MINISTRY OF EDUCATION AND TRAINING
NONG LAM UNIVERSITY
SCIENCES DEPARTMENT
Physics Group

Course: **Introductory Physics Experiments 1**

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CONTENTS

UNIT 1: ERRORS THEORY

When measuring a quantity we must use instruments and our senses. Therefore, we cannot determine the exact value of the quantity to be measured. On making different measurements of a particular quantity we often obtain different values; it means that we have errors on this quantity.

There are different types of errors and each type of error required different calculation. For example, a quantity to be measured, called X, after several measurements have been made and then analyzed***, the results must be wriiten as follows:***

$$X = \overline{X} \pm \overline{\Delta X} \qquad [1.1]$$

Where X is the **quantity** to be measured, $\overline{X}$ is the **avarage** of X, and $\overline{\Delta X}$ the **average absolute error** on measuring X.

1. The average value of quantity X

It is denoted by $\overline{X}$ and given by

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \qquad [1.2]$$

where n is the number of measurements made on X, and X_i is the value of X obtained in the ith measurement.

2. The average absolute error

It is denoted by $\overline{\Delta X}$**.** This quantity gives the uncertainty of the value to be obtained of X and is given by

$$\overline{\Delta X} = \overline{\Delta X_{random}} + \overline{\Delta X_{instrument}} \qquad [1.3]$$

where $\overline{\Delta X_{random}}$ is the **average error** due to the **randomness** and $\overline{\Delta X_{instrument}}$ is that due to **instrumentation**. This quantity gives the uncertainty on measuring X.

3. The average error due to randomness

It is denoted by $\overline{\Delta X_{random}}$. This type of error is due to the inherently random nature of measuring directly a particular quantity many times. It depends on several factors: *the quantity to be measured, the accuracy of the instruments, human's limited* *capability of reading, and external environment*. As a result, each measurement of the same quantity gives a little bit different values.

$\overline{\Delta X_{random}}$ is given by

$$\overline{\Delta X_{random}} = \frac{\sum_{i=1}^{n} \left| X_i - \overline{X} \right|}{n} \qquad [1.4]$$

3. The instrumental error

It is denoted by $\overline{\Delta X_{instrument}}$. This type of error is due to the **lack of accuracy** of the instruments.

It is calculated as follows:

- Reading the value on using the instrument. For example, on the micrometer, the lowest division is 0.01mm, thus $\overline{\Delta X_{instrument}} \propto$ 0.01mm.
- Getting $\frac{1}{2}$ or 1 of value of the lowest division. As a result, for example, on the micrometer, the lowest division is 0.01mm, thus $\overline{\Delta X_{instrument}}$ = 0.01mm/2 = 0.005 mm.
- For electrical instruments such as ammeter, voltmeter, etc., we have by convention

$$\overline{\Delta X_{instrument}} = 1\% \ X_{max}$$

where X_{max} is the lowest division of the instrument used.

Noting that, in these experiment we only get the value of $\overline{\Delta X_{instrument}}$

$$\overline{\Delta X_{instrument}} = \textit{the lowest division} \qquad [1.5]$$

Consequently, the instrument should be chosen so that the instrument's measuring scale is at the **nearest to the value to be measured**. The **instrumental error is then small, giving the smaller value of** $\overline{\Delta X}$ **and better accuracy of the measurement.**

Combining equations [1.2] , [1.3] , [1.4] , [1.5] we obtain the final result [1.1]

4. The average relative error

It is denoted by $\bar{\varepsilon}$ and given by

$$\bar{\varepsilon} = \frac{\overline{\Delta X}}{\overline{X}} \qquad [1.6]$$

The average relative error is used to evaluate the accuracy of the measurement. Therefore, to evaluate the accuracy of the measurement we need to find both **the average relative error** and **the average absolute error**.

5. Formulae to find errors indirectly

This is shown on the table below.

Function of the quantity to be measure, X(a, b, c)	The formulae to calculate errors	
	The average absolute error $\overline{\Delta X}$	The average relative error $\bar{\varepsilon} = \frac{\overline{\Delta X}}{\overline{X}}$
X = a + b + c	$\overline{\Delta X} = \overline{\Delta a} + \overline{\Delta b} + \overline{\Delta c}$	$\bar{\varepsilon} = \frac{\overline{\Delta a} + \overline{\Delta b} + \overline{\Delta c}}{\bar{a} + \bar{b} + \bar{c}}$
X = a – b	$\overline{\Delta X} = \overline{\Delta a} + \overline{\Delta b}$	$\bar{\varepsilon} = \frac{\overline{\Delta a} + \overline{\Delta b}}{\bar{a} - \bar{b}}$
X = a.b	$\overline{\Delta X} = \bar{a}.\overline{\Delta a} + \bar{b}.\overline{\Delta b}$	$\bar{\varepsilon} = \frac{\overline{\Delta a}}{\bar{a}} + \frac{\overline{\Delta b}}{\bar{b}}$
$X = a^n$	$\overline{\Delta X} = n(\bar{a})^{n-1}\overline{\Delta a}$	$\bar{\varepsilon} = n\frac{\overline{\Delta a}}{\bar{a}}$

7. Writing the results and rounding the numbers

The value of the quantity to be measured is written in the form $X = \overline{X} + \overline{\Delta X}$, obeying the following rules:

(1) The value of $\overline{X}$ is written in the standardized form: $\overline{X} = a.10^n$ with 1 < a < 10.

(2) The value of $\overline{\Delta X}$ is normally written with a non-zero digit and in accordance with the power value n of $\overline{X}$.

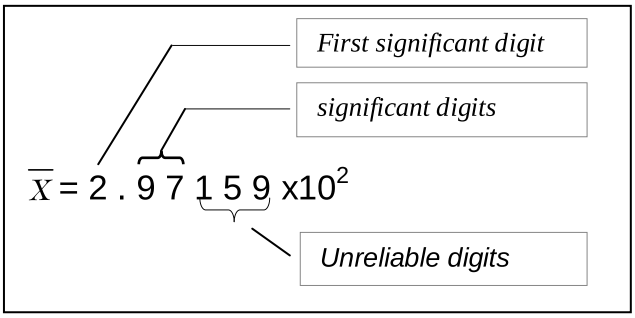
(3) Discard the unreliable digits in $\overline{X}$ (the digit whose order is smaller than the power value n of $\overline{X}$).

Example: We have raw values: $\overline{X} = 297.159$ and $\overline{\Delta X} = 0.2765$, now follow the steps

(1) Standardixing $\overline{X}$: $\overline{X} = 2.97159 \times 10^2$

(2) Keeping a non-zero digit and rounding $\overline{\Delta X}$ such there is an accordance in the power between $\overline{X}$ and $\overline{\Delta X}$: $\overline{\Delta X}$ = 0.003 x 10^2

(3) Discarding the unreliable digits in $\overline{X}$ and rounding the result numbers.



$\overline{\Delta X}$ = 0.003 x 10^2

Thus: $\overline{X}$ = 2.972 x 10^2

Finally: X = (2.972 $\pm$0.003) x 10^2

Example:

Determine the result of measurment of density D of the solid using the formula $D = \frac{m_1 - m_2}{m_3 - m_2} d_0$. The data are given

$$m_1 = (18.55 \pm 0.01)\, g \;;\; m_2 = (10.02 \pm 0.01)\, g \;;\; m_3 = (13.17 \pm 0.01)\, g \;; d_0 = (1.00 \pm 0.05)\, g / cm^3$$

- *Calculating D*

$$D = \frac{m_1 - m_2}{m_3 - m_2} d_0 \Rightarrow \overline{D} = \frac{\overline{m_1} - \overline{m_2}}{\overline{m_3} - \overline{m_2}} \overline{d_0} = \frac{18.55 - 10.02}{13.17 - 10.02} \times 1.00 = 2.7079\, g / cm^3$$

- *Calculating* $\overline{\Delta D}$

Getting natural logarithm both sides of the equation for calculating D, we have

$$\ln D = \ln(m_1 - m_2) - \ln(m_3 - m_2) + \ln d_0$$

Differentiating this equation

$$\frac{dD}{D} = \frac{d(m_1 - m_2)}{(m_1 - m_2)} - \frac{d(m_3 - m_2)}{(m_3 - m_2)} + \frac{d(d_0)}{d_0}$$

After some manipulations, it reduces to

$$\frac{dD}{D} = \left[\frac{1}{m_1 - m_2}\right] dm_1 + \left[\frac{m_1 - m_3}{(m_1 - m_2)(m_3 - m_2)}\right] dm_2 - \left[\frac{1}{m_3 - m_2}\right] dm_3 + \frac{d(d_0)}{d_0}$$

Converting to $\frac{\overline{\Delta D}}{\overline{D}}$:

$$\frac{\overline{\Delta D}}{\overline{D}} = \left|\frac{1}{\overline{m_1} - \overline{m_2}}\right|\overline{\Delta m_1} + \left|\frac{m_1 - m_3}{(\overline{m_1} - \overline{m_2})(\overline{m_3} - \overline{m_2})}\right|\overline{\Delta m_2} + \left|\frac{1}{\overline{m_3} - \overline{m_2}}\right|\overline{\Delta m_3} + \frac{\Delta(d_0)}{d_0}$$

Substituting the numbers, we have $\frac{\overline{\Delta D}}{\overline{D}} = 0.059$

We now calculate: $\overline{\Delta D} = \overline{D} \times 0.059 = 2.7079 \times 0.059 = 0.159766 g/cm^3$ The result received

$\overline{D} = 2.7079 g/cm^3$ (in standardized form)

$\overline{\Delta D} = 0.159766 g/cm^3 \approx 0.2 g/cm^3$: keeping one significant digit

Rewriting to make sure an accordance in power: $\overline{D} = 2.7 g/cm^3$

Final result: $D = (2.7 \pm 0.2) g/cm^3$

8. Drawing a diagram

In many experiments, we often need to represent the results by **drawing a diagram based on the collected data, depicting the relationship between two quantities of interest.**

- *How to draw a diagram*

  (1) Make a data table.

$\overline{X}$	
$\overline{\Delta X}$	
$\overline{y}$	
$\overline{\Delta y}$	

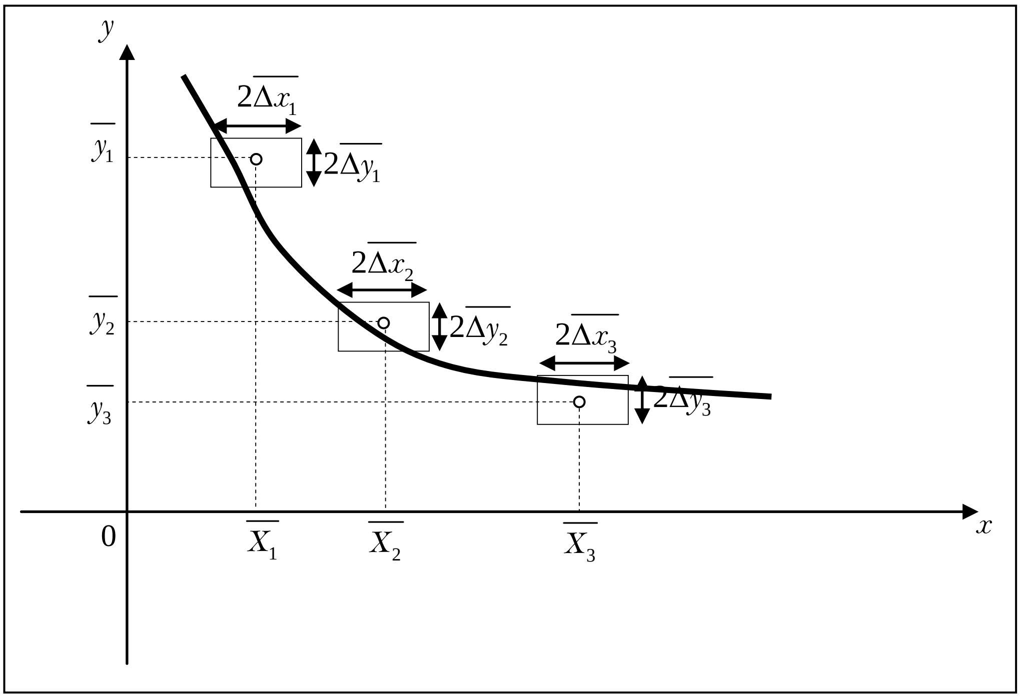
  (2) Setting up the coordinates (an ordinate and an abscissa).

  (3) Putting units on the two axes

  (4) Choose proper scales

  (5) Drawing error rectangles whose centers are coincident with the measured values ($\overline{X}$ and $\overline{y}$) and sides are $2\overline{\Delta x}$ and $2\overline{\Delta y}$, respectively.

(6) Drawing a smooth curve connecting those rectangles.



UNIT 2: MEASURING THE SIZE OF OBJECTS BY MICROMETER and VERNIER CALIPER

The purpose of the experiment

Help the students know to use vernier to increase accuracy of measurement and to adjust to ***Zero correction***.

A/ MEASURING THE SIZE OF OBJECTS BY MICROMETER

Micrometer is an instrument measuring the size of objects with high accuracy (from 0.01mm to 0.02 mm).

I. Theoretical backgrounds

1. Construction of outside micrometer

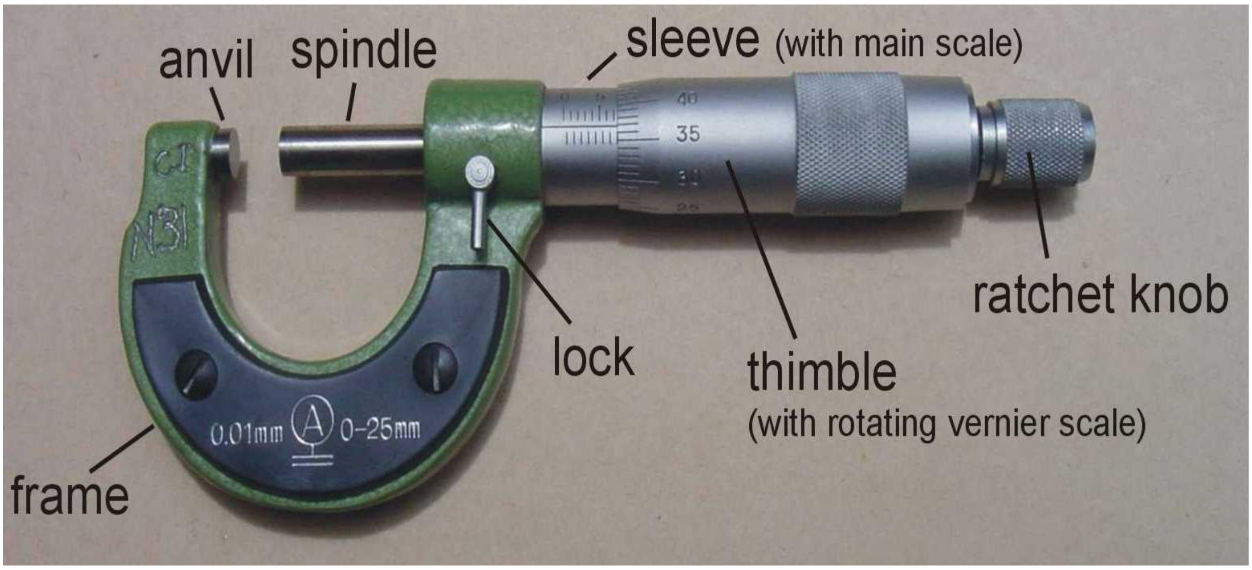


Figure 2.1

- **Frame:** The frame is made of cast iron on which the whole assembly is attached.
- **Barrel/Sleeve:** Main scale is graduated on it with 0.5 mm distance.
- **Thimble:** Divisions are marked on this cylindrical portion. Knurling is made on it for better gripping.
- **Spindle:** Spindle is one of the contacting surface during measurement. It moves to and fro as thimble rotated.
- **Anvil:** It is the another contacting surface which is fixed in Frame.
- **Lock nut:** This nut is used to lock the movement of the spindle.
- **Ratchet:** Ratchet is used to rotate and apply uniform pressure during measurement.

A micrometer comprising a main body holding an anvil at one end portion thereof and a spindle moving to and away from the anvil at the other end portion thereof through an inner sleeve, an outer sleeve covering the outside of the inner sleeve and fixed thereon, and a thimble unitedly connected to the spindle on the outside of the outer sleeve in a manner that the thimble rotates, said outer sleeve being provided with graduations and numerals on the outer circumferential surface along the axial direction, and the thimble being provided with graduations and numerals on the outer circumference thereof.

2. Graduation of Outside micrometer

In metric micrometer the pitch of the spindle thread is 0.5 mm. Thereby in one rotation of the thimble, the spindle advances by 0.5 mm. On the barrel (sleeve) a 25 mm long datum line is marked. This line is further graduated to millimeters and half millimeters. The graduations are numbered as 0, 5, 10, 15, 20 and 25 mm.

The circumference of the bevel edge of the thimble is graduated into 50 divisions and marked 0-5-10-15...45-50 in a clockwise direction. The distance moved by the spindle during one rotation of the thimble is 0.5 mm.

Figure 2.2

3. Reading of Outside micrometer

Step 1: First note the minimum range of the outside micrometer. While measuring with a 50 to 75 mm micrometer, note it as 50 mm.

Step 2: The least count of a Metric micrometer is 0.01 mm. It is *the ratio of value of 1 main scale division and total graduations on thimble*. i.e. 0.5/50.

Step 3: Then read the barrel (sleeve) graduations. Read the value of the visible lines on the left of the thimble edge.

Step 4: Next, read the thimble graduations. Multiply these graduations with least count.

Step 5: Add all above readings together. The sum of these readings is the actual reading of the object.

Example of Reading – 1

Figure 2.3

Example of Reading - 2

Figure 2.4

Example of Reading – 3

Figure 2.5

Example of reading – 4

Figure 2.6

4. ***Zero correction*.** Always check whether full closure of the jaws actually gives a zero reading. Special wrenches are available to set the zero reading exactly. Alternatively, the zero reading may be treated as a correction value to be added to (or subtracted from) all readings made with the instrument. This value is called a "zero correction."

II. Instruments

(1) Micrometers

(2) Some copper wires

(3) Some metallic balls

III. Practice

1. Adjusting "zero correction" of the micrometer
2. Measuring the diameter of a copper wire: A wire is measured five times at five different positions on the wire.
3. Measuring the diameter, d, of a ball: measure five times the diameter of a ball at five different positions on the ball, then calculate the ball's volume V and its error ΔV .

$$V = \frac{1}{6}\pi d^3 \text{ và } \Delta V = 3\frac{\overline{\Delta d}}{\overline{d}}$$

IV. Reporting (see the reporting form of unit 2A)

THE REPORTING FORM OF UNIT 2A

1. Use the micrometer to measure diameters d_1, d_2 of two steel balls and those of six copper wires. Then establish the result tables as follows:

Table 2.1: The diameters of two steel balls

Measurement	d_1	$\Delta d_{1(random)}$	d_2	$\Delta d_{2(random)}$
1				
2				
3				
4				
5				
The average value				

Table 2.2: The diameters of 2 copper wires

Measurement	D_1	$\Delta D_{1(random)}$	D_2	$\Delta D_{2(random)}$
1				
2				
3				
4				
5				
The average value				

2. Calculating the volumes of two steel balls ($\overline{V}_{ball\ 1}, \overline{V}_{ball\ 2}$)
3. Calculating the corresponding errors
   a. $\overline{\Delta D_1}$, $\overline{\Delta D_2}$,
   b. $\varepsilon_{V_{ball\ 1}}$, $\varepsilon_{V_{ball\ 2}}$, $\Delta V_{ball\ 1}$, $\Delta V_{ball\ 2}$

where $\varepsilon_{ball\ 1} = \dfrac{\overline{\Delta V}_{ball\ 1}}{\overline{V}_{ball\ 1}}$, $\varepsilon_{ball\ 2} = \dfrac{\overline{\Delta V}_{ball\ 2}}{\overline{V}_{ball\ 2}}$

Writing the results

$D_1 = \overline{D_1} \pm \overline{\Delta D_1}$ $\qquad$ $D_2 = \overline{D_2} \pm \overline{\Delta D_2}$

$V_{ball\ 1} = \overline{V}_{ball\ 1} \pm \overline{\Delta V}_{ball\ 1}$ $\qquad$ $V_{ball\ 2} = \overline{V}_{ball\ 2} \pm \overline{\Delta V}_{ball\ 2}$

4. Show usages of the vernier in a micrometer. Give some examples. In order to obtain an accuracy of 0.005 mm for the micrometer, how does its contruction have to be changed? Describe this micrometer's construction then.

B/ MEASURING THE SIZE OF OBJECTS BY VERNIER CALIPER

I. Theoretical backgrounds

1. Construction of the vernier caliper

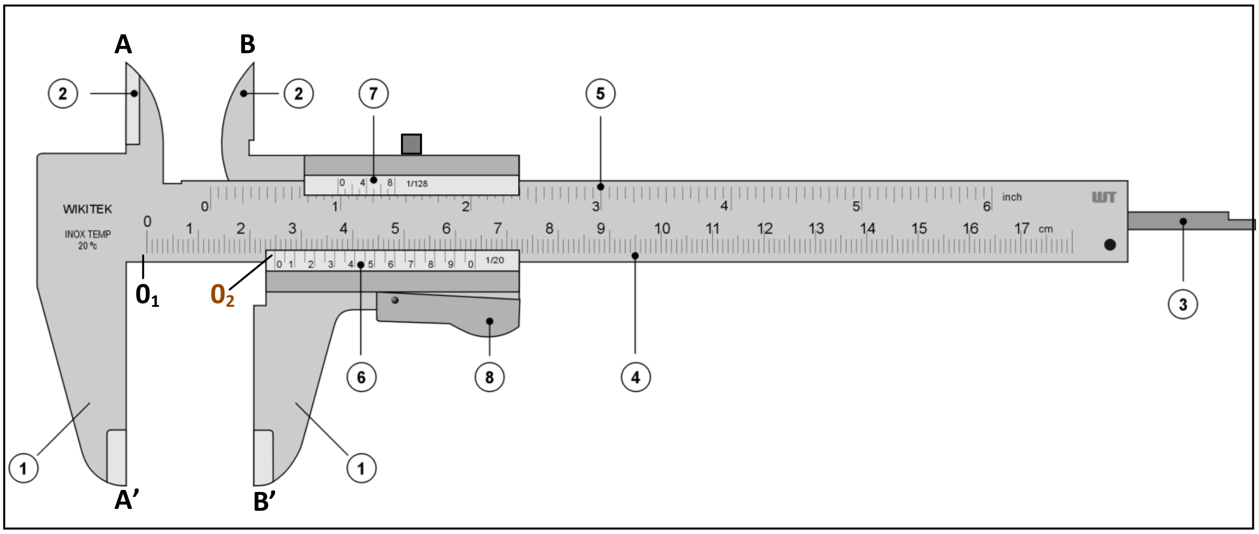


Figure 2.7

1 - **Outside jaws**: used to take external measures of objects

2 - **Inside jaws**: used to take internal measures of objects

3 - **Depth probe**: used to measure the depth of objects

4 - **Main scale** (cm)

5 - **Main scale** (inch)

6 - **Vernier** (cm)

7 - **Vernier** (inch)

8 - **Retainer**: used to block movable part

The vernier caliper consists of two components

- The fixed component: rule T is divided into mm, connecting jaw A and jaw A'. A and A' lie on a straight line.
- The sliding component: Depth probe C is attached to edge B and edge B' of the vernier caliper. It can move on rule T. B and B' lie on another straight line that is parallel to the line connecting A and A'

2. Reading a vernier Caliper

A *vernier caliper* is used to precisely measure dimensions to within 0.01 *mm*. It's important that you learn to read it properly – a small error in measurement may have a great effect on subsequent calculations.

A picture of a typical vernier caliper appears below. Note that it can be used to measure inner and outer dimensions of objects, as well as the depth of a hole. You will usually be using the larger "jaws" to measure outer dimensions.

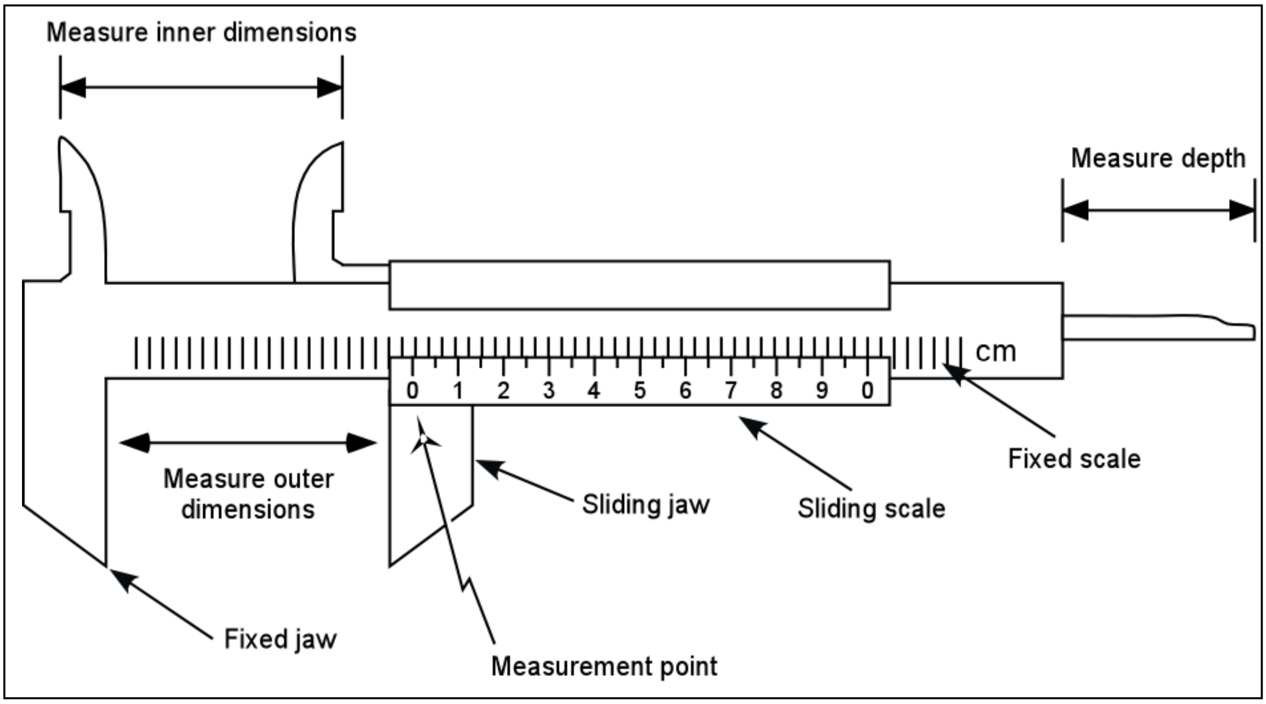


Figure 2.8

Make sure that you read the correct scale. The fixed portion of the scale is typically marked in increments of 1.0 mm; the sliding scale is marked in 0.01 *mm* increments.

3. Measurements are taken as follows:

Step 1: *Close the sliding jaw so that it fits snugly on the object to be measured. If the object is circular or spherical, make sure you're measuring at the widest point.*

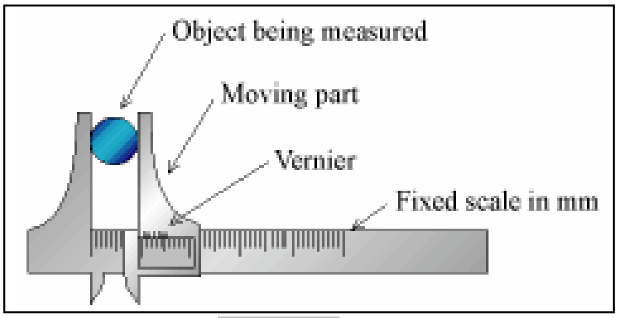


Figure 2.9

Step 2: *Remove the caliper from the object without changing the position of the sliding jaw.*

Step 3: *First, read the "0" position of the vernier scale (sliding scale) on the main scale (fixed scale) to get a rough reading.*

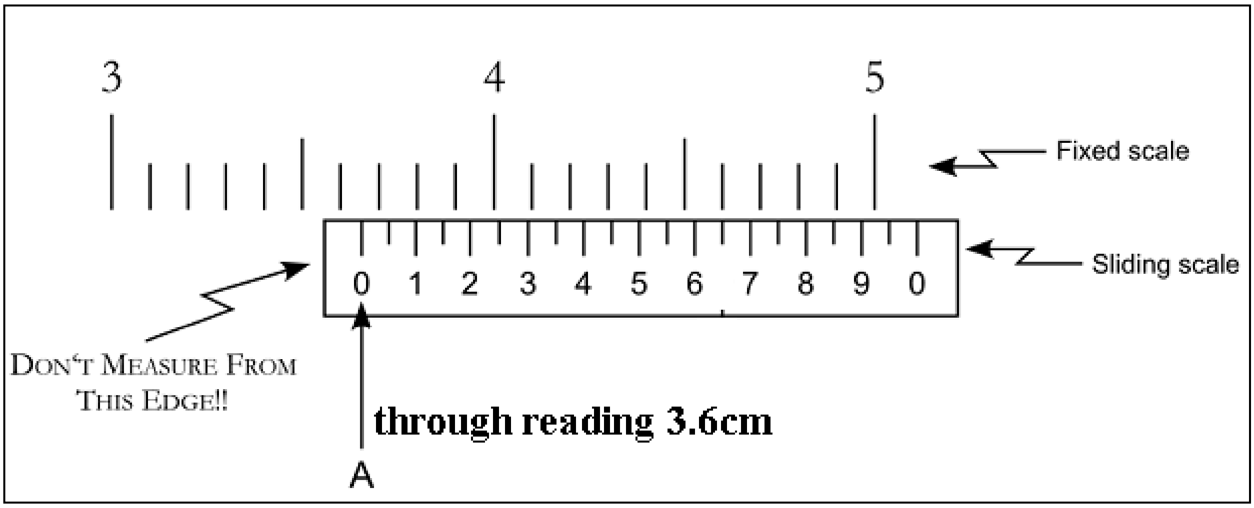


Figure 2.11

Step 4: *Next, look along the vernier scale until one of the vernier division coincides with the main scale, to get a reading on vernier scale. Multiply these graduations with least count.*

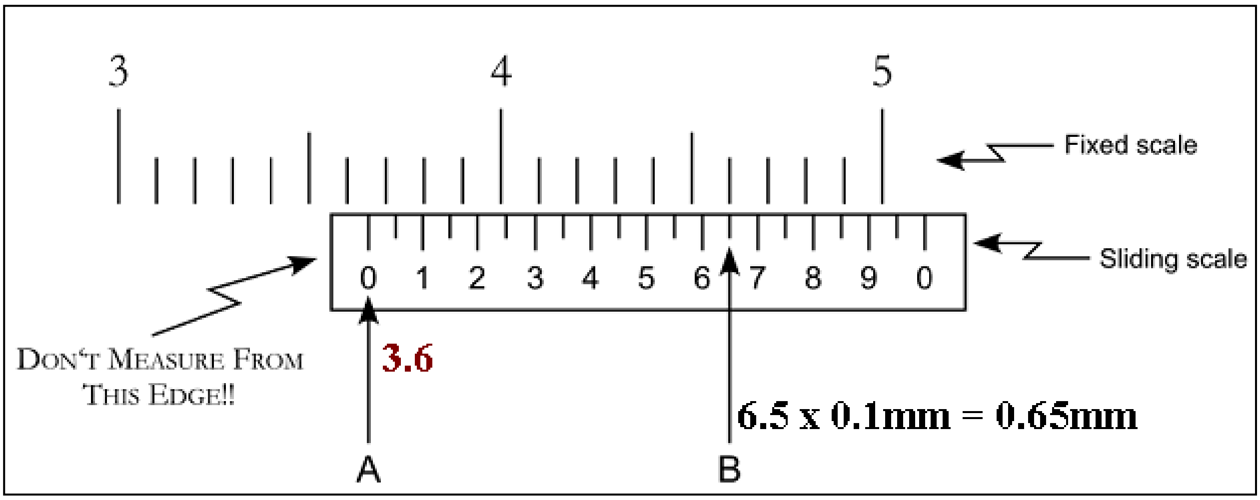


Figure 2.12

Step 5: *Obtain accurate reading Add all above readings together. The sum of these readings is the actual reading of the object to be measured.*

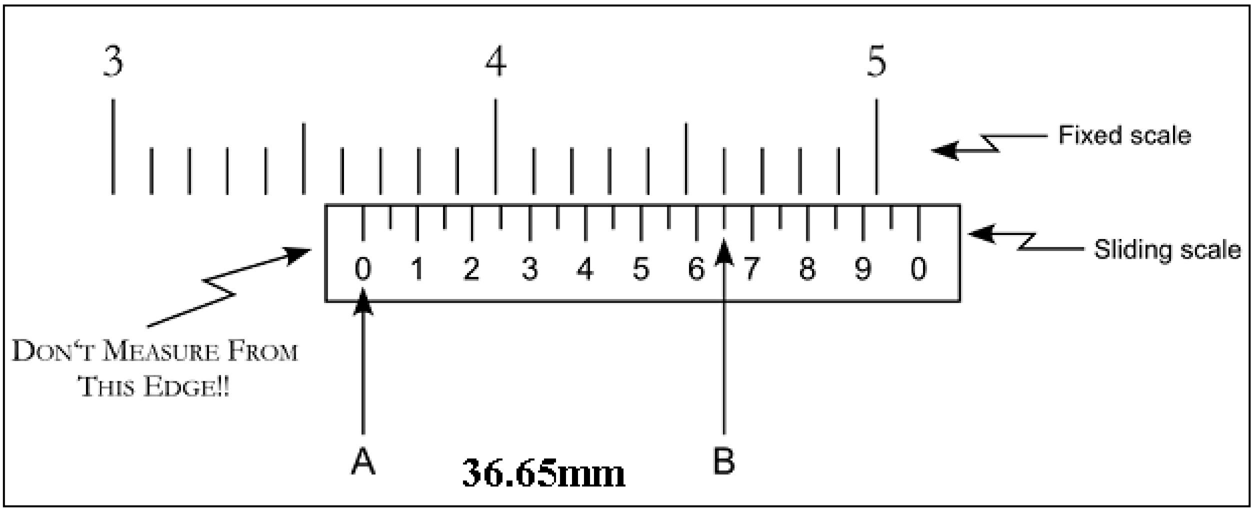


Figure 2.13

II. Instruments

(1) The vernier caliper

(2) The quill cylinder

(3) The rectangular cylinder

III. Procedure

Practice using the vernier caliper by measuring several objects. Check your measurements with your lab partner; if there is disagreement, check the vernier scale again. Be sure to ask if you're still unsure as to the correct procedure!

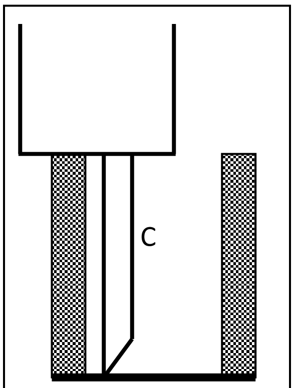


Figure 2.14

1. Measuring capacity of vessel

$$V = \frac{\pi}{4} d^2 h$$

d: The inner diameter

h: Depth of the object (using the **Depth probe**)

2. Measuring volume of rectangular block

$$\mathbf{V} = \boldsymbol{a} \times \boldsymbol{b} \times \boldsymbol{c}$$

Measuring five times the sides a, b, c of the block at different positions.

IV. Reporting: (see the reporting form of unit 2B)

THE REPORTING FORM OF UNIT 2B

1. Use the vernier caliper to measure

- Diameter d and height h_2 of a cylinder which has a base (cylinder);
- Sides a, b, c of a rectangular block
- Depths h_1, h_2, h_3, h_4,h_5, h_6.

Then, put the results obtained into the below tables:

Table 3.1: A cylinder which has a base

Measurement	d	Δd_{random}	h	Δh_{random}
1				
2				
3				
4				
5				
The average value				

Table 3.2: Sides a, b, c of retangular block

Measurement	a	Δa_{random}	b	Δb_{random}	c	Δc_{random}
1						
2						
3						
4						
5						
The average value						

2. Calculating the volumes of the three samples mentioned above

$\overline{V}_{cylinder}$; $\overline{V}_{rectangular}$

3. Calculating the corresponding errors:

$$\overline{\Delta d},\ \overline{\Delta h} \qquad \overline{\Delta a},\ \overline{\Delta b},\ \overline{\Delta c}$$

4. Calculating the errors

$$\left(\overline{\varepsilon}_{V_{cylinder}}, \overline{\Delta V}_{cylinder}\right)\ ;\ \left(\overline{\varepsilon}_{V_{rectangular}}, \overline{\Delta V}_{rectangular}\right)$$

5. Writing the results

$$V_{cylinder} = \overline{V}_{cylinder} \pm \overline{\Delta V}_{cylinder}$$

$$V_{retangular} = \overline{V}_{rectangular} \pm \overline{\Delta V}_{rectangular}$$

Show usages of the vernier caliper. Give some examples. In order to obtain an accuracy of 0.01 mm for the vernier caliper, how does its contruction have to be changed? Describe ernier caliper’s construction then.

UNIT 3: DETERMINING THE WAVELENGTH OF MONOCHROMATIC LIGHT

I. The purposes of the experiment

- Observing the interference of white light with Young's double-slit experiment.
- Determining the wavelength of monochromatic light with Young's double-slit experiment.
- This experiment is to make student familiar to using instruments to produce the interferent phenomenon.

II. Theoretical backgrounds

YOUNG ' S DOUBLE-SLIT EXPERIMENT

Young used a monocharomatic light source (primary source, **S**) and projected the light onto two very narrow slits (**S_1** & **S_2**), as shown in *Figure 3.1*. The light from the source will then diffract through the slits, and the patterns can be projected onto a screen. Since there is only one source of light, the set of two waves which emanate from the slits will be in phase with each other.

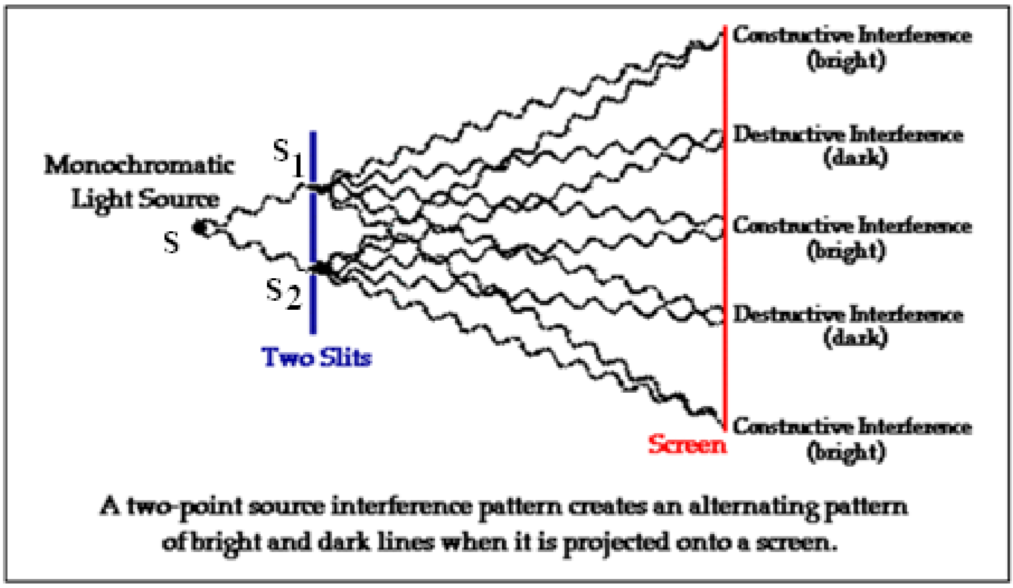


Figure 3.1: *Schematic diagram of Young ' s double-slit experiment. Two slits behave as coherent sources of light waves that produce an interference pattern on the viewing screen (drawing not to scale).*

As a result, these two slits, denoted as S_1 and S_2 , serve as a pair of coherent light sources. The light waves from S_1 and S_2 produce on a viewing screen a visible pattern of bright and dark parallel bands called fringes, as shown in *Figure 3.2*. When the light from S_1 and that from S_2 both arrive at a point on the screen such that constructive interference occurs at that location, a ***bright fringe*** appears. When the light from the two slits combines destructively at any location on the screen, a ***dark fringe*** results.

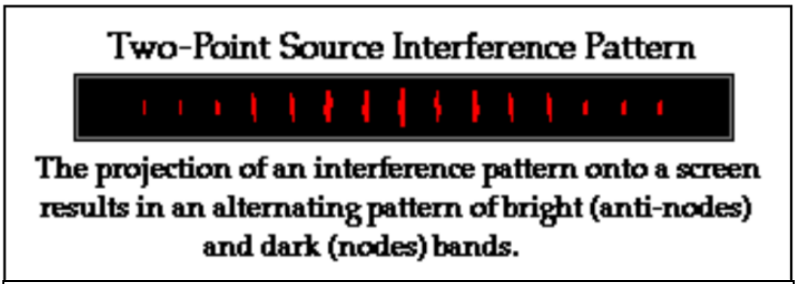


Figure 3.2: *A typical pattern from a two-slit experiment of interference.*

We can describe Young ' s experiment quantitatively with the help of *Figure 3.3*. The viewing screen is located a perpendicular distance L from the double- slitted barrier. S_1 and S_2 are separated by a distance d, and the source is monochromatic. To reach any arbitrary point P, a wave from the lower slit travels farther than a wave from the upper slit by a distance $d\sin\theta$. This distance is called the path difference δ (lowercase Greek delta).

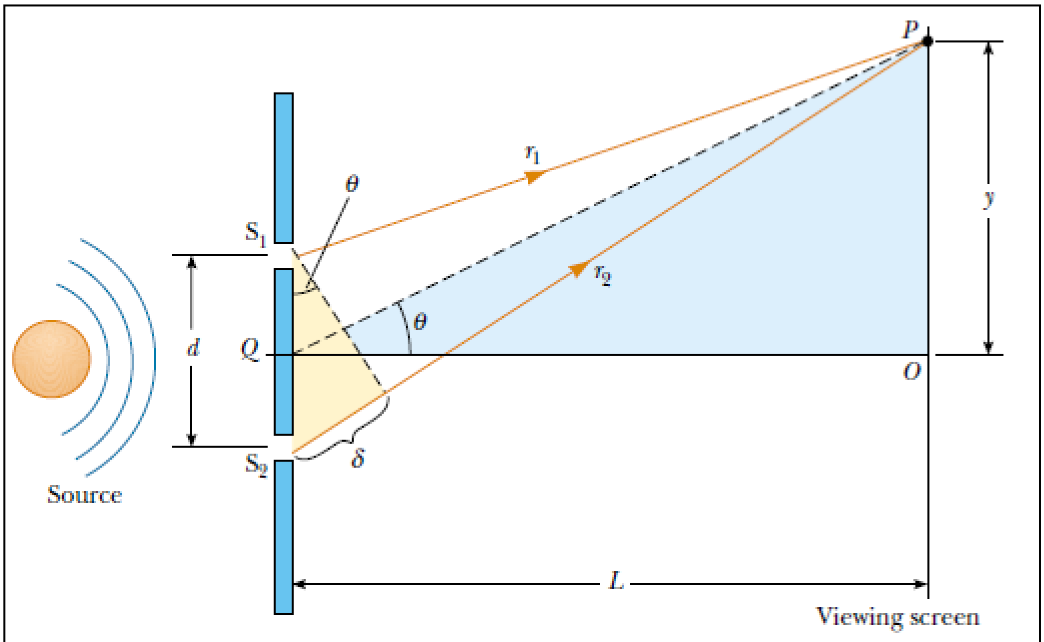


Figure 3.3: *Geometric construction for describing Young's double-slit experiment (not to scale).*

If we assume that two rays, S_1P and S_2P, are parallel, which is approximately true because L is much greater than d, then δ is given by

$$\boldsymbol{\delta = S_2P - S_1P = r_2 - r_1 = dsin\theta} \qquad [3.1]$$

where d = S_1S_2 is the distances between the two coherent light sources (i.e., the two slits).

If δ is either zero or some integer multiple of the wavelength, then the two waves are in phase at point P and constructive interference results. Therefore, the condition for bright fringes, or constructive interference, at point P is

$$\boldsymbol{\delta = r_2 - r_1 = n\lambda} \qquad [3.2]$$

where n = 0, ±1, ±2 , ….

The number **n** in equation [3.2] is called the order number. The central bright fringe at $\theta = 0$ (n = 0) is called the zeroth-order maximum. The first maximum on either side, where n = ±1, is called the first-order maximum, and so forth.

When δ is an odd multiple of n/2, the two waves arriving at point P are 180° out of phase and give rise to destructive interference. Therefore, the condition for dark fringes, or destructive interference, at point P is

$$\boldsymbol{\delta = r_2 - r_1 = (n + \tfrac{1}{2})\lambda} \qquad [3.3]$$

where n = 0, ±1, ±2, ...

It is useful to obtain expressions for the positions of the bright and dark fringes measured vertically from O to P. In addition to our assumption that L >> d, we assume that d >> λ . These can be valid assumptions because in practice L is often of the order of 1 m, d a fraction of a millimeter, and λ a fraction of a micrometer for visible light. Under these conditions, θ is small; thus, we can use the approximation $sin\theta \approx tan\theta$. Then, from triangle OPQ in *Figure 3.3*, we see that

$$\boldsymbol{y = \overline{OP} = Ltan\theta \approx Lsin\theta} \qquad [3.4]$$

From equations [3.1], [3.2] and [3.4], we can prove that the positions of the bright fringes measured from O are given by the expression

$$\boldsymbol{y_{bright} = n\frac{\lambda L}{d}} \qquad [3.5]$$

Similarly, using equations [3.1], [3.3] and [3.4], we find that the dark fringes are located at

$$\boldsymbol{y_{dark} = (n + 1/2)\frac{\lambda L}{d}} \qquad [3.6]$$

Using the formular [3.5] and [3.6], we determine the distance between two adjacent bright fringe [$y_{bright(n+1)} - y_{bright(n)}$] or distance between two adjacent dark fringe [$y_{dark\,(n+1)} - y_{dark\,(n)}$]. This resulf is given by

$$\boldsymbol{i = y_{bright(n+1)} - y_{bright(n)} = y_{dark(n+1)} - y_{dark(n)} = \frac{\lambda L}{d}} \quad [3.7]$$

As we demonstrate in the following example, Young's double-slit experiment provides a method for measuring the wavelength of light. If we have m adjacent bright fringes, we will have (m – 1) of value i in [3.7], therefore, we determine the value of λ. In fact, Young used this technique to do just that. Additionally, the experiment gave the wave model of light a great deal of credibility. It was inconceivable that particles of light coming through the slits could cancel each other in a way that would explain the dark fringes. As a result, the light interference show that light is of wave nature.

III. Instruments

(1) A solid-state lamp (laze) 1÷1,5mW

(2) A plate has two slits. These slits are parallel to each other, separated by a distance d = 0.15mm (Young's double-slit).

(3) A viewing screen.

(4) Some of bases.

(5) A measuring tape (tape-line) into milimeter.

(6) Transformer

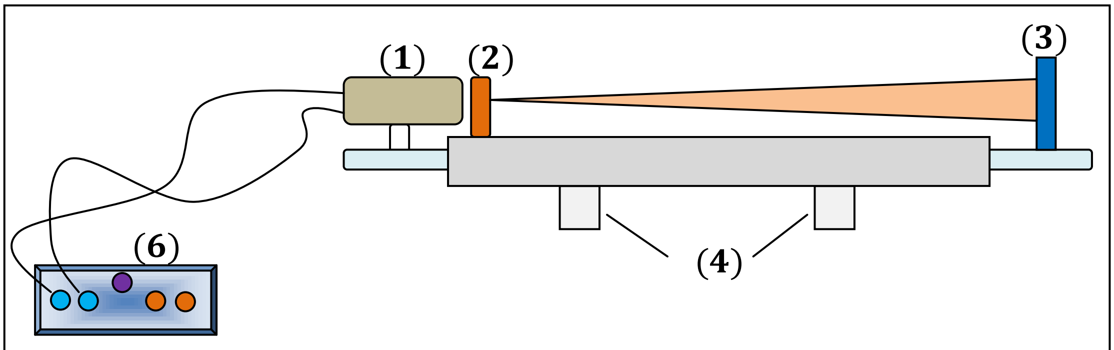


Figure 3.4: The experiment arrangement.

IV. Procedure

Step 1: Attch the solid-state lamp and the Young-slit to the bracket. (?)

Step 2: Connect the lamp to the alternating source of 220V and adjust the Young-slit so that the light from the lamp can shine through the Young-slit.

Step 3: Put the viewing screen on the bracket. The viewing screen and Young-slit are separated by a distance 1m (L_1 = 1m). Use the measuring tape to get value l_1, the distance of five adjacent bright fringes or five adjacent dark fringes.

Step 4: Calcultate $\boldsymbol{i_1} = \frac{l_1}{4} = \frac{\lambda L_1}{d}$ and after that find the value of λ with $\boldsymbol{\lambda} = \frac{d i_1}{L_1}$

Repeat these above steps five times with the other value of L and determine the corresponsding values of $\boldsymbol{\lambda}$.

THE REPORTING FORM OF UNIT 3

(1) Question: Write the equation of λ in terms d, l, L and the corresponding significance of these quantities.

(2) Experiment's result: Finish the below data sheet and calculate the average values and corresponding errors.

Given: $d = 0.150\ mm \pm 0.005mm$ is the distance between S_1 and S_2.

measurment	L(mm)	ΔL	$l(mm)$	Δl	$\lambda = \frac{dl}{4L}$
1					
2					
3					
4					
5					
Average value					

The final result $\boldsymbol{\lambda} = \bar{\boldsymbol{\lambda}} \pm \overline{\Delta\boldsymbol{\lambda}}$

Unit 4: MEASURING MASS DENSITY OF A SOLID USING THE JAR METHOD

I. The purpose of the experiment

This experiment is to make student familiar to the method of scaling repeatedly.

II. Theoretical backgrounds

1. Mass density

The mass density D of a substance of uniform composition is its mass per unit volume:

$$D = \frac{m_{object}}{V} \qquad [4.1]$$

m_{object} : The mass of the object (kg)

V: The volume of the object (m^3)

2. Method of measuring

- If the object has a simple shape such as a sphere, a cube, ect., first we can use vernier caliper or micrometer to determine its volume and use a scale to find the mass of the object.
- The object has a complicated shape such we can use find the object's volume by comparing its mass with the mass of an amount of water, which has the same volume as that of the object. This method is called jar method

$$D_0 = \frac{m_{water}}{V} \qquad [4.2]$$

m_{water} : The mass of the water

D_0: The mass density of the water

From equations [4.1] and [4.2], we have

$$D = \frac{m_{object}}{m_{water}} D_0 \qquad [4.3]$$

III. Instruments

(1) A balance and a set of weights

(2) A glass jar

(3) Water

(4) The solid object whose density is to be measured

(5) Wipers (using to clean the glass jar)

IV. Procedure

With a balance, use the method of repeated scalings to measure the mass of the object.

Step 1: Make the balance stable on a horizontal plane by using a plumb -line (adjusting screws at the balance's stand).

Step 2: Repeat weighings in an order as follows:

a. The first weighing (*Figure 4.1*)

Put intermediate object B on the left scale of the balance and put a jar full of water and several weights on the right scale of the balance. Adjust the amount of weights to make the total mass on the right scale equal to the mass on the left scale.

$$m_B = m_{water+jar} + m_1 \qquad [4.4]$$

m_B: The mass of object B

m_1: The total mass of the weights on the right scale after adjusting

$m_{water+jar}$: The mass of the jar full of water

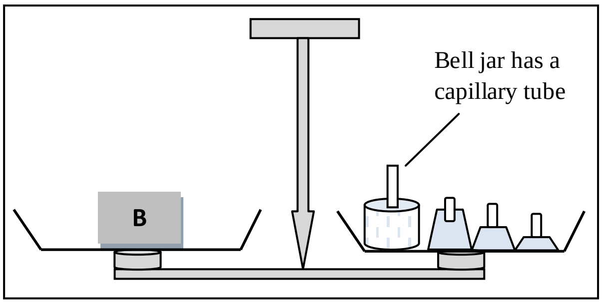


Figure 4.1

b. The second weighing (*Figure 3.2*)

Keep the same object B on the left scale, put the solid object of interest on the right scale, and take out some weights until the two masses on both scale are equal

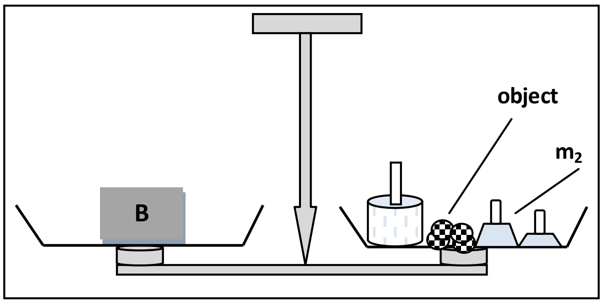


Figure 4.2

$$m_B = m_{water+jar} + m_{object} + m_2 \qquad [4.5]$$

$\mathbf{m_{object}}$: The mass of the solid object of interest .

$\mathbf{m_2}$: The total mass of those weights still on the right scale.

c. The third weighing (*Figure 4.3*)

Keep the same object B on the left scale, put the solid object of interest into the jar still full of water. Some water will be displaced out of the jar via a capillary, whose volume is called $V_{water/out}$. The volume of the object of interest, V_{object}, is equal to $V_{water/out}$. Clean gently the jar until its outside is dry then adjust the weights on the right scale until the two masses on both scales are equal

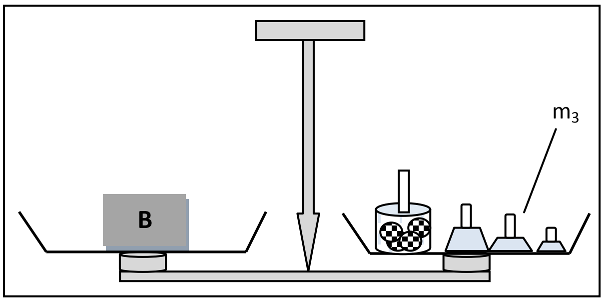


Figure 4.3

$$\mathbf{m_B = m'_{water + jar} + m_{object} + m_3} \qquad [4.6]$$

$\mathbf{m'_{water+jar}}$: The mass of the jar plus the mass of water still in the jar.

From equations [4.4] và [4.5], we have $\mathbf{m_{object} = m_1 - m_2}$

From equations [4.4] và [4.5]: we have $\mathbf{m_{water/out} = m_3 - m_2}$

$\mathbf{m_{water/out}}$: The mass of the water which is displaced out of the jar.

Putting those results in equation [4.3], we have

$$D = \frac{m_1 - m_2}{m_3 - m_2} D_0 \qquad [4.7]$$

Step3: Repeat step 2, each weighting is carried five times, and record the foundings.

V. Reporting: (see the reporting form of unit 4**)**

THE REPORTING FORM OF UNIT 4

1. Describe the method used to measure the mass density of a solid body which has a complicated shaped. Give the procedure to establish the equation calculating the mass density of this body.
2. Weigh the mass m_1, m_2, m_3. Each weighting is carried out five times.
3. Calculating the mass densities D_1, D_2, D_3, D_4, D_5 then from those densities find the average density $\overline{D}$.
4. Calculating the errors

   + $\overline{\Delta m_1}, \overline{\Delta m_2}, \overline{\Delta m_3}$

   + $\overline{\varepsilon_D}$, $\overline{\Delta D}$, $\left(\varepsilon_D = \frac{\Delta D}{D}\right)$ or $\left(\varepsilon_D = \frac{\overline{\Delta D}}{\overline{D}}\right)$

   Writing the results $D = \overline{D} \pm \overline{\Delta D}$

Given

+ The accuracy of the balance is 10 mg.

+ $D_0 = (996.0 \pm 0.1) kg/m^3$

<u>Table 4.1</u>**: The mass m_1, m_2, m_3.**

Measurement	m_1	m_2	m_3	$\Delta m_{1(random)}$	$\Delta m_{2(random)}$	$\Delta m_{3(random)}$
1						
2						
3						
4						
5						
The average value						

UNIT 5: MEASURING THE MASS DENSITY OF A LIQUID USING THE HYDROSTATIC METHOD

I. The purpose of the experiment

This experiment is to make student familiar to the method of scaling repeatedly.

II. Theoretical backgrounds

The mass density of the fluid is ratio of the mass of the liquid and the mass of the water having the same volume

The formula for calculating the mass density of a liquid

$$\rho = \frac{m_{liquid}}{m_{water}} \qquad [5.1]$$

m_{liquid} The mass of an amount of the liquid of interest

m_{water} The mass of an amount of water, having the same volume as that of the liquid.

To determine m_{fluid}, m_{water}, we compare the Archimedes forces (buoyant forces) acting on an object which is submerged in turn in the liquid and the water - ***hydrostatic method***

III. Instruments

(1) A balance and a set of weights

(2) An intermediate object B

(3) A pycnometer

(4) An amount of the fluid of interest

(5) Water

IV. Procedure

Step 1: Make the balance stable on a horizontal plane by using a plumb -line (adjusting screws at the balance's stand)

Step 2: Repeat weighings in an order as follows:

(a) The first weighing (*Figure 5.1*):

Put intermediate object B on the left scale of the balance and several weights and a hanging object on the right scale of the balance. Adjusting weighing to the amount of weights to make the total mass on the right scale equal to the mass on the left scale.

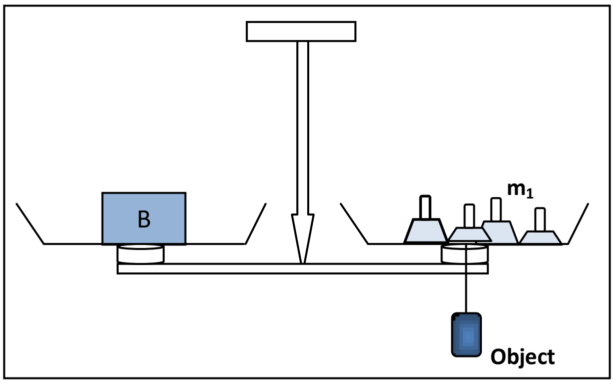


Figure 5.1

$$m_B = m_{hanging-object} + m_1 \qquad [5.2]$$

m_B: The mass of the object B

$m_{hanging\text{-}object}$: The mass of the hanging object on the right scale

m_1: The total mass of the weights on the right scale after adjusting.

(b) The second weighing (Figure 5.2)

Keep the same object B on the left scale, put the hanging object on the right scale into the liquid of interest, and some weights until the two masses on both scale are equal

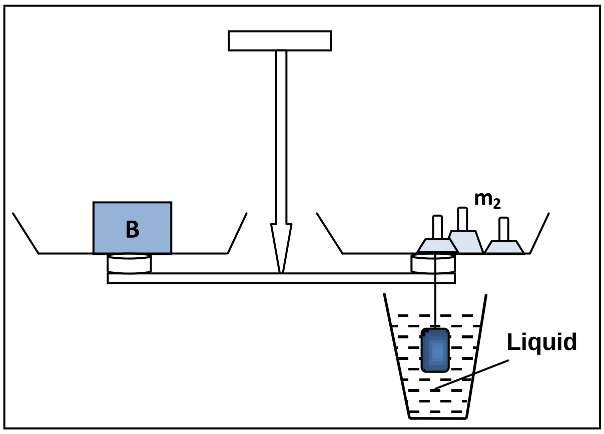


Figure 5.2

$$m_B = m_{hanging-object} - m_{liquid} + m_2 \quad [5.3]$$

$m_L g$: The weight of the liquid which is displaced, it is equal to Archimedes force (buoyant force)

Where

$m_{hanging\text{-}object}$: The mass of the solid object of interest.

m_2: The total mass of those weights still on the right scale.

(c) The third weighing (*Figure 5.3*):

Keep the same object B on the left scale, put the hanging object on the right scale into water, and *put in or take out* some weights until the two masses on both scales are equal

$$m_B = m_{hanging-object} - m_{water} + m_3 \quad [5.4]$$

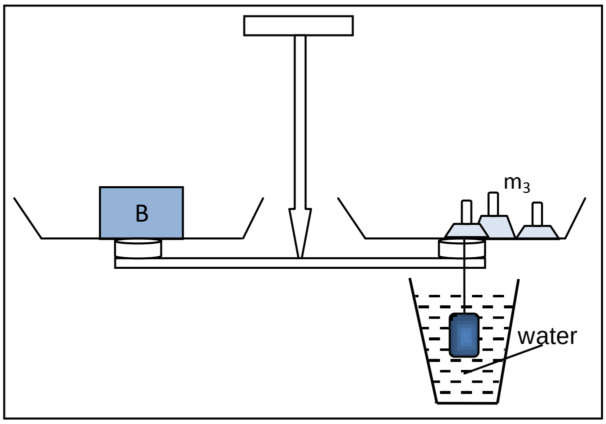


Figure 5.3

Caution: We must wipe the hanging object off the residue liquid before putting it into the water.

From equations [5.2] và [5.3], we have

$$m_{liquid} = m_2 - m_1 \quad [5.5]$$

From equations [5.2] và [5.4], we have

$$m_{water} = m_3 - m_1 \quad [5.6]$$

Put the results from [5.5], [5.6] into [5.1]. We obtain

$$\rho = \frac{m_2 - m_1}{m_3 - m_1} \quad [5.7]$$

Step3: Repeat step 2, each weighting is carried five times, and record the foundings.

V. Reporting: (see the reporting form of unit 5**)**

THE REPORTING FORM OF UNIT 5

1. Describe the method used to measure the mass density of a liquid. Give the procedure to establish the equation calculating the mass density ρ of a liquid by using the hydrostatic method.
2. Weigh the mass m_1, m_2, m_3. Each weighting is carried out five times.
3. Calculating the mass density ρ_1, ρ_2, ρ_3, ρ_4, ρ_5 then from those densities find the average density $\bar{\rho}$.
4. Calculating the errors

   + $\overline{\Delta m_1}, \overline{\Delta m_2}, \overline{\Delta m_3}$

   + $\bar{\varepsilon}_\rho, \overline{\Delta\rho}$ where $\left(\varepsilon_\rho = \frac{\Delta\rho}{\rho}\right)$

   Writing the results $\rho = \bar{\rho} \pm \overline{\Delta\rho}$

Given, the accuracy of the balance is 10 mg.

Table 5.1: **The mass m_1, m_2, m_3**

Measurement	**m_1**	**m_2**	**m_3**	$\Delta m_{1(random)}$	$\Delta m_{2(random)}$	$\Delta m_{3n(random)}$
1						
2						
3						
4						
5						
The average value						

UNIT 6: DETERMINING THE SURFACE TENSION COEFFICIENT OF A LIQUID

I. The purposes of the experiment

- Examine capillary phenomenon in a thin glass tube containing a liquid.
- Use results of the examination to determine the surface tension coefficient of the liquid.

II. Theoretical backgrounds

- **Phenomenon:** Dip a thin glass tube with a rather small inside diameter into water such that it is at right angle with the water surface. We will see that the level of the liquid inside the tube is different from that of the liquid outside the tube.

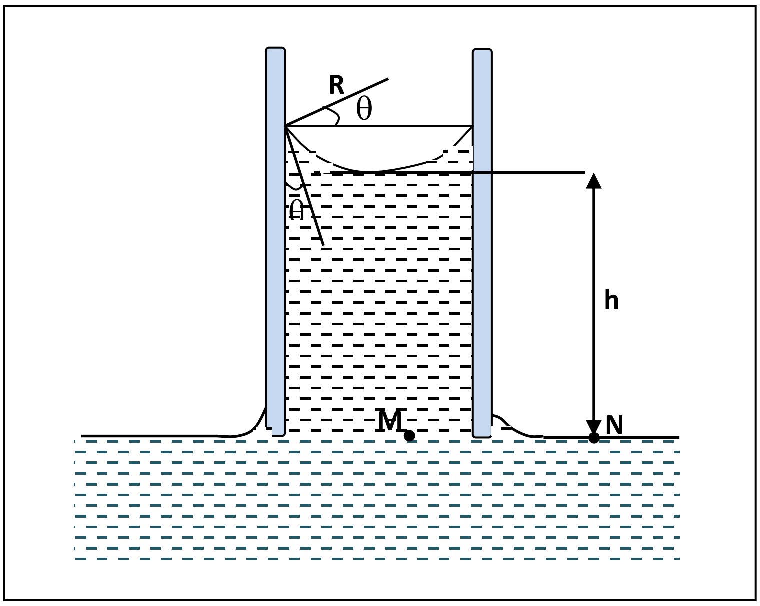


Figure 6.1

The capillary phenomenon is the one in which the surface of a liquid where it contacts a solid is elevated or depressed due to the force by which a liquid is drawn along a very narrow tube. Such a tube is called a capillary tube.

Actually, the existence of surface tension gives rise to a **hydrostatic pressure difference**, ΔP, between two fluids separated by a curved interface.

$$\Delta P = \frac{2\sigma}{R}$$

Where σ is the surface tension coefficient in the interface, and R is the radius of the interfacial curvature.

We examine the case in which the liquid surface level inside the tube is elevated. Consider two point M and N at the same level, as shown in Figure 6.1

The pressure at N

$$\mathbf{P_N = P_0} \qquad [6.1]$$

Where P_0 is the atmospheric pressure.

The pressure at M

$$P_M = P_0 + \rho g h + \Delta P \qquad [6.2]$$

$\rho g h$: The static pressure due to the water column of height h; ρ is the mass density of liquid; *g* is acceleration due to gravity.

Because M and N are of the same level, we have

$$\mathbf{P_M = P_N} \qquad [6.3]$$

From equations [6.1], [6.2], [6.3], we have

$$h = -\frac{\Delta P}{\rho g} \qquad [6.4]$$

In this case the capillary tube is a thin cylinder of inside diameter r, the curved interface is concave. The curved interface has the form a spherical top whose radius is R

$$R = -\frac{r}{cos\theta} \qquad [6.5]$$

Where θ is the contact angle and R is negative because the the curved interface is concave.

ΔP is given by

$$\Delta P = \frac{2\sigma}{R} \qquad [6.6]$$

Where σ is **the surface tension** in the interface.

- From equations [6.5], [6.6], we have

$$h = -\frac{2\sigma}{R\rho g} \qquad [6.7]$$

- From equations [6.5], [6.7] we have

$$h = \frac{2\sigma cos\theta}{R\rho g} = \frac{4\sigma cos\theta}{d\rho g} \qquad [6.8]$$

Where d is the inside diameter of the tube.

Equation [6.8] expresses the **Jurin's rule** which is used to find the height of the liquid column inside the capillary tube.

In our lab, the liquid used is alcohol. Because alcohol wets fully the glass, the contact angle θ is zero. Thus, ffrom equation [6.8], we obtain

$$h = \frac{4\sigma}{d\rho g} \qquad [6.9]$$

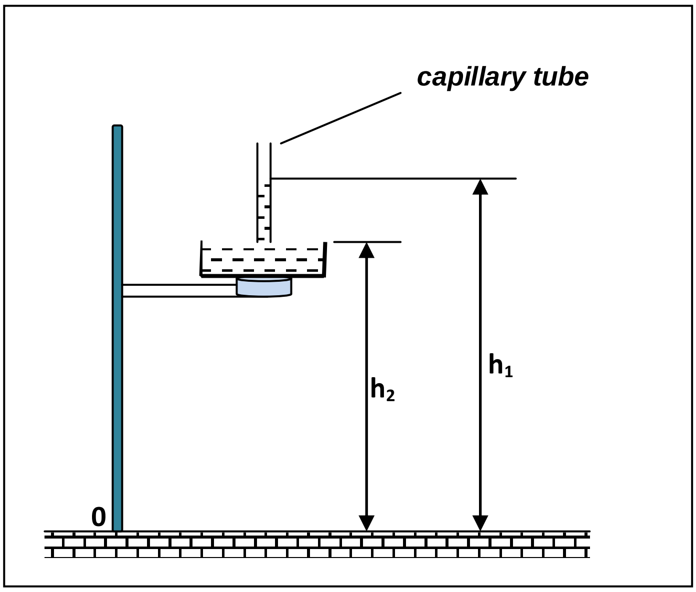


Figure 6.2

III. Instruments

(1) A capillary tube

(2) A disk containing alcohol

(3) A vertical clamp

(4) An inverted observing tool

IV. Procedure

Step 1: Dip the capillary tube into the alcohol, move it up and down several times, then clamp it vertically.

Step 2: Turn a screw at the inverted observing tool such that one of its division lines is coincident to the alcohol level of the liquid inside the tube. Record height h_1 of this level.

Turn the screw again such that one of another division line is coincident to the alcohol level outside the tube. Record the height h_2 of this level.

Then we have

$$\mathbf{h = h_1 - h_2} \quad [6.10]$$

Carry step 1 and step 2 five times and change the position of the tube on the alcohol surface.

Use equation [6.9] to calculate the surface tension coefficient σ of the liquid.

V. Reporting: (see the reporting form of unit 6)

THE REPORTING FORM OF UNIT 6

1. What phenomenon occurs on the surface of the liquid ? Describe the experiment and explain this phenomenon.

2. Describe how to measure the surface tension coefficient σ of a liquid through the capillary phenomenon.

3. Use an observing tool to measure height h_1, h_2. This is carried out five times.

4. Calculating

+ $\bar{h}, \bar{\sigma}$, where σ is the surface tension coefficient of the liquid.

+ $\overline{\Delta h_1}, \overline{\Delta h_2}, \overline{\varepsilon_\sigma}, \overline{\Delta\sigma}$, $\left(\varepsilon_\sigma = \dfrac{\Delta\sigma}{\sigma}\right)$ or $\left(\varepsilon_\sigma = \dfrac{\overline{\Delta\sigma}}{\bar{\sigma}}\right)$

Writing the results: $\sigma = \bar{\sigma} \pm \overline{\Delta\sigma}$

Given

+ The wetting angle of the liquid is 30°. ($\theta = 30^0$)

+ $\rho = (996.0 \pm 0.1)\text{kg}/\text{m}^3$

+ d = $(1.00 \pm 0.01)\text{mm}$

+ g = $(9.86 \pm 0.02)\text{m}/\text{s}^2$

Table : The heights, h_1 and h_2, are measured by observing tool

Measurment	**h_1**	**h_2**	**h**	$\Delta h_{1(random)}$	$\Delta h_{2(random)}$
1					
2					
3					
4					
5					
The average value					