Experiment No. 1
Measurements and Uncertainties

Objectives:

(1) Learn to use Vernier Caliper and micrometer to measure lengths.
(2) Make some elementary measurements of lengths and mass and derive other quantities, from them such as the value of π , volume V and density ρ.
(3) Determine the uncertainty or the experimental error for both the measured and calculated quantities.

Equipment:

Meter stick, micrometer, vernier caliper, electric balance, iron spheres, iron cylinders, irregular iron pieces, circular, spherical, and cylindrical wooden pieces.

Theory:

Any experimental measurement or result has an uncertainty associated with it. In today's lab, you will perform a set of very simple measurements and estimate the uncertainty associated with each of them. Then you will do some calculations using the values you just measured. The results of those calculations will also have an uncertainty associated with them.

The uncertainty- measures how far an experimental quantity might be from the "true value", the same as the accuracy. Accuracy – indicates how close a measurement is to the actual or expected known value. The Precision – shows how close a set of measurements are to one another.

The experimental error – is the difference between the actual or expected value, and the measured value. The standard error is the absolute uncertainty of the average value.

To reduce experimental errors and uncertainties of a calculated quantity it is useful to perform the measurement several times changing the measured parameters and finding the mean value or the average of the calculated quantity $\overline{R}$ defined as:

$$\overline{R} = \sum_{i}^{N} \frac{R_i}{N} \quad (R_i \textit{ the result for each trial, and N is the number of trials})$$

The uncertainty is then obtained from the STANDARD ERROR, or the absolute uncertainty of the average value, i.e. the standard deviation given by:

$$\Delta\overline{R} = \sqrt{\frac{\sum_{i}^{N} (R_i - \overline{R})^2}{N(N-1)}}, \quad d_i = R_i - \overline{R}$$ measures the deviation of each result from the mean.

Another way to obtain the best value of a calculated quantity is to make graphs or plots, when the relation between variable y and x is linear and the equation is represented by a straight line which is given by:

$$y = ax + b$$

Where: a is the slope of the line, b is its y-intercept (x=0) when x is the independent variable and y is the dependent variable. If the line passes through the origin (x=0,y=0),

$$y = ax\,.$$

In this experiment, you will learn how to use some measuring instruments, a ruler, vernier caliper, and micrometer to measure lengths and digital balance to measure mass, and to calculate some constant quantities such as the value of π and density ρ from the measured quantities. You will also learn to express experimental errors in the form of uncertainties, which is the smallest the smallest division of the graduated scale of the measuring device and standard deviation or the error in the mean of multiple values of data, and the percentage error which measures how one is close from the true accepted value.

For any round object, the circumference c is directly proportional to its diameter d, such that:

$$c = \pi d$$

Where π is constant. By measuring the values of c and d for many round objects one can determine the value of $\bar{\pi}$ as the mean value of the individual values of π , or by plotting the values of c versus d, one can obtain the slope of the curve to be the best value of π

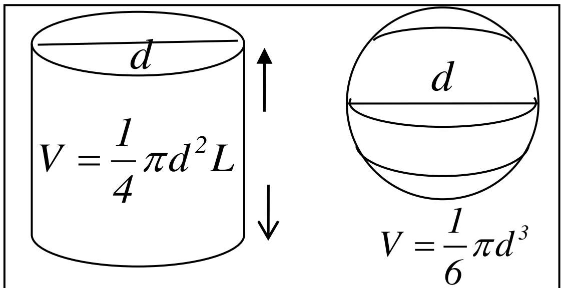


Fig.1.1: Volume of a sphere and Cylinder

For an object of any material, the density ρ is defined as the ratio of the mass m to its volume V.

$$\rho = \frac{M}{V}$$

For a sphere of radius r the volume is given by (Fig.1.1),

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{1}{6}\pi d^3$$ d being the sphere diameter.

For a cylinder, it is given by $V = \pi r^2 L = \pi\left(\frac{d}{2}\right)^2 L = \frac{1}{4}\pi d^2 L$,

Where r is the radius of its base, d is the diameter, and L is the height of the cylinder.
For irregular objects, one finds V by measuring the size of water displaced by the object, measuring m, and calculating the density ρ.

Procedure:

(I) Measure the circumference of a given round object (wooden cylinder) using a paper strip and the meter ruler.

(2) Measure the diameter of the round object using the vernier caliper and record your measurements in Table 1 of the report sheet. (See 1.2)

(3) Calculate the value of π each measurement, its mean value $\bar{\pi}$, and its error $\Delta\bar{\pi}$, as stated in the sheet.

(4) Plot c vs. d, determine the slope and then calculate the percentage error for this value of slope which $= \pi$.

(5) Measure the diameter d of a rod cylinder using the micrometer.

(6) Measure the height (length) L of the cylinder using the vernier caliper.

(7) Determine the masse m and calculate the density ρ for your iron piece.

(8) Calculate the density ρ and its uncertainty $\Delta\rho$.

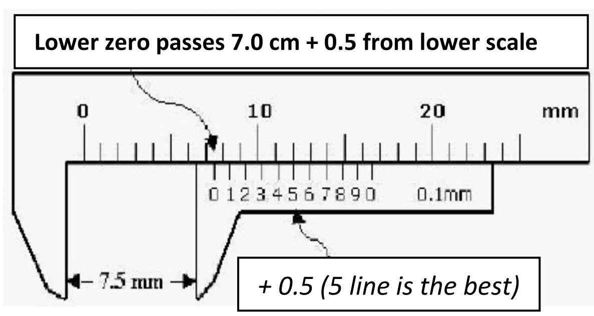
$\rho = \dfrac{M}{V}$	Where V is the volume is given by,
$V = \dfrac{1}{6}\pi d^3 \quad (sphere)$	$V = \dfrac{1}{4}\pi d^2 L \quad (cylinder)$

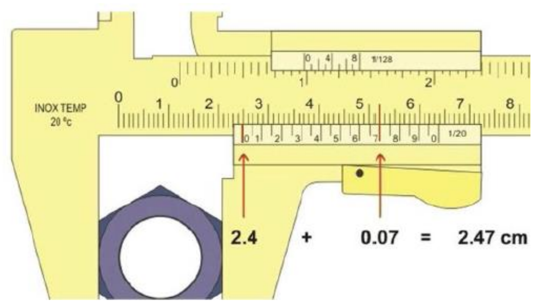
And the uncertainty $\Delta\rho = \rho\left[\dfrac{\Delta m}{m} + \dfrac{\Delta V}{V}\right]$

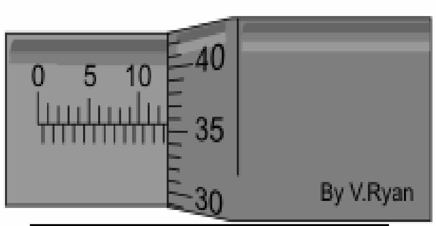
$$\Delta\rho = \rho\left[\frac{\Delta m}{m} + \frac{2\Delta d}{d} + \frac{\Delta L}{L}\right], \qquad \text{for cylindrical shape.}$$

$$\Delta\rho = \rho\left[\frac{\Delta m}{m} + \frac{3\Delta d}{d}\right] = \rho\left[\frac{\Delta m}{m} + \frac{3\Delta r}{r}\right], \qquad \text{for spherical shape.}$$

Compare your result with the true value of the density of the cylinder.







12.5 + 0.36 =12.86

7.5 + 22 = 77.7mm

Fig.1.2: Readings of Vernier and Micrometer

Exp. No. 1

Measurements

Name: ………………………………………………………….………….. Grade: …................................

Student's No.: ……………………………………….…...... Day and Date: …………………………

Partner's Names: ……………………………………………………….... Sec.: …………………

Part I: Data and Calculation:

No. of trails	**Circumference c(cm)**	**Diameter d(cm)**	$\pi = c/d$	**Deviation** $d_i = \pi_i - \bar{\pi}$	d_i^2
Mean Value $\bar{\pi}$ **=**			$\sum_{i=1}^{N} d_i^2$ **=**		

(1) Calculate the value of π for each measurement.

(2) Calculate the average or the mean value $\bar{\pi}$.

(3) Calculate the deviation of each value from its mean $d_i = \pi_i - \bar{\pi}$.

(4) Calculate d_i^2 and $\sum_{i=1}^{N} d_i^2$

(5) Tabulate your results in Table 1.

(6)Calculate the error in the mean $\Delta\bar{\pi}$

(Standard error)

$$\Delta\bar{\pi} = \sqrt{\frac{\sum_{i}^{n} (d_i)^2}{N(N-1)}}$$

(7) Plot a graph between c and d and determine the slope of this graph S.

(8) What does this slope represent?

(9) Calculate the percentage error in π giving the real value of $\pi = 3.143$.

Percentage error = $\frac{| \text{measured value} - \text{true value} |}{\text{true value}} \times 100\%$ =

Part II: Measuring the Density of a cylindrical rod.

Object	Diameter	height	Mass	Volume	Density
	$d \pm \Delta d$ (cm)	$L \pm \Delta L$ (cm)	$m \pm \Delta m$ (gm)	$V \pm \Delta V$ (cm^3)	$\rho \pm \Delta\rho$ (gm/cm^3)
Cylinder					

Calculation:

The volume of the object = V =

ΔV =

Density ρ =

$\Delta\rho$ =

Derive the SI unit of density ρ.