite that from which light is incident, the object appears to be at a point behind the lens (its "negative" focal length).

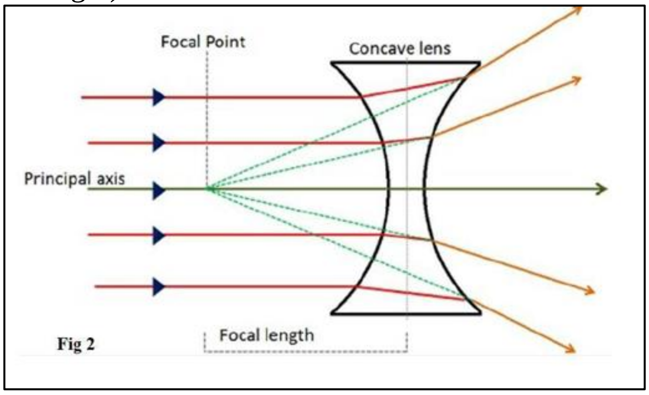
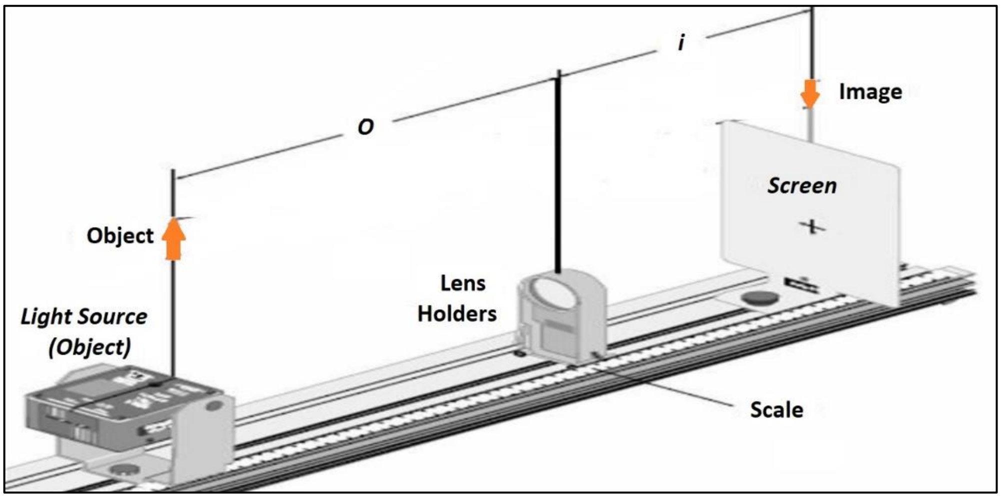


Fig 2

For spherical lenses a general equation can be used to determine the focal length and magnification of an image. This equation is called the General Law of Lenses equation:

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i} \qquad (1)$$

f is the focal length
o is the distance between the object and the lens.
i is the distance between the lens and white screen.



Remember
f is positive in the convex lenses and negative in the case of concave lenses.
o is positive in the case of the real body and the body in the case of a negative placebo.
i is positive in the case of the real image and in the case of negative image.

Procedure:
First, determined the focal length of convex lens

1. Place the light source (luminous body) near one end of the optical table and place the convex lens, a suitable distance from it. Place the monitor assigned to receive the body image in the bright side of the lens.
2. Move the screen back and forth until you get the clearest picture of the body bright.
3. Measure the distance between the lens and the screen (i) and record the value at table. And measure the distance between the lens and the object (o) and record the value at table (1).
4. Repeat the data collection steps Four more times, increasing the distance between the lens holder and the light source in each trial. Record the object distance and corresponding image distance for each trial into Table 1.
5. Calculate the inverse of each object distance and image distance value in Table 1. Record your results in the $\frac{1}{o}$ and $\frac{1}{i}$ in columns of the table.

   <u>For calculation method</u>
6. calculate the value of focal length(f) for each distance by using equation 1and record the results in Table
7. Calculate the average value of focal length (f)
8. Calculate the percentage error for focal length.

   <u>For Graphical method</u>

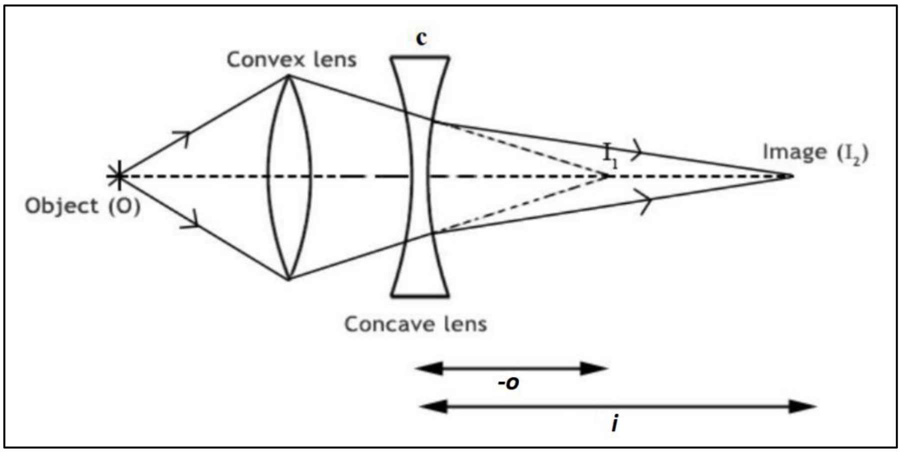
9. Plot a graph of $\frac{1}{o}$ versus $\frac{1}{i}$ in the blank Graph axes. Be sure to label both axes with the correct scale and units.
10. Draw a line of best fit through your data in the Graph.
11. Use the $y_{\text{intercept}}$ and $x_{intercept}$ from the graph to determine an experimental value for the focal length f of your lens where:

$$\frac{1}{f} = \frac{\mathrm{y_{intercept}} + \mathrm{x_{intercept}}}{2}$$

12. Calculate the percentage error for focal length.

Second, determined the focal length of concave lens

1. A collimated beam of light appears to diverge from the focus of a concave lens. As a result, we will use a convex lens in combination with the concave lens to find its focal length.
2. Place a convex lens in front of the light source then move the screen back and forth until you get the clearest picture of the body bright.
3. add concave lens (c) between the screen and the convex lens. as shown in the figure below.



4. Now you can see the image of the body that was visible on the screen disappeared now, or distorted. Measure the distance between the concave lens and white screen and record to a virtual object distance (- o).
5. Now, move the screen to the new focus created by the lens system.
6. Measure the distance between the concave lens and the screen and record image distance (i) in table 2.
7. Repeat the data collection steps from 1 to 6 four more times, increasing the distance between the lens holder and the light source in each trial. Record the object distance and corresponding image distance for each trial into Table 2.
8. Calculate the inverse of each object distance and image distance value in Table 1. Record your results in the $-\frac{1}{o}$ and $\frac{1}{i}$ in columns of the table.

For calculation method

9. calculate the value of focal length(f) for each distance by using equation 1and record the results in Table
10. Calculate the average value of focal length (f)
11. Calculate the percentage error for focal length.

For Graphical method

12. Plot a graph of $-\frac{1}{o}$ versus $\frac{1}{i}$ in the blank Graph axes. Be sure to label both axes with the correct scale and units.

13. Draw a line of best fit through your data in the Graph.
14. Use the $y$intercept and $xintercept$ from the graph to determine an experimental value for the focal length f of your lens where:

$$\frac{1}{f} = \frac{\mathrm{y_{intercept}} + \mathrm{x_{intercept}}}{2}$$

15. Calculate the percentage error for focal length.