Ministry of Higher Education

The Higher Institute Of

Engineering & Technology

(Tanta)

Physics – Lab Experiments Maual

Physics (I) Lab Course

By

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Evaluation Sheet

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إرشادات الأمن والسلامة في معمل الفيزياء

التجارب العلمية مفهوم أساسي من مقومات دراسة الفيزياء، ولكن إذا لم يؤخذ الحذر عند إجراءها فإنها قد تكون مصدر خطر؛ ولهذا فإن الحرص على سلامتك وسلامة زملائك يقتضي منك التقيّد ببعض القواعد الضرورية لتجنب الخطر وهي:

1- مراعاة النظام والهدوء أثناء الدخول إلى المختبر وأثناء الخروج منه.

2- المختبر ليس مكاناً للعب واللهو، ولا مكاناً للتسلية وتبادل الحديث والسمر، بل هو مكان لتحصيل العلم وإتقان المهارة.

3- التزم بتعليمات المعيد ومسؤول المختبر وإرشاداتهما.

4- لا تستخدم اللمس والشم والتذوق للتعرف على المواد أو اختبارها، فقد يكون في ذلك ضرر كبير.

5- لا تعبث بالأجهزة الكهربائية، أو بالأدوات والآلات التي لا علاقة لها بالدرس.

6- تجنب الجلوس على الطاولات أو القواعد المخصصة للأجهزة، وليكن جلوسك في الأماكن المخصصة لك (المقاعد).

7- لا تعبث بمفاتيح الغاز أو المفاتيح الكهربائية، أو صنابير الماء، ولا تلمس مآخذ التيار الكهربائي ولا الأسلاك وبخاصة إذا كانت مكشوفة.

8- احذر لمس السوائل التي لا تعرف طبيعتها، أو التي قد تكون منسكبة على الطاولات.

9- نظِّف الأدوات والأجهزة بعد الانتهاء من التجربة، وأعد كل شيء مكانه.

Experiment 1.

Precision Measuring Tools & ERRORS

OBJECTIVES:

- To develop skills in measurement using the vernier caliper and micrometer caliper.
- To apply the rules for significant figures in experimental computations.
- To perform simple algebraic operations following the rules of significant figures.

THEORY:

Measurement of physical quantities is an important aspect one has to deal with in physics. It is from measurements of quantities where one deduces or confirms basic physical laws. In fact, this process of deducing or confirming conclusions from measured quantities is an underlying tenet of all the sciences – physical, behavioral or social. Indeed, measurement is a cornerstone of the scientific method.

Most physical measurements involve the reading of some scale. However, the finesse of the graduation of the scale is limited and the width of the lines marking the boundaries is by no means zero. This leads the observer to estimate the last digit of the measurement. Thus the numbers resulting from measurements are to some extent uncertain. The level of uncertainty depends on the apparatus used; the skill of the observer and the number of experiment performed. The way the measured number is written or reported implies this level of uncertainty.

For example in Figure 1 the length of the pencil using ruler B is between the 10 cm and the 20mm mark. It is certain that the length of the pencil is greater than 10mm and less than 20 mm. However, a portion of the length of the ruler is still unaccounted for. Thus, the observer has to estimate the value, say to around 18 mm. the last digit, which is 8, is uncertain. On the other hand, using ruler A, the reading may be 18.3 mm where the last digit 3 is an estimate. The place value of the estimate reflects the accuracy of the instrument. Ruler A has an accuracy of up to the tenth place of a millimeter (mm), whereas ruler B has an accuracy of just up to the unit’s place of a millimeter (mm).

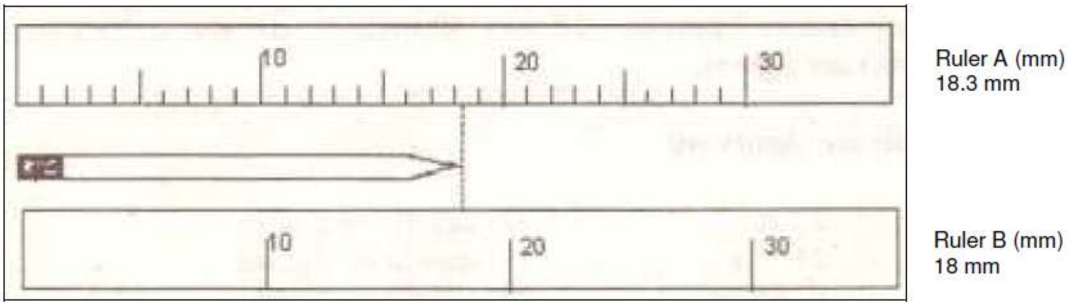


Figure 1: Length measurement of a pencil using two rulers with different graduation.

Significant Figures

The figures that can be obtained directly the measuring instrument followed by the first estimated figure of the measurement are called *significant figures*. Although an estimate figure is used, this figure is still significant because it gives meaningful information (although uncertain) about the measured object.

One and only one estimated or doubtful figure is retained and regarded as significant in reading a physical measurement.

In measurements, each digit in the measured value is defined as significant or non-significant. Since non-zero numbers give values on the measurement, all non-zero numbers are significant. Only zeros have the possibility of being non-significant. As a rule, the number of significant figures in a measurement depends on the accuracy of the instrument used, but it is incorrect to think that the number of significant figures determines the accuracy of the measurement. It is the place value of the last significant figure to the right of the decimal point, which will determine the accuracy of the instrument used in the measurement.

Rules for Determining the Number of Significant Figures:

1. *Values which are either exact numbers or numbers with perfect certainty contain an infinite number of significant figures.* Numbers by definition often appear in calculations. Examples are the numbers two (2) and π in the expression for the circumference of a circle (i.e., $c = 2 \pi r$). These numbers are assumed to have an unlimited number of significant figures. Exact numbers that appear in simple counting operations such as the number of trials, number of vibrations, number of dots, and defined numbers such as 100 cm in one meter, 60 seconds in one minute, 7 days a week, 12 months a year, are also assumed to have an unlimited number of significant figures. Numbers measured with perfect certainty such as 7 pencils, 10 books, 50 students, etc. also can contain an infinite number of significant figures.

2. *Non-zero digits are significant.*

Examples:

3.5 m (2) significant figures

24.7 kg (3) significant figures

9,186 (4) significant figures

3. *Zeroes between non-zero digits are significant*.

Examples:

90,057 m (5) significant figures

200.063 g (6) significant figures

84,000.05 mm (7) significant figures

4. *Zeroes to the right of a decimal point and to the right of a non-zero digit are significant.*

Examples:

7.0 km (2) significant figures

3.00 x 108 m (3) significant figures

145.0900 g (7) significant figures

5. *Zeroes to the left of an expressed decimal point and to the right of a non-zero digit are significant.*

Examples:

70,000.0 s (6) significant figures

6,500.0 g (5) significant figures

800.0 cm (4) significant figures

6. *Zeroes to the right of the decimal point and to the left of a non-zero digit are not significant* (for values without non-zero digits to the left of a decimal point).

The zeros are just used to show the place-value of the non-zero digits.

Examples:

0.00097 m (2) significant figures

0.000456 kg (3) significant figures

0.0281 s (3) significant figures

7. *Zeroes to the right of a non-zero digit but to the left of an understood decimal point are not significant.*

Examples:

538,000 cm (3) significant figures

720,000 g (2) significant figures

150 s (2) significant figures

Rules 6 and 7 can be easily addressed if the number is expressed in scientific notation, using only significant figures in the number placed in the argument (before the power of 10). To illustrate, the examples in rule 6 and rule 7 are presented below in scientific notation, with the number of significant figures indicated.

Values	Scientific Notation	Number of Significant Figures
Rule #6		
0.00097	9.7×10^{-4}	2
0.000456	4.56×10^{-4}	3
0.0281	2.81×10^{-2}	3
Rule #7		
538,000	5.38×10^{5}	3
720,000	7.2×10^{5}	2
150	1.5×10^{2}	2

Significant Figures and Algebraic Operations

Some physical quantities are usually obtained, not by direct measurement, but by using a mathematical formula. For example, the volume of a cylinder is obtained by using the formula πr2h. The radius (*r*) and the height (*h*) of the cylinder are the quantities directly measured. The final digit in the reading of these two quantities is an estimated value. In the computation of the volume, the level of accuracy of the measurement must still be reflected in the final answer.

The digits which are not significant must be dropped out continually; the answer must be rounded off to keep only the correct number of significant figures. The following rules may be used for the retention of significant figures in a computation.

1. Rounding off numbers

The process of rounding off numbers to a certain number of significant figures is done so as to preserve the level of accuracy of the original measurements involved in a mathematical operation. In rounding off numbers to a certain number of significant figures, retain the number of digits specified starting from the leftmost side. If the digit next to the last retained digit is greater than 4, add 1 to the last retained digit. Otherwise, simply maintain the value of the last retained digit.

Examples: Round off the following numbers to *three* significant figures.

a. 350,892 $\Rightarrow$ 351,000

b. 86,524 $\Rightarrow$ 86,500

c. 7.514 $\Rightarrow$ 7.51

2. Additions and Subtractions

When adding or subtracting measured values, the final answer should be rounded off to the *accuracy of the least accurate* measurement.

Examples:

a.
5.852 m
\+ 3.25 m
\+ 38.6 m
47.702 m $\Rightarrow$ 47.7 m

This is the least accurate measurement. It is accurate up to the tenth of meter.

Final answer rounded off up to the tenth of a meter.

b. 809 kg

+ 273.2 kg

+ 75.699 kg

1157.899 kg ⟹ 1160 kg

This is the least accurate measurement. It is accurate up tothe unit's place of kilogram.

Final answer rounded off up to the unit's place of kilogram

3. Multiplication and Division

In multiplication and division, the number of significant figures in the final product or quotient equals the least number of significant figures in any of the original factors.

Examples:

a. 10.340 cm × 1.51 cm = 15.6154cm^2 ⟹ 15.6 cm^2

(5 sf) (3 sf) (3 sf)

b. 2 π × $(53.70\ mm)^2$ = 18120 mm^2

(4 sf) (4 sf)

The number 2 and π both contain an infinite number of significant figures whereas the second term 53.70 has four. Thus the least number of significant figures among the factors involved is four. In this case the number 2 and π should be rounded off to *one more significant figure than the least*. The constant π should be rounded off to 3.1416 since the true value of π, to ten digits is 3.141592654. This gives (2.0000)(3.1416)(2884) = 18120.7488 = 18120 mm^2. *The final* *answer is rounded off to the same number as the least number of significant figures.*

c. $(47.213 \times 12.1\ \text{cm})/0.072\ \text{s} = (47.2 \times 12.1\ \text{cm})/0.072\ \text{s}$
$\Rightarrow 7.9 \times 10^2\ \text{cm/s}$
(5 sf) (3 sf) (2 sf) (2 sf)

The Micrometer Caliper

The micrometer caliper is an instrument used for very precise measurements of external dimensions. The object to be measured is placed between the *anvil* and the *spindle*. The *thimble* is then rotated to advance the spindle until the object is gripped gently between the two jaws of the caliper. The *ratchet* is used to tighten up the grip by the same amount each time and thus avoid using too much force.

The caliper consists of a fixed main scale on the *sleeve* and a movable auxiliary scale on the *thimble*. The auxiliary scale is circular and has 50 divisions. One revolution of the thimble moves the spindle by half a millimeter.

This implies that the distance between adjacent lines on the thimble corresponds to 0.01 mm.

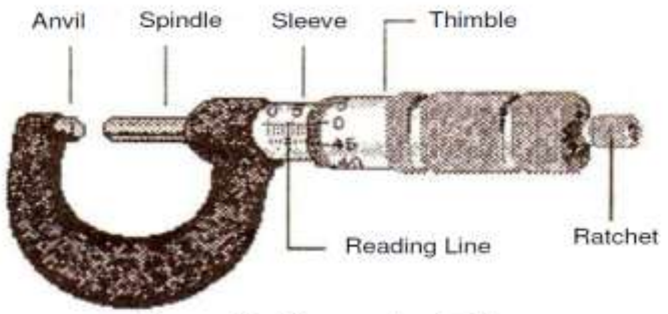


Figure 2: Micrometer Caliper

The main scale has 25 main divisions etched on the *sleeve* or *barrel*, which is located along the trunk of the micrometer caliper. The distance between the lines is 1.0 mm. thus the maximum reading possible is 25 mm. The lines just below the main divisions divide the upper lines such that the distance between an upper line and an adjacent lower line is 0.5 mm.

How to use the micrometer caliper:

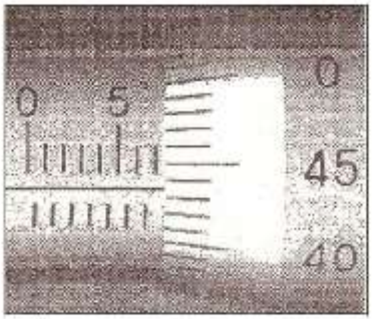
1. Check the zero position of the caliper. A properly calibrated micrometer caliper must have the main and auxiliary scales simultaneously giving a zero reading when the jaws (the anvil and the spindle) of the caliper are completely closed. In case of error, add the correction (may be either positive or negative) to every reading.

2. Place the body to be measured between the anvil and spindle. Rotate the thimble until the object is gripped gently between the two jaws of the caliper.

Turn the ratchet slowly until it clicks several times. This prevents an error due to varying degrees of tightness of the jaws.

3. Read the main scale and the circular scale. Refer to the examples below.

<u>Example #1:</u>



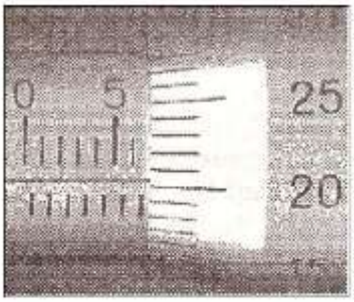
Main scale reading: 7.00 mm

Circular scale reading: <u>+ 0.435 mm</u>

Final reading ⟹ 7.435 mm

Converted to cm: 0.7435 cm

<u>Example #2:</u>



Main scale reading: 6.50 mm

Circular scale reading: <u>+ 0.203 mm</u>

Final reading ⟹ 6.703 mm

Converted to cm: 0.6703 cm

The Vernier Caliper

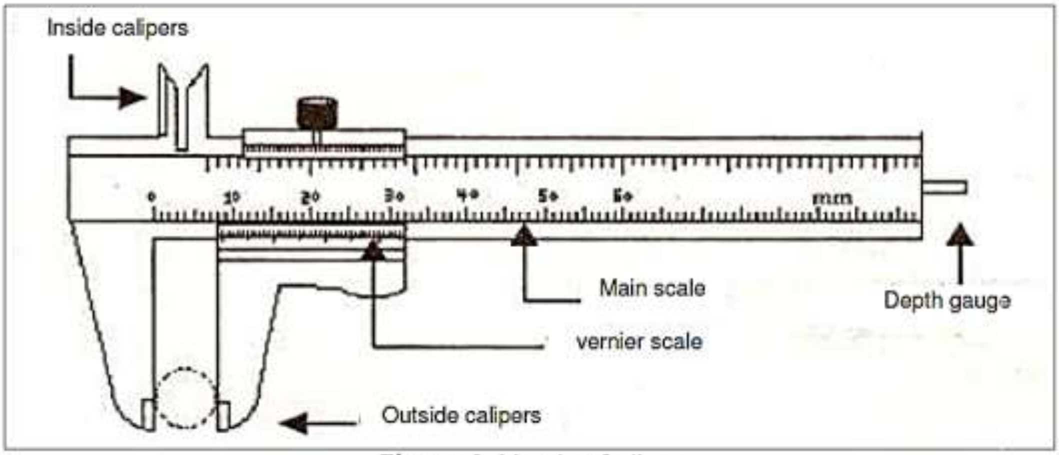


Figure 3. Vernier Caliper

The vernier caliper consists of a fixed part with a *main* engraved scale and a movable jaw with an engraved *vernier scale*. The main scale is calibrated in inches on the upper part and millimeters on the lower part. The lower calibration has a maximum of 200 divisions with each division equal to one mm. The vernier scale usually has 10 major divisions. The *least count* of the caliper is the smallest value that can be read directly from a vernier scale. For example if the least count indicated on the caliper is 0.05 mm and its vernier scale has 20 divisions, each division corresponds to a 0.05 mm. This means that the vernier scale divides one division on the main scale into 20 subdivisions. When the jaws are closed the zero line or index of the vernier scale coincides with the zero line on the main scale. When the jaws are opened, the fraction of the main scale division that the vernier scale has moved is determined by noting which vernier divisions coincides with a main scale division.

How to use the vernier caliper:

The vernier caliper measures lengths, outer and inner diameters, and internal depths with the use of its outside jaws or calipers, inner calipers, and depth gauge respectively. To measure the width of a small rectangular block, open the movable jaw and place between the outside jaws the block to be measured. Close the jaws on the object and do the following steps to get the reading:

1. Observe where the zero line or index of the vernier scale falls on the main scale. For example, Fig. 4 shows the zero line of vernier scale just after the 21 mm mark of the main scale. Thus the main scale reading is 21mm.
2. Note the line on the vernier scale that coincides on the main scale. In Fig.4, the vernier division marked “1” coincides exactly with a line on the main scale.

This division is the second from the zero line. If the least count of the vernier is 0.05 mm, this means that two divisions correspond to 0.05 mm x 2, which is equal to 0.1 mm. So the scale marked “1” in the vernier coinciding with the main scale corresponds to a 0.1 mm reading.

3. Obtain the final reading by adding the main scale reading obtained in number 1 and vernier scale reading in number 2. That is:

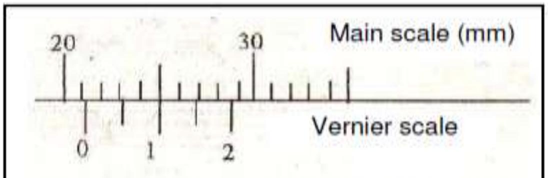


Figure 4: Final reading is 21.1 mm

Main scale reading: 21.0 mm

Circular scale reading: + 0.1 mm

Final reading ⟹ 21.1 mm

or 2.11 cm

E X P E R I M E N T A L E R R O R S

OBJECTIVES:

- Identify the types of experimental errors and its sources, and explain how these errors can be reduced.
- Interpret data with the use of statistical methods of dealing with errors.

THEORY:

Measurements of physical quantities are almost always affected by factors giving rise to variations in reading. There will always be some degree of uncertainty in the results. These variations in measurements, calculations or observations of a quantity from the true or standard value are called *errors*. An error that tends to make an observation too high is called a *positive error* and one that makes it too low *a negative error*. Experimental errors are generally classified as systematic and random errors.

1. Systematic Errors

A *systematic error* is one that always produces an error of the same sign, e.g., one that would make all observations too low. Systematic errors may be due to personal, instrumental or external factors.

(a) Personal Errors

Personal errors may arise from a personal bias of the observer in reading an instrument, in recording an observation, or his particular method of taking data, as well as mistakes in mathematical calculations. Some specific examples include: (1) Having a bias for a particular measurement. (e.g. favoring the first measurement obtained, being prejudiced in favor of the smartest member of the group or consciously taking the lowest reading, trying to fit the measurements to some preconceived idea.) (2) Taking incorrect readings form measuring instruments caused by not looking at the scale markers at a perpendicular angle.

This is also called a *parallax* error. For instance, the position of the water level in a graduated cylinder may appear different if viewed from above or below a line of sight perpendicular to the scale. (3) Not following the rules on significant figures.

(4) Human reaction time when instantaneous measurements are necessary.

Personal errors may be eliminated by observing proper caution and disregarding personal biases in taking measurements.

(b) External Errors

External errors are usually caused by external conditions such as temperature, atmospheric pressure, wind, and humidity. Temperature changes may result to expansion or contraction of measuring scales. The presence of vibration may also affect the result of sensitive experiments.

Steps or corrections should be taken to reduce the effect of the above mentioned factors giving rise to systematic errors in the experiment. These errors may be reduced by improving experimental techniques, using calibrated and more accurate measuring instruments, and including correction factors in the computation when necessary.

2. Random Errors

A *random error* is one in which positive and negative errors are equally probably. Random or erratic errors appear as variations due to a large number of unpredictable conditions and other unknown factors each of which contributes to a total error. These unknown factors or unpredictable variations in experimental situations are usually beyond the control of the observer. The unpredictable fluctuations in temperature or line voltage, and the mechanical vibrations of the experimental set-up are examples of these contributing factors.

Random errors may be minimized by taking a large number of observations.

One may then apply the descriptive measures of statistics to arrive at certain definite conclusions about the magnitude of the errors.

Estimating errors

Here we will assume that systematic errors do not exist and then make a reasonable estimate of the random errors.

Example. Use vernier calipers capable of measuring to 0.01 cm, the length of the same object might be read as (2.36 ± 0.01) cm. in this case the possible error is $\pm$ 0.01 cm and the P.P.e. is $(\pm 0.01 \times 100)/2.36 = \pm 0.4\ \%$

If alarge numbers of readings of one quantity are taken, the mean value is likely to be close to the true value.

<u>Combining errors</u>

The result of an experiment is often calculated from an expression containing the different quantities measured. The compined effect of the error in the various measurments has to be estimated.

Error in addition:

Suppose a result x is obtained by addition of two quantities say a and b i.e. $x = a + b$

Let Δa and Δb are absolute errors in the measurments of a and b Δx be the corresponding absolute error in x:

$\therefore x \pm \Delta x = (a \pm \Delta a) + (b \pm \Delta b)$

$x \pm \Delta x = (a + b) \pm (\Delta a + \Delta b)$

$\therefore \Delta x = (\Delta a + \Delta b)$

Error in subtraction:

Suppose a result x is obtained by subtraction of two quantities say a and b

i.e. $x = a - b$

$\therefore x \pm \Delta x = (a \pm \Delta a) - (b \pm \Delta b)$

$x \pm \Delta x = (a - b) \pm (\Delta a + \Delta b)$

$\therefore \Delta x = (\Delta a + \Delta b)$

Error in product:

Suppose a result x is obtained by product of two quantities say a and b

i.e. $x = a \times b$ (1)

$x \pm \Delta x = (a \pm \Delta a) \times (b \pm \Delta b)$

$x \pm \Delta x = ab \pm a\Delta b \pm b\Delta a \pm \Delta a\, \Delta b$

$x \pm \Delta x = x \pm a\Delta b \pm b\Delta a \pm \Delta a\, \Delta b$

$\therefore \pm \Delta x = \pm a\Delta b \pm b\Delta a \pm \Delta a\, \Delta b$ (2)

Dividing equation (2) by (1) we have propagation of errors product.

Exercises

1. Distinguish among the types and causes of experimental errors. Give a specific example of each.

2. How can each type of experimental error be reduced or minimized?

3. What is the difference between measurement accuracy and precision? Explain their general dependence on the various types of errors.

4. What determines the number of significant figures in reporting measurement values? What would be the effect of reporting more or fewer figures or digits than are significant?

5. In expressing experimental error or uncertainty, when does one use (a) experimental error and (b) percent difference?

6. What is the statistical significance of one standard deviation? Two standard deviations?

7. How could the function $y = 3t^2 + 4$ be plotted on a Cartesian graph to produce a straight line? What would be the numerical values of the slope and intercept of the line?

Experiment 2.

Measurement of g: Use of a simple pendulum

OBJECTIVE:

To measure the acceleration due to gravity using a simple pendulum.

Theory

A simple pendulum may be described ideally as a point mass suspended by a massless string from some point about which it is allowed to swing back and forth in a place. A simple pendulum can be approximated by a small metal sphere which has a small radius and a large mass when compared relatively to the length and mass of the light string from which it is suspended. If a pendulum is set in motion so that is swings back and forth, its motion will be periodic. The time that it takes to make one complete oscillation is defined as the period T. Another useful quantity used to describe periodic motion is the frequency of oscillation. The frequency f of the oscillations is the number of oscillations that occur per unit time and is the inverse of the period, f = 1/T. Similarly, the period is the inverse of the frequency, T = l/f. The maximum distance that the mass is displaced from its equilibrium position is defined as the amplitude of the oscillation.

When a simple pendulum is displaced from its equilibrium position, there will be a restoring force that moves the pendulum back towards its equilibrium position. As the motion of the pendulum carries it past the equilibrium position, the restoring force changes its direction so that it is still directed towards the equilibrium position. If the restoring force $\vec{F}$ is opposite and directly proportional to the displacement x from the equilibrium position, so that it satisfies the relationship

$\vec{F}$ = - k $\vec{x}$ (1)

then the motion of the pendulum will be simple harmonic motion and its period can be calculated using the equation for the period of simple harmonic motion

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad (2)$$

It can be shown that if the amplitude of the motion is kept small, Equation (2) will be satisfied and the motion of a simple pendulum will be simple harmonic motion, and

Equation (2) can be used.

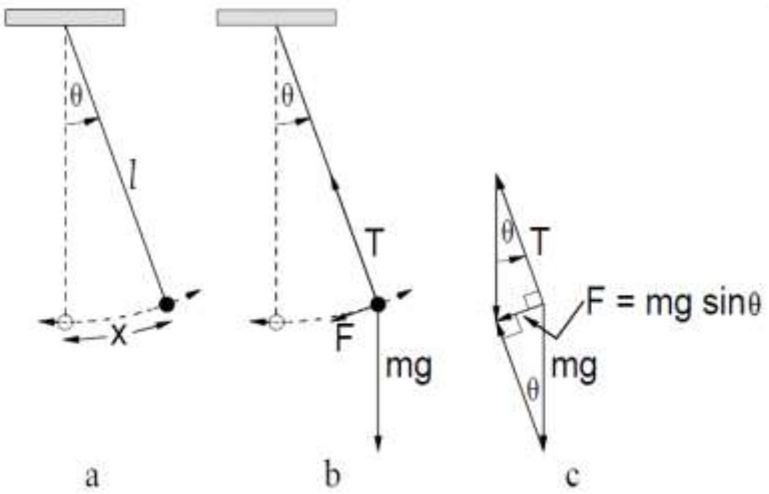


Figure 1. Diagram illustrating the restoring force for a simple pendulum.

The restoring force for a simple pendulum is supplied by the vector sum of the gravitational force on the mass. mg, and the tension in the string, T. The magnitude of the restoring force depends on the gravitational force and the displacement of the mass from the equilibrium position. Consider Figure 1 where a mass m is suspended by a string of length l and is displaced from its equilibrium position by an angle θ and a distance x along the arc through which the mass moves. The gravitational force can be resolved into two components, one along the radial direction, away from the point of suspension, and one along the arc in the direction that the mass moves. The component of the gravitational force along the arc provides the restoring force F and is given by

F = - mg sinθ (3)

where g is the acceleration of gravity, θ is the angle the pendulum is displaced, and the minus sign indicates that the force is opposite to the displacement. For small amplitudes where θ is small, sinθ can be approximated by θ measured in radians so that Equation (3) can be written as

F = - mg θ (4)

The angle θ in radians is (*x/l*), the arc length divided by the length of the pendulum or the radius of the circle in which the mass moves. The restoring force is then given by:

F = - mg $\frac{x}{l}$ (5)

and is directly proportional to the displacement x and is in the form of Equation (1) where k = $\frac{mg}{l}$. Substituting this value of k into Equation (2), the period of a simple pendulum can be found by:

$$T = 2\pi\sqrt{\frac{m}{({}^{mg}/_{l})}} \qquad (6\ )$$

and

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad (7)$$

Therefore, for small amplitudes the period of a simple pendulum depends only on its length and the value of the acceleration due to gravity.

Apparatus

The apparatus for this experiment consists of a support stand with a string clamp, a small spherical ball with a 125 cm length of light string, a meter stick, a vernier caliper, and a timer.

PROCEDURE:

The period T of a simple pendulum (measured in seconds) is given by equation (7)

$$T = \frac{\text{time for 30 oscillations}}{\text{30 oscillations}} \qquad (8)$$

using equation (7) to solve for "g", L is the length of the pendulum (measured in meters) and g is the acceleration due to gravity (measured in meters/sec2). Now with a bit of algebraic rearranging, we may solve Eq. (7) for the acceleration due to gravity g. (You should derive this result on your own).

$$g = 4\pi^2 L/T^2 \qquad (9)$$

1. Measure the length of the pendulum to the middle of the pendulum bob. Record the length *l* of the pendulum in the table below.
2. With the help of a lab partner, set the pendulum in motion until it completes 30 to and fro oscillations, taking care to

record this time. Then the period T for one oscillation is just the number recorded divided by 30 using (eq. 8). And calculate T^2.

3. Repeat steps 1,2 for several time by varing the length *l* and determine T and T^2.

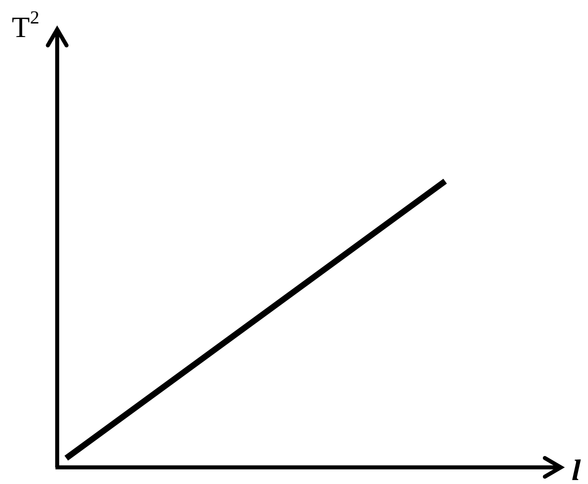
4. Plot T^2 (on y-axis) Vs. *l* (on x-axis).

5. Find the slope of the resulting which equal:

Slope = $\frac{4\pi^2}{g}$

Then find "g"

l cm									
T_{30},s									
T									
T^2									



Questions:

1. What is your evidence for believing or disbelieving that your reaction time is always the same? Is your reaction time different for different stimuli?
2. Suggest possible explanations why reaction times are different for different people.
3. Will the reaction time significantly affect measurements you might make using instruments for this course? How could you minimize its role?
4. What role does reaction time play in applying the brakes to a car in an emergency situation? Estimate the distance a car travels at 100 km/h during your reaction time in braking.
5. Give examples for which reaction time is important in sports.

Experiment 3.

Determination of the refractive index of a liquid using a liquid lens

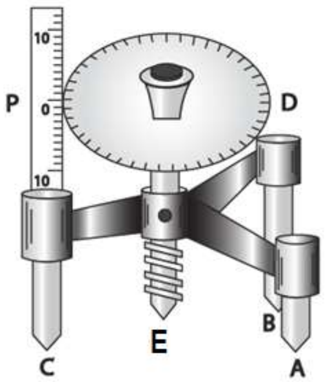
Objective

Determination of the refractive index of a liquid (water) using a compound glass- liquid lens.

Aparatuse

A spherometer

It consists of a metallic tripod frame work supported on three fixed Legs (A, B and C) of equal lengths. P is the fixed scale and D is the moving scale. The head of the screw has a graduated disk used to measure fractional turns of the screw. The vertical scale is used to measure the height or depth of the curvature of the surface.The vertical scale divisions are on 1 mm, which is the pitch of the threads of the screw. The head of the screw is graduated into 100 divisions.



We can get hight of E from the fixed scale and the moving one. The distance between any two arms of the tripod is *l*, hence A, B and C form an equilateral triangle.

Using a spherometer to measure the radius of curvature, R, of a lens surface.

1. Adjst the spirometer, making the tips of A, B, C and E contact. Check the main –meter P and moving scale D at zero
2. Screw E upwards, and put the lens to be measured under it. Screw E dowenwards carfully until E reaches the surface of the lens, and record the value E.
3. Measure the distanc *l* (between two legs) by a vernier caliper, and get the average value.
4. Calculate the surface of radius R from the formula:

$$R = \frac{l^2}{6h} + \frac{h}{2}$$

Theory

We know the focus is the point of intersection of the rays which are refracted from the lens when the parallel rays are incident. And the distance between the focal and center is called focal length f_g.

Strength of lens F_g:

$$\boldsymbol{F_g = \frac{1}{f_g}} \quad \textbf{(1)}$$

$$\boldsymbol{F_g = (n_g - 1)(\frac{1}{R_1} - \frac{1}{R_2})} \quad \textbf{(2)}$$

Where ng is the refractive index of glass ≅1.45.

The sign of R is positive if the sphere. Of which the surface is a part of, and the object are on opposite sides, while the negative sign if the center of the sphere and the object are on the same side.in this manner R_1 and R_2 have opposite sign, and thus brackets in Eq.2 is equal to 2/R. R were measured using the spherometer.

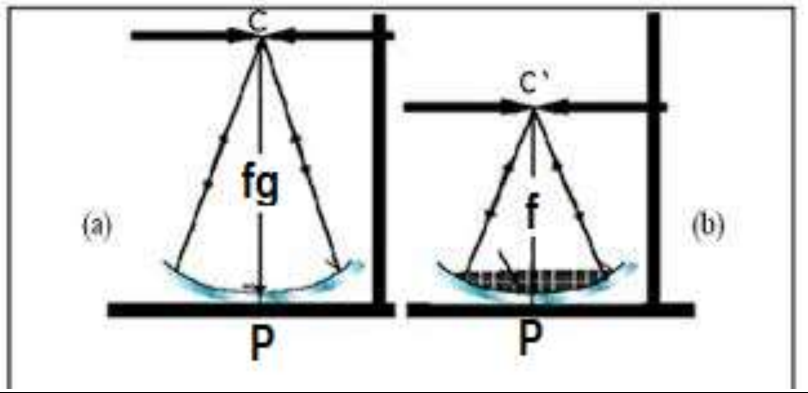
Experimental procedure

1. Place the concave mirror horizontally on the wooden block.
2. With the help of the optical needle, remove the parallax between the needle and its image. This position of the tip of the needle corresponds to the centre of curvature of the mirror. Measure the distance (PC = fg).

4. Repeat the observations many times.and the average distance gives focal length of glass convex lens f_g.

3. Now pour a little quantity of the liquid on the mirror and again remove the parallax between the needle and its image. Measure the distance (PC' = f).

4. Repeat the observations many times.and the average distance gives focal length of the compound lens composed of the convex lens and the plano-concave liquid lens.



5. The reciprocal of this measured distance equal the strength of the compound lens, and equals the numerical sum of the strengths of the liquid and glass lenses.

$$F = F_g + F_l = \frac{1}{f_g} + (n_l - 1)(\frac{1}{R_1} - \frac{1}{R_2})$$

$$= \frac{1}{f_g} + (n_l - 1)\left(\frac{-1}{R} - \frac{1}{\infty}\right) \qquad (4)$$

$$= \frac{1}{f_g} - \frac{(n_l - 1}{R})$$

Where R is the value measured before by the spherometer.

6. From Eq. 3, we can deduce the refractive index of the used liquid.

   Error = ………..mm, l = …....mm, h’ = ………mm

   h = h’- error = ………………………………… = …………. mm

   R = ………………………………… = ……………………..mm

   f_g = ……………. cm = ………..m, F_g = ……………. Δ

   f = …………………cm = ………. m, F = ………………….. Δ

   F_l = …………………… Δ, n_l = ……………………

Experiment 4.

Determintion the coefficient of viscosity of fluid using Stokes' Method

Objective

To determine the coefficient of viscosity of a known fluid using Stokes' method. **Equipment needed**

A glass vessel with glycerine, micrometer calliper, stopwatch, ruler.

Theory

Viscosity refers to the friction within a fluid from flowing freely and is essentially a frictional force between different layers of fluid as they move past one other. The tangential force F required to move a layer of area S and located a perpendicular distance x from an immobile surface is given by:

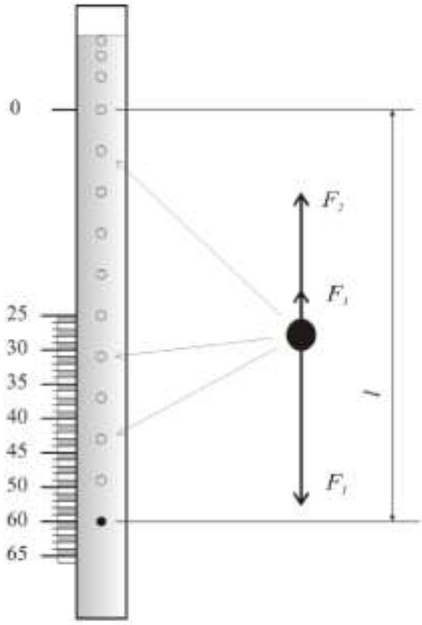
$$F = \eta \frac{dv}{dx} S \qquad (1)$$

where η is the coefficient of viscosity.

Provided the flow the velocity is not too large, the fluid flows smoothly and the flow is said to be laminar.

The mutual influences of layers of fluid which move past one another are conditioned by the molecule intermediate attraction of fluid. This prevents also the motion of solid body in fluid because the whole surface of body is covered with thin molecular layers by molecules of fluid. Therefore the force, which prevents the motion of a body in a fluid, can be found by the force of viscosity. It is possible only then, when the velocity of the body is smaller than the velocity of laminar flow of fluid. Otherwise the whirls will arise and the formula (1) given by Newton is useless. In general it is complicated to find the formula of frictional force F_t .In case of regular bodies the problem will simplify. For a spherical bodies Stokes derived the following formula:

$$F_t = 6\pi\eta r v \qquad (2)$$



where η is the coefficient of viscosity, r is the radius of the sphere and v is the velocity of the sphere. In this experiment the formula (2) is used to determine the coefficient of viscosity. Computing the frictional force Ft the sphere dropping through a column of liquid is observed. (see figure 1).

There are three forces acting on the sphere ball dropped into the liquid (figure 13.1). 1) The force of gravity

$F_1 = mg = Vg\rho$ (3)

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

Figure 1.

$F_2 = F_b = Vg\rho_o$ (4)

where ρ_o is the density of the liquid.

3) Viscous drag force

$F_3 = 6\pi\eta rv$ (5)

Both forces F_2 and F_3 act upwards – buoyancy tending to „float“ the sphere and the drag force resisting the acceleration of gravity. The only force acting downwards is the body force resulting from gravitational attraction (mg).

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

$F_1 = F_2 + F_3$ (6)

or

Vgρ = Vgρ = 6πηrv

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:

$$\eta = \frac{2r^2(\rho - \rho_o)g}{9\,v} \qquad (7)$$

The formula (7) is valid in case of the volume of liquid is infinity large.

Experimental procedure

1. Determine the radius R of the vessel using the vernir and the mass m of the sphere balls.

2. Familiarise yourself with the provided stopwatch.

3. Determine the radius of the sphere

4. Drop the ball through the hole into the glass cylinder and measure the time t it takes the ball to sink the given distance s through the glycerine.

5. Find the speed v = L/t and make the velocity correction expressed by:

$$v_t = v(1 + 2.4\frac{r}{R})$$

6. Use the data r and v_t in eq.7 to determind η.

(ρ = ,ρ_o =)

7. Repeat the procedure for another 3…5 different steel balls.

8. Record the results into the following Table.

Sphere	**D**	**r**	**t**	**v**	**v_t**	**R^2/v_t**	**η**
(1)							
(2)							
(3)							

Questions

1) What is viscosity, the coefficient of viscosity?

2) How depends the coefficient of viscosity on temperature?

3) What kind of flow is said to be laminar?

4) Formulate the formula of Newton and Stokes.

5) Upon what depend the distance of accelerated falling ball?

6) What does the Reynolds number characterise?

7) What does the velocity gradient show?

8) Derive the units of the coefficient of viscosity in SI- and CGS system.

9) Is it a great mistake if we use the formula (8) instead of the formula (7) in our work?

10) How is it possible to measure the coefficient of viscosity on given experiment when the density of the ball is smaller than the liquids one?

Experiment 5.

Measurement of acceleration due to gravity (g) by a compound pendulum

Aim: (i) To determine the acceleration due to gravity (g) by means of a compound pendulum.

(ii) To determine radius of gyration about an axis through the center of gravity for the compound pendulum.

Apparatus and Accessories:

(i) A bar pendulum, (ii) a knife–edge with a platform, (iii) a sprit level, (iv) a precision stop watch, (v) a meter scale and (vi) a telescope.

Theory:

A simple pendulum consists of a small body called a “bob” (usually a sphere) attached to the end of a string the length of which is great compared with the dimensions of the bob and the mass of which is negligible in comparison with that of the bob. Under these conditions the mass of the bob may be regarded as concentrated at its center of gravity, and the length of the pendulum is the

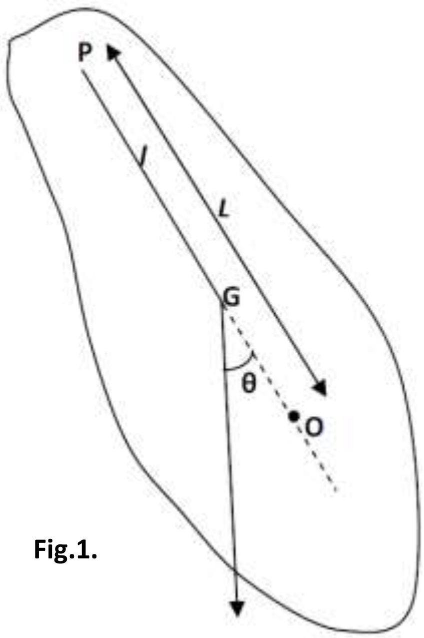


Fig.1.

distance of this point from the axis of suspension. When the dimensions of the suspended body are not negligible in comparison with the distance from the axis of suspension to the center of gravity, the pendulum is called a compound, or physical, pendulum. A rigid body mounted upon a horizontal axis so as to vibrate under the force of gravity is a compound pendulum.

In Fig.1 a body of irregular shape is pivoted about a horizontal frictionless axis through P and is displaced from its equilibrium position by an angle θ. In the equilibrium position the center of gravity G of the body is vertically below P. The distance GP is *l* and the mass of the body is *m*.

The restoring torque for an angular displacement θ is

$\tau = -mg\,l\sin\theta$ (1)

For small amplitudes ($\theta \approx 0$),

$$I\frac{d^2\theta}{dt^2} = -mgl\theta \qquad (2)$$

where I is the moment of inertia of the body through the axis P.

Eq. (2) represents a simple harmonic motion and hence the time period of oscillation is given by

$$T = 2\pi\sqrt{\frac{I}{mgl}} \qquad (3)$$

Now I = $I_G + ml^2$, where I_G is the moment of inertia of the body about an axis parallel with axis of oscillation and passing through the center of gravity G.

$I_G = mK^2$ (4)

where K is the radius of gyration about the axis passing through G. Thus,

$$T = 2\pi\sqrt{\frac{mk^2+ml^2}{mgl}} = 2\pi\sqrt{\frac{\frac{k^2}{l}+l}{g}} \qquad (5)$$

The time period of a simple pendulum of length L, is given by

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad (6)$$

Comparing with Eq. (5) we get

$$L = l + \frac{k^2}{l} \qquad (7)$$

This is the length of "equivalent simple pendulum". If all the mass of the body were concentrated at a point O (See Fig.1) such that OP = $l + \frac{k^2}{l}$, we would have a simple pendulum with the same time period. The point O is called the 'Centre of Oscillation'. Now from Eq. (7)

$$l^2 - lL + k^2 = 0 \qquad (8)$$

i.e. a quadratic equation in l. Equation 6 has two roots l_1 and l_2 such that

$l_1 + l_2 = L$

and $l_1 \; l_2 = k^2$ (9)

Thus both l_1 and l_2 are positive. This means that on one side of C.G there are two positions of the centre of suspension about which the time periods are the same. Similarly, there will be a pair of positions of the centre of suspension on the other side of the C.G about which the time periods will be the same. Thus there are four positions of the centers of suspension, two on either side of the C.G, about which the time periods of the pendulum would be the same. The distance between two such positions of the centers of suspension, asymmetrically located on either side of C.G, is the length L of the simple equivalent pendulum. Thus, if the body was supported on a parallel axis through the point O (see Fig. 1), it would oscillate with the same time period T as when supported at P. Now it is evident that on either side of G, there are infinite numbers of such pair of points satisfying Eq. (9). If the body is supported by an axis through G, the time period of oscillation would be infinite. From any other axis in the body the time period is given by Eq. (5).

From Eq.(6) and (9), the value of g and K are given by

$$g = 4\pi^2 \frac{L}{T^2} \quad (10)$$

$K = \sqrt{l_1 l_2}$ (11)

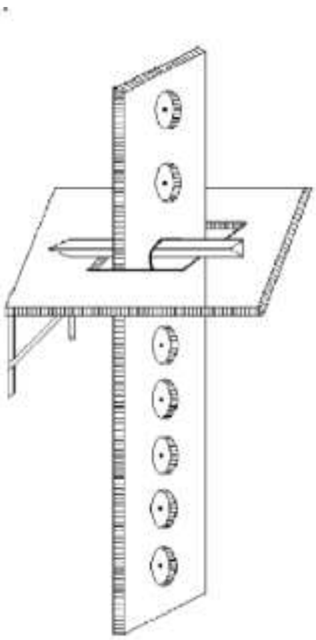
By determining L, l_1 and l_2 graphically for a particular value of T, the acceleration due to gravity g at that place and the radius of gyration K of the compound pendulum can be determined.

From equ. 3

$dT^2 = (4\pi^2k^2/g) + (4\pi^2/g)\, l^2$ (12)

Description:

The bar pendulum consists of a metallic bar of about one meter long. A series of circular holes each of approximately 5 mm in diameter are made along the length of the bar. The bar is suspended from a horizontal knife-edge passing through any of the holes (Fig. 2). The knifeedge, in turn, is fixed in a platform provided with the screws. By adjusting the rear screw the platform can be made horizontal.



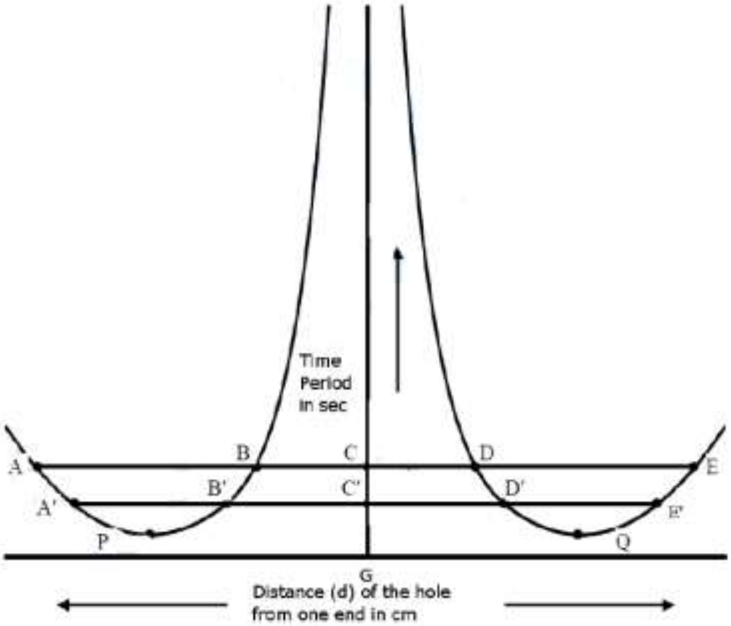


Fig.2. **Fig.3.**

Procedure:

(1) Suspend the bar using the knife edge of the hook through a hole nearest to one end of the bar.With the bar at rest, focus a telescope so that the vertical cross-wire of the telescope is coincident with the vertical mark on the bar.

(2) Allow the bar to oscillate in a vertical plane with small amplitude (within 40 of arc).

(3) Note the time for 20 oscillations by a precision stop-watch by observing the transits of the vertical line on the bar through the telescope. Make this observation three times and find the mean time t for 20 oscillations. Determine the time period T.

(4) Measure the distance d of the axis of the suspension, i.e. the hole from one of the edges of the bar by a meter scale.

(5) Repeat operation (1) to (4) for the other holes till C.G of the bar is approached where the time period becomes very large.

(6) Invert the bar and repeat operations (1) to (5) for each hole starting from the extreme top.

(7) Draw a graph with the distance d of the holes as abscissa and the time period T as ordinate. The nature of graph will be as shown in Fig. 3.and then estimate the radius of gyration k from the minimum period on the graph. Find g from the formula:

$$T_{min} = 2\pi\sqrt{\frac{2k}{g}}$$

(8) Draw a herozontal line that intercepts the curve in two points, define the values l_1 and l_2, and then define k from Eq.6

(9) Draw a relation between dT^2 on the vertical axis and d^2 on the herozontal axis. Find the slope of the straight line, from which you can find out the value of g.

d								
t_{10}								
T= $t_{10}/10$								
T^2								
d^2								
dT^2								

d_{min}. = k = ….. cm T_{min} = ……….. s

l_1 = ………. cm l_2 = ……... cm

k = ……… g = ……………

slope = ………………

Experiment 6.

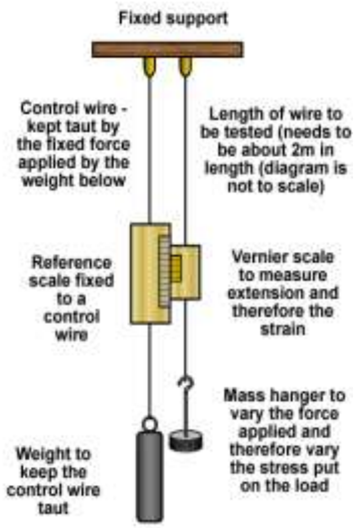
Measurement of the Young's Modulus of Elasticity

Objective

To measure the Youngs Modulus of elasticity of a metal wire.

Apparatus

The apparatus consists of a heavy steel tripod base with leveling screws, two steel support rods 150 cm long, an upper yoke to securely hold a collet that grips the wire to be tested, and a center yoke holding a dial indicator sensitive to movements of 0.01 mm. the collet will grip wires ranging up to 1.2 mm in diameter. The dial indicator senses wire movment via a small level arm resting on top of a lower pin vise.



Theory

When a solid is stretched, compressed, or deformed in some other way, it is said to contain a strain. To produce a strain in a solid one must apply some force to the solid, for example by pressing on its surface. Note that the word strain refers to the deformation, not to the force required to produce that deformation. The strain thus produced, will in general vary as a function of position within the body of the object. Thus, at every point within the body of the object, we can quantify the strain both by the magnitude of the stretching of the body at that point and by the direction and way in which it is stretching. At some points within the body the strain may be a pure elongation or compression of the material while at other points the strain may be a shearing deformation. Strain is a measurement of deformation. However, if you apply a force to a larger amount of material, it will deform more than applying that force to a smaller amount of material. We want to know the material property that tells us how much a material will deform, thus we must divide our measured deformation by the amount of material to give us a unitless quantity. Thus, strain is defined as:

$$(strain)\ e = \frac{\Delta L}{L} = \frac{change\ in\ length}{total\ length} \qquad (1)$$

The Youngs Modulus is given by the ratio of stress to strain for the stretching-type strains only. In other words, there is no shear involved. For example, the Youngs Modulus of a particular metal could be measured by subjecting a wire made of this metal to a stretching force, as we do in this lab. The ratio of the stress being applied to the resulting strain in the wire is the Youngs Modulus, Y. (By the way, the Poisson Ratio is the ratio of the relative length change due to stretching to the relative narrowing of the wire due to the stretching. We will not be concerned with the Poisson ratio in this lab.)

In the case of a stretched wire, the stress in the wire will be uniform and equal to the ratio of the applied force to the cross-sectional area of the wire:

$$\sigma = \frac{F}{A} \qquad (2)$$

where F is the force applied in the direction you are measuring (in another direction would cause shear, which is delt with with other Modulus's but not in the Young's Modulus which we are studying). Since the Young's Modulus is stress over strain, then:

$$Y = \frac{\sigma}{e} = \frac{F/A}{\Delta L/L} = \frac{Mg/\pi r^2}{\Delta L/L} = \frac{MgL}{\pi r^2 \Delta L}$$

Or $$Y = \frac{gL}{\pi r^2} \frac{M}{\Delta L} \quad (3)$$

Procedure:

1. Measure the diameter of the wire at different locations using a micrometer and record the average value of radius r.
2. Measure the length of wire hanged with no mass suspended and record it as L.
3. Suspend the mass and record the elongation ΔL caused by the weight of its mass W = mg. Record the measurements in table.
4. Repeate step 3 for the new loads.
5. For each load estimate the stress as Eq. 2 and strain Eq.1.
6. Draw the graph of stress on the vertical axis and the strain on the horizontal axis. Then estimate the slope that is equal to Young's modulus of elasticity.

L = …... m, r = D/2 = ……..… m, A = ……… m^2

M								
ΔL								
stress								
strain								

Experiment 7.

Meagerment of the speed of sound in air

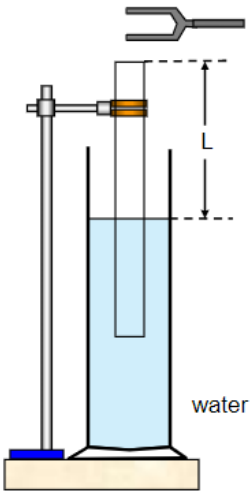
Objective

To determine the speed of sound by measuring the length of an column vibrating at its fundamental frequency (1^{st}. Harmonic).

Theory

For a sinusoidal wave with constant frequency f and wavelength λ, propagating in a medium, the speed of sound in said medium is given by:

$c = \lambda f$ (1)



This means that if we can determine both the frequency and wavelength of the wave, we can measure the speed of sound in the medium. For this experiment, the medium in question is air at room temperature and atmospheric pressure. When an acoustic wave enters through the open end of a half-closed tube and hits the closed end, part of the wave is reflected back down the tube towards the open end. At specific wavelengths, the incident and the reflected wave form a standing wave. In the antinodes of the standing wave, the points on the standing wave where the amplitude is maximal, the amplitude of the standing wave is greater than the amplitude of the incident wave alone. The opening of the tube will always be a displacement antinode of the standing waves. The wavelengths at which the standing waves occur are called the resonance wavelengths of the tube. For the half-closed tube, the resonances occur when the length of the tube equals an odd number of quarter wavelengths of the incident wave:

$\lambda_n = 4L/ n$, $\quad\quad$ $n = 1, 3, 5, \ldots$. (2)

The number n is often referred to as the nth harmonic of the tube. L is the length of the tube. The resonance frequencies f_n of the tube, the frequencies at which standing waves occur in the tube, can be found by combining equations 1 and 2:

$f_n = cn /4L$, $\quad\quad$ $n = 1, 3, 5, \ldots$. (3)

Resonance only occurs when the first object is vibrating at the natural frequency of the second object. So if the frequency at which the tuning fork vibrates is not identical to one of the natural frequancies of the air column inside the resonance tube, resonance will not occur and the two objects will not together with a loud sound. But the resonance tube can be moved up and down within the water, thus decreasing or increasing the length of the air column. An increasing in the length of a vibrational system (here, the air in the tube) increases the wavelength and decreases the natural frequency of that system. Conversely, a decrease in the length decreases the wavelength and increases the natural frequency. So by moving the resonance tube up and down within the water, the natural frequency of the air in the tube could be matched to the frequency at which the tuning fork vibrates. When the match is achieved, the tuning fork forces the air column inside of the resonance tube to vibrate at its own natural frequency and resonance is achieved. Always, the result of resonance is a big vibration-that is, a loud sound.

PROCEDURE:

1. Place a tube into a graduated cylinder and fill to the 550 ml mark.
2. Select a tuning fork and its frequency. (Higher frequancies work the best)

   f = ………… Hz
3. Strike the tuning fork (on a non-metal object) and hold it ~1cm above the open end of the tube. Move both the fork

and the tube up and down to find the air column length that gives the loudest sound.

4. Measure the length of the air column in meters.(Don't include the water).

   L = …………… m

5. Repeate steps 2 to 4 for other 6-7 tuning forks and form the following table.

f								
L								
1/L								

6. Draw the graph of f vs. 1/L, from which you can determine the slope

c = slope/4 = ……………. m/s.