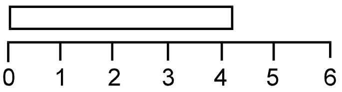
CHAPTER-35
MEASUREMENT ERRORS AND EXPERIMENTS

1. ERRORS IN MEASUREMENT

To get some overview of error, least count and significant figures, lets consider the example given below. Suppose we have to measure the length of a rod. How can we!

(a) Lets use a cm scale: (a scale on which only cm marks are there)



We will measure length = 4 cm

Although the length will be a bit more than 4, but we cannot say its length to be 4.1 cm or 4.2 cm, as the scale can measure upto cm only, not closer than that.

* It (this scale) can measure upto cm accuracy only.

* so we'll say that its **<u>least count</u>** is 1 cm

To get a closer measurement,
We have to use a more minute scale, that is mm scale

(b) Lets use an mm scale : (a scale on which mm marks are there)

We will measure length "ℓ"= 4.2 cm, which is a more closer measurement. Here also if we observe closely, we'll find that the length is a bit more than 4.2, but we cannot say its length to be 4.21, or 4.22, or 4.20 as this scale can measure upto 0.1 cms (1 mm) only, not closer than that.

* It (this scale) can measure upto 0.1 cm accuracy

Its **<u>least count</u>** is 0.1 cm

Max **<u>uncertainty</u>** in "ℓ"can be = 0.1cm

<u>Max possible error</u> in "ℓ" can be = 0.1cm

Measurement of length = 4.2 cm. has two **<u>significant figures</u>** ; 4 and 2, in which 4 is absolutely correct, and 2 is reasonably correct (Doubtful) because uncertainty of 0.1 cm is there.

To get more closer measurement

(c) We can use Vernier callipers : (which can measure more closely , upto 0.01 cm)

Then we'll measure length "ℓ" = 4.23 cm which is more closer measurement.

* It can measure upto 0.01 cm accuracy

Least count = 0.01 cm   Max **<u>uncertainty</u>** in "ℓ" can be = 0.01cm

<u>Max possible error</u> in "ℓ" can be = 0.01cm

Measurement of length = 4.23 cm. has three **<u>significant figures</u>** ; 4 , 2 and 3, in which 4 and 2 are absolutely correct , and 3 is reasonable correct (Doubtful) because uncertainty of 0.01 cm is there.

To get further more closer measurement :-

(d) We can use Screw Gauge : (which can measure more closely , upto 0.001 cm)

we'll measure length l = 4.234 cm.

* **<u>Max possible uncertainty (error)</u>** in **l** can be = 0.001 cm

* length = 4.234 cm. has four **<u>significant figures</u>** ;

4,	2,	3 and	4.
absolutely correct	absolutely correct	absolutely correct	Reasonably correct

To get further more closer measurement

(e) We can Use microscope :

we'll measure length l = 4.2342 cm.

* **<u>Max possible uncertainty (error)</u>** in **l** can be = 0.0001cm

* length = 4.2342cm. has five **<u>significant figures</u>** ; 4, 2, 3, 4 and 2

2. SIGNIFICANT FIGURES

From the above example, we can conclude that, in a measured quantity,

Significant figures are = Figures which are absolutely correct + The first uncertain figure

2.1 Common rules of counting significant figures :

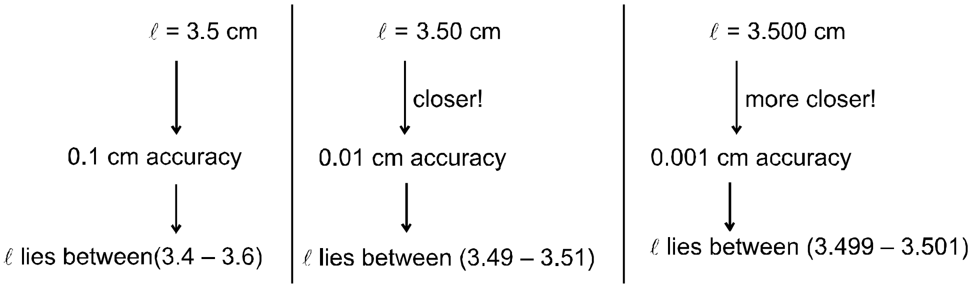
Rule 1 : All non-zero digits are significant

e.i. 123.56 has five S.F.

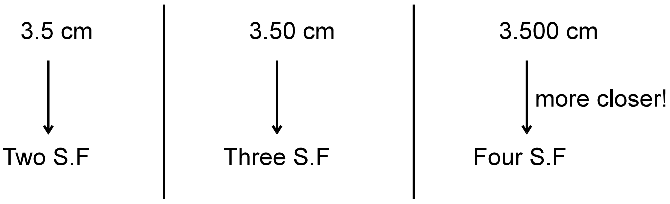
Rule 2 : All zeros occurring between two non-zeros digits are significant (obviously)

e.i. 1230.05 has six S.F.

Rule 3 :



So trailing zeroes after decimal place are significant (Shows the further accuracy)



Once a measurement is done, significant figures will be decided according to closeness of measurement. Now if we want to display the measurement in some different units, the S.F. shouldn't change (S.F. depends only on accuracy of measurement)

Number of S.F. is always conserved, change of units cannot change S.F.

Suppose measurement was done using mm scale, and we get ℓ = 85 mm (Two S. F.)

If we want to display it in other units.

$$\begin{tikzcd}
\text{85 mm} \arrow[r] \arrow[d] & \text{8.5 cm} \arrow[r] & \text{0.085 m} \arrow[d] \\
\text{85000 μm} = 8.5 \times 10^{4}\ \text{μm} & & \text{0.000085 km} = 8.5 \times 10^{-5}\ \text{km}
\end{tikzcd}$$

All should have two S.F.

The following rules support the conservation of S.F.

Rule 4: From the previous example, we have seen that,

$0.\underbrace{0000}_{\text{Not significant}}85$ km → also should has two S.F.; 8 and 5, So leading Zeros are not significant.

In the number less than one, all zeros after decimal point and to the left of first non-zero digit are insignificant (arises only due to change of unit)

0.000305 has three S.F.

⇒ 3.05×10^{-4} has three S.F.

Rule 5 : From the previous example, we have also seen that

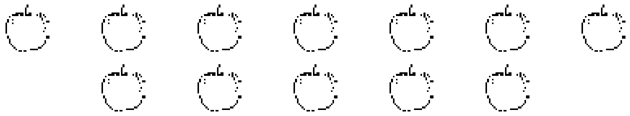
$85\underbrace{000}_{\text{Not significant}}$ μm → should also has two S.F., 8 and 5. So the trailing zeros are also not significant.

The terminal or trailing zeros in a number without a decimal point are not significant. (Also arises only due to change of unit)

154 m = 15400 cm = 15400 mm = 154×10^9 nm

all has only three S.F. all trailing zeros are insignificant

Rule 6 : There are certain measurement, which are exact i.e.



Number of apples are = 12 (exactly) = 12.000000........... ∞

This type of measurement is infinitely accurate so, it has ∞ S.F.

* Numbers of students in class = 125 (exact)

* Speed of light in the vacuum = 299,792,458 m/s (exact)

Example 1. Count total number of S.F. in 3.0800
Solution : S.F. = Five , as trailing zeros after decimal place are significant.

Example 2. Count total number of S.F. in 0.00418
Solution : S.F. = Three, as leading zeros are not significant.

Example 3. Count total number of S.F. in 3500
Solution : S.F. = Two, the trailing zeros are not significant.

Example 4. Count total number of S.F. in 300.00
Solution : S.F. = Five, trailing zeros after decimal point are significant.

Example 5. Count total number of S.F. in 5.003020
Solution : S.F. = Seven, the trailing zeros after decimal place are significant.

Example 6. Count total number of S.F. in 6.020×10^{23}
Solution : S.F. = Four ; 6, 0, 2, 0 ; remaining 23 zeros are not significant.

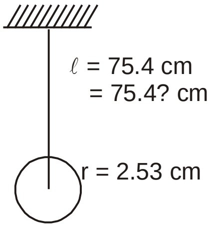
Example 7. Count total number of S.F. in 1.60×10^{-19}
Solution : S.F. = Three ; 1, 6, 0 ; remaining 19 zeros are not significant.

2.2 Operations according to significant figures:

Now lets see how to do arithmetic operations ie. addition, subtraction, multiplication and division according to significant figures

(a) Addition ⟵⟶ subtraction

For this, lets consider the example given below. In a simple pendulum, length of the thread is measured (from mm scale) as 75.4 cm. and the radius of the bob is measured (from vernier) as 2.53 cm.



Find $\ell_{eq} = \ell + r$

ℓ is known upto 0.1 cm (first decimal place) only. We don't know what is at the next decimal place. So we can write ℓ =75.4 cm = 75.4? cm and the radius r = 2.53 cm.

If we add ℓ and r, we don't know which number will be added with 3. So we have to leave that position.

ℓ_{eq} = 75.4? + 2.53 = 77.9? cm = 77.9 cm

Rules for Addition ⟵⟶ subtraction : (based on the previous example)

- * First do the addition/subtraction in normal manner.
- * Then round off all quantities to the decimal place of least accurate quantity.

423.5 + 20.23 + 10.15 | 486.2 – 35.18

i.e.

$$\begin{array}{r} 423.5 \\ +\ 20.23 \\ +\ 10.15 \\ \hline 453.8\textcircled{8} \end{array} \xrightarrow[\text{to one decimal place}]{\text{Round off}} 453.9 \qquad \begin{array}{r} 486.2 \\ -\ 35.18 \\ \hline 451.0\textcircled{2} \end{array} \xrightarrow[\text{to one decimal place}]{\text{Round off}} 451.0$$

Rules for Multiply ⟵⟶ Division

Suppose we have to multiply 2.11 x 1.2 = 2.11 ? x 1.2 ?

$$\begin{array}{r} 2\,.\,11\ ? \\ \underline{\times\ \ 1.2\ ?} \\ ?\ \ ?\,?\,? \\ 4\ 2\ \ 2\ ?\ \times \\ \underline{2\ 1\ 1\ \ ?\ \times\ \times} \\ 2.5\ \ ?\ \ ?\,?\,? \end{array} = 2.5$$

So answer will come in least significant figures out of the two numbers.

- ✪ Multiply divide in normal manner.
- ✪ Round off the answer to the weakest link (number having least S.F.)

$$\underset{5\text{ S.F.}}{312.65} \times \underset{3\text{ S.F}}{26.4} = 8253.960 \xrightarrow{\text{round off to three S.F.}} 8250$$

Example 8. A cube has a side $\ell = 1.2 \times 10^{-2}$ m. Calculate its volume

Solution : $\ell = 1.2 \times 10^{-2}$

$V = \ell^3 = \underset{\text{Two S.F.}}{(1.2 \times 10^{-2})}\quad \underset{\text{Two S.F.}}{(1.2 \times 10^{-2})}\quad \underset{\text{Two S.F.}}{(1.2 \times 10^{-2})}$

$= 1.728 \times 10^{-6}\ \text{m}^3$

$\downarrow$ Round off to 2 S.F.

$= 1.7 \times 10^{-6}\ \text{m}^3$ **Ans.**

Rules of Rounding off

- ✪ If removable digit is less than 5 (50%) ; drop it.

$$\underline{\mathbf{47.8}}33 \xrightarrow[\text{till one decimal place}]{\text{Round off}} 47.8$$

- ✪ If removable digit is greater than 5(50%), increase the last digit by 1.

$$\underline{\mathbf{47.8}}62 \xrightarrow[\text{till one decimal place}]{\text{Round off}} 47.9$$

If removable number is exactly 5(50%)

If last number is even drop 5

If last number is odd, increase the last digit by 1

✪ $\underline{20.6}5 \rightarrow 20.6$ $\qquad$ $\underline{20.7}5 \rightarrow 20.8$

Example 9. In ohm's law exp., reading of voltmeter across the resistor is 12.5 V and reading of current i = 0.20 Amp. Estimate the resistance in correct S.F.

Solution : $R = \frac{V}{i} = \frac{12.5 \rightarrow 3\text{ SF}}{0.20 \rightarrow 2\text{ SF}} = 62.5\ \Omega \xrightarrow[\text{round off to 2 S.F.}]{} 62\ \Omega$

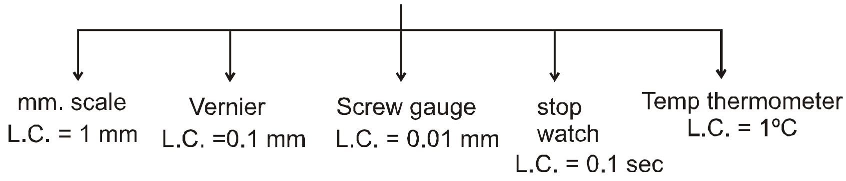
Example 10. Using screw gauge radius of wire was found to be 2.50 mm. The length of wire found by mm. scale is 50.0 cm. If mass of wire was measured as 25 gm, the density of the wire in correct S.F. will be (use π = 3.14 exactly)

Solution :
$$\rho = \frac{m}{\pi r^2 \ell} = \frac{\overset{\nearrow(\text{two S.F.})}{25}}{\pi\underset{\swarrow\text{three S.F}}{(0.250)^2}\underset{\searrow\text{three S.F.}}{(50.0)}} = \underline{2.5}465 \xrightarrow[\text{S.F.}]{\text{two}} 2.5 \text{ gm/cm}^3$$

3. LEAST COUNT

We have studied (from page 1) that no measurement is perfect. Every instrument can measure upto a certain accuracy; called least count.

Least count : The Smallest quantity an instument can measure



4. PERMISSIBLE ERROR

Error in measurement due to the limitation (least count) of the instrument, is called permissible error. From mm scale → we can measure upto 1 mm accuracy (least count = 1mm). From this we will get measurement like ℓ = 34 mm

↓

Max uncertainty can be 1 mm.

Max permissible error ($\Delta\ell$) = 1 mm.

But if from any other instrument, we get ℓ = 34.5 mm then max permissible error ($\Delta\ell$) = 0.1 mm

and if from a more accurate instrument, we get ℓ = 34.527 mm then max permissible error ($\Delta\ell$) = 0.001 mm

= place value of last number

Max permissible error in a measured quantity = least count of the measuring instrument and if nothing is given about least count then Max permissible error = place value of the last number

5. MAX. PERMISSIBLE ERROR IN RESULT DUE TO ERROR IN EACH MEASURABLE QUANTITY :

Let Result f(x, y) contains two measurable quantity x and y

Let error in x = $\pm \Delta x$ i.e. $x \in (x - \Delta x, x + \Delta x)$

error in y = $\pm \Delta y$ i.e. $y \in (y - \Delta y, y + \Delta y)$

Case - (I) : If f(x, y) = x + y

df = dx + dy

error in f = $\Delta f = \pm \Delta x \pm \Delta y$

max possible error in f = $(\Delta f)_{max}$ = max of $(\pm \Delta x \pm \Delta y)$

$(\Delta f)_{max} = \Delta x + \Delta y$

Case - (II) : If f = x – y

df = dx – dy

$(\Delta f) = \pm \Delta x \mp \Delta y$

max possible error in f = $(\Delta f)_{max}$ = max of $(\pm \Delta x \mp \Delta y)$

$\Rightarrow (\Delta f)_{max} = \Delta x + \Delta y$

For getting maximum permissible error, sign should be adjusted, so that errors get added up to give maximum effect

i.e. f = 2x – 3y - z

$(\Delta f)_{max} = 2\Delta x + 3\Delta y + \Delta z$

Example 11. In resonance tube exp. we find ℓ_1 = 25.0 cm and ℓ_2 = 75.0 cm. The least count of of the scale used to measure ℓ is 0.1 cm. If there is no error in frequency. What will be max permissible error in speed of sound (take f_0 = 325 Hz.)

Solution : $V = 2f_0\,(\ell_2 - \ell_1)$

$(dV) = 2f_0\,(d\ell_2 - d\ell_1)$

$(\Delta V)_{max}$ = max of $[2f_0(\pm\,\Delta\ell_2 \mp \Delta\ell_2] = 2f_0\,(\Delta\ell_2 + \Delta\ell_1)$

$\Delta\ell_1$ = least count of the scale = 0.1 cm

$\Delta\ell_2$ = least count of the scale = 0.1 cm

So max permissible error in speed of sound $(\Delta V)_{max}$ = 2(325Hz) (0.1 cm + 0.1 cm) = 1.3 m/s

Value of $V = 2f_0\,(\ell_2 - \ell_1)$ = 2(325Hz) (75.0 cm - 25.0 cm) = 325 m/s

so V = (325 ± 1.3) m/s

Case-(III) : If $f(x, y, z) = (\text{constant})\, x^a y^b z^c$ to scatter all the terms, Lets take log on both sides

$\ell n\, f = \ell n\,(\text{constant}) + a\,\ell n\, x + b\,\ell n\, y + c\,\ell n\, z$

$\downarrow$ Differentiating both sides

$$\frac{df}{f} = 0 + a\frac{dx}{x} + b\frac{dy}{y} + c\frac{dz}{z}$$

$$\frac{\Delta f}{f} = \pm\, a\,\frac{\Delta x}{x} \pm b\frac{\Delta y}{y} \pm c\frac{\Delta z}{z}$$

$$\left(\frac{\Delta f}{f}\right)_{max} = \text{max of } (\pm\, a\,\frac{\Delta x}{x} \pm b\,\frac{\Delta y}{y} \pm c\frac{\Delta z}{z})$$

i.e. $f = 15\, x^2\, y^{-3/2}\, z^{-5}$

$$\frac{df}{f} = 0 + 2\frac{dx}{x} - \frac{3}{2}\frac{dy}{y} - 5\frac{dz}{z}$$

$$\frac{\Delta f}{f} = \pm\, 2\frac{\Delta x}{x} \mp \frac{3}{2}\frac{\Delta y}{y} \mp 5\,\frac{\Delta z}{z}$$

$$\left(\frac{\Delta f}{f}\right)_{max} = \text{max of } (\pm\, 2\frac{\Delta x}{x} \mp \frac{3}{2}\frac{\Delta y}{y} \mp 5\frac{\Delta z}{z})$$

$$\left(\frac{\Delta f}{f}\right)_{max} = 2\frac{\Delta x}{x} + \frac{3}{2}\frac{\Delta y}{y} + 5\,\frac{\Delta z}{z}$$

✪ **sign should be adjusted, so that errors get added up**

Example 12. If measured value of resistance R = 1.05 Ω, wire diameter d = 0.60 mm, and length ℓ = 75.3 cm. If maximum error in resistance measurment is 0.01 Ω and least count of diameter and length measuring device are 0.01 mm and 0.1 cm respectively, then find max. permissible error in resistivity $\rho = \dfrac{R\left(\dfrac{\pi d^2}{4}\right)}{\ell}$

Solution :

$$\left(\frac{\Delta\rho}{\rho}\right)_{max} = \frac{\Delta R}{R} + 2\frac{\Delta d}{d} + \frac{\Delta\ell}{\ell}$$

ΔR = 0.01 Ω

Δd = 0.01 mm (least count)

$\Delta\ell$ = 0.1 cm (least count)

$$\left(\frac{\Delta\rho}{\rho}\right)_{max} = \left(\frac{0.01\,\omega}{1.05\,\omega} + 2\,\frac{0.01\text{mm}}{0.60\text{mm}} + \frac{0.1\text{cm}}{75.3\text{cm}}\right) \times 100 = 4.3\ \%.$$

Example 13. In ohm's law experiment, potential drop across a resistance was measured as v = 5.0 volt and current was measured as i = 2.0 amp. If least count of the voltmeter and ammeter are 0.1 V and 0.01A respectively then find the maximum permissible error in resistance.

Solution : $R = \frac{v}{i} = v \times i^{-1}$

$$\left(\frac{\Delta R}{R}\right)_{max} = \frac{\Delta v}{v} + \frac{\Delta i}{i}$$

Δv = 0.1 volt (least count)

Δi = 0.01 amp (least count)

$$\% \left(\frac{\Delta R}{R}\right)_{max} = \left(\frac{0.1}{5.0} + \frac{0.01}{2.00}\right) \times 100\ \% = 2.5\ \%$$

Example 14. In Searle's exp to find Young's modulus, the diameter of wire is measured as D = 0.050 cm, length of wire is L = 125 cm, and when a weight, m = 20.0 kg is put, extension in the length of the wire was found to be 0.100 cm. Find maximum permissible error in young's modulus (Y).

Solution : $\frac{mg}{\pi d^2/4} = Y\left(\frac{x}{\ell}\right) \Rightarrow Y = \frac{mg\ell}{(\pi/4)\ \ d^2 x}$

$$\left(\frac{\Delta Y}{Y}\right)_{max} = \frac{\Delta m}{m} + \frac{\Delta \ell}{\ell} + 2\frac{\Delta d}{d} + \frac{\Delta x}{x}$$

here no information of least count is given so maximum permissible error in ℓ = place value of last number.

m = 20.0 kg ⇒ Δm = 0.1 kg (place value of last number)

ℓ = 125 cm ⇒ $\Delta \ell$ = 1 cm (place value of last number)

d = 0.050 cm ⇒ Δd = 0.001 cm (place value of last number)

x = 0.100 cm ⇒ Δx = 0.001 cm (place value of last number)

$$\left(\frac{\Delta Y}{Y}\right)_{max} = \left(\frac{0.1kg}{20.0kg} + \frac{1cm}{125cm} + \frac{0.001cm}{0.05cm} \times 2 + \frac{0.001cm}{0.100cm}\right) \times 100\% = 6.3\%$$

Example 15. To find the value of 'g' using simple pendulum T = 2.00 sec; ℓ = 1.00 m was measured. Estimate maximum permissible error in 'g'. Also find the value of 'g'. (Use $\pi^2 = 10$)

Solution : $T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow g = \frac{4\pi^2\ell}{T^2}$

$$\left(\frac{\Delta g}{g}\right)_{max} = \frac{\Delta \ell}{\ell} + 2\frac{\Delta T}{T} = \left(\frac{0.01}{1.00} + 2\frac{0.01}{2.00}\right) \times 100\ \% = 2\ \%$$

value of $g = \frac{4\pi^2\ell}{T^2} = \frac{4 \times 10 \times 1.00}{(2.00)^2} = 10.0\ m/s^2$

$\left(\frac{\Delta g}{g}\right)_{max}$ = 2/100 so $\frac{\Delta g_{max}}{10.0} = \frac{2}{100}$ so $(\Delta g)_{max} = 0.2$ = max error in 'g'

so 'g' = (10.0 ± 0.2) m/s^2

OTHER TYPES OF ERRORS :

1. Error due to external Causes :

These are the errors which arise due to reasons beyond the control of the experimentalist, e.g., change in room temperature, atmospheric pressure, humidity, variation of the acclectrion due to gravity etc. A suitable correction can, however, be applied for these errors if the factors affecting the result are also recorded.

2. Instrumental errors :

Every instrument, however cautiously manufactured, possesses imperfection to some eaxtent. As a result of this imperfection, the measurements with the instrument cannot be free from errors. Errors, however small, do occur owing to the inherent manufacturing defects in the measuring instruments are called instrumental errors. These errors are of constant magnitude and suitable corrections can be applied for these errors. e.i.. Zero errors in vernier callipers, and screw gauge, backlash errors in screw gauge etc

3. Personal or chance error :

Two observers using the same experiment set up, do not obtain exactly the same result. Even the observations of a single experimentalist differ when it is repeated several times by him or her. Such errors always occur inspire of the best and honest efforts on the part of the experimentalist and are known as personal errors. These errors are also called chance errors as they depend upon chance. The effect of the chance error on the result can be considerably reduced by taking a large number of observations and then taking their mean. How to take mean, is described in next point.

4. Errors in averaging :

Suppose to measure some quantity, we take several observations, a_1, a_2, a_3…. a_n .To find the absolute error in each measurement and percentage error , we have to follow these steps

(a) First of all mean of all the observations is calculated : $a_{mean} = (a_1 + a_2 + a_3 + \ldots + a_n) / n$. The mean of these values is taken as the best possible value of the quantity under the given conditions of measurements..

(b) **Absolute Error :** The magnitude of the difference between the best possible or mean value of the quantity and the individual measurement value is called the absolute error of the measurement. The absolute error in an individual measured value is:

$$\Delta a_n = |\, a_{mean} - a_n \,|$$

The arithmetic mean of all the absolute errors is taken as the final or mean absolute error.

$$\Delta a_{mean} = (|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \ldots\ldots\ldots\ldots + |\Delta a_n|)/n$$

$$\Delta a_{mean} = \left(\sum_{i=1}^{n} |\,\Delta a_i\,| \right) \bigg/ n$$

we can say $a_{mean} - \Delta a_{mean} \le a \le a_{mean} + \Delta a_{mean}$

(c) **Relative and Percentage Error**

Relative error is the ratio of the mean absolute error and arithmetic mean.

Relative error = $\dfrac{\Delta a_{mean}}{a_{mean}}$

When the relative error is expressed in percent, it is called the percentage error.

Thus, Percentage error = $\dfrac{\Delta a_{mean}}{a_{mean}} \times 100\%$

Example 16. In some observations, value of ‘g’ are coming as 9.81, 9.80, 9.82, 9.79, 9.78, 9.84, 9.79, 9.78, 9.79 and 9.80 m/s^2. Calculate absolute errors and percentage error in g.

Solution :

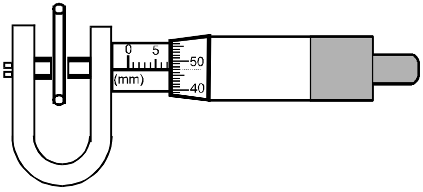
S.N.	Value of g	Absolute error $\Delta g = \lvert g_i - \bar{g} \rvert$
1	9.81	0.01
2	9.80	0.00
3	9.82	0.02
4	9.79	0.01
5	9.78	0.02
6	9.84	0.04
7	9.79	0.01
8	9.78	0.02
9	9.79	0.01
10	9.80	0.00
	$g_{mean} = 9.80$	$\Delta g_{mean} = \frac{\sum \Delta g_i}{10}$ $= \frac{0.14}{10} = 0.014$

percentage error = $\frac{\Delta g_{mean}}{g_{mean}} \times 100 = \frac{0.014}{9.80} \times 100\ \% = 0.14\ \%$

so ‘g’ = $(9.80 \pm 0.014)\ m/s^2$

EXPERIMENT - 1

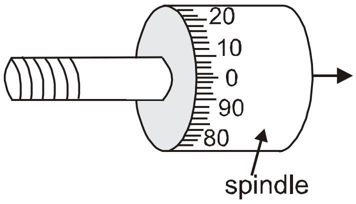
Screw gauge (Micrometer)



Screw gauge is used to measure closely upto $\left(\frac{1\ \text{mm}}{100}\right)$. How can it divide 1 mm in 100 parts !

To divide 1 mm in 100 parts, a screw is used. In one rotation, the screw (spindle) moves forward by 1 mm. (Called pitch of the screw)

The rotation of the screw (spindle) is divided in 100 parts (called circular scale), hence 1 mm is divided in 100 parts



1 rotation ≡ 1 mm

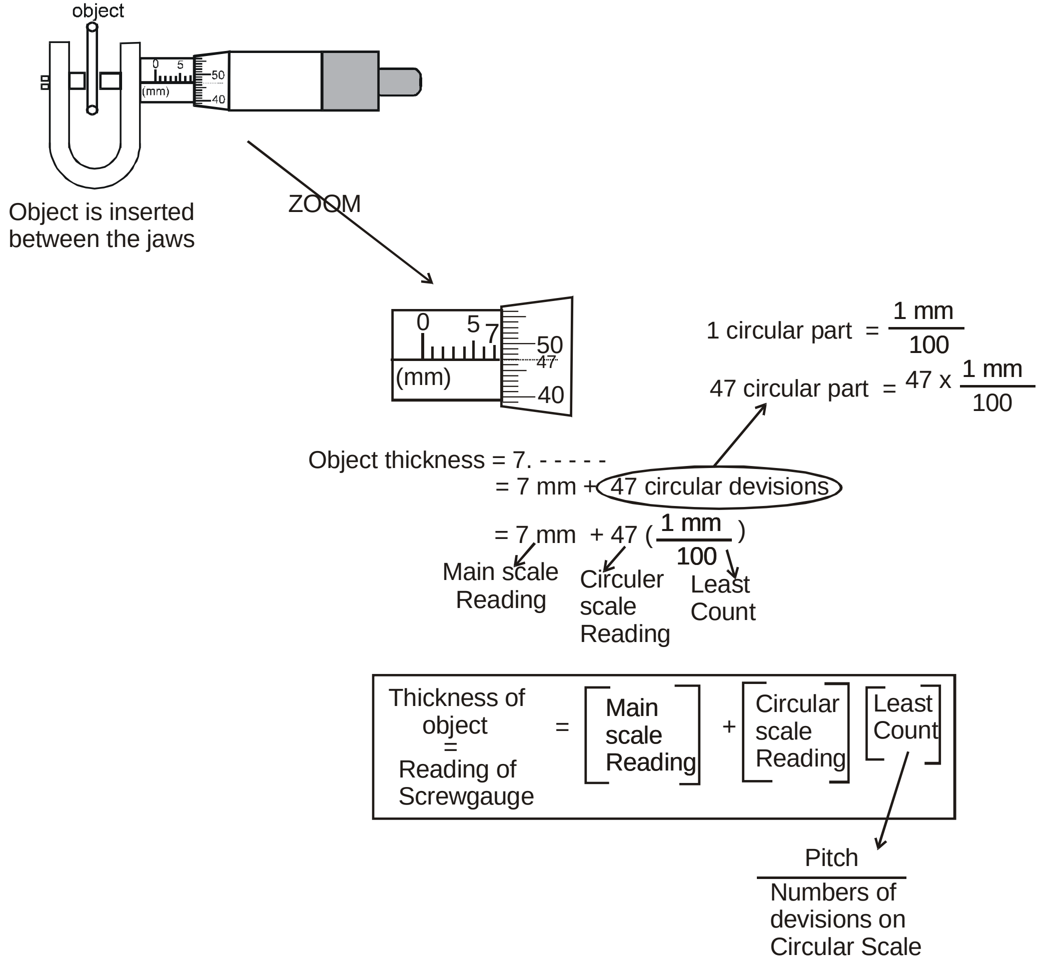
100 circular parts ≡ 1 mm

so 1 circular part ≡ $\frac{1\ \text{mm}}{100}$ = Least count of screw gauge

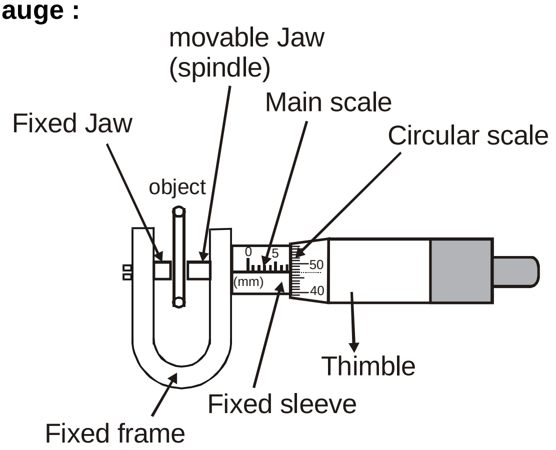
So lets generalize it

$$\text{Least count of a screw gauge} = \frac{1\text{ mm} \longrightarrow \text{pitch of screw}}{100 \longrightarrow \text{number of divisions on circular scale}}$$

How to find thickness of an object by screw gauge !



Description of screw gauge :



The object to be measured is put between the jaws. The sleeve is hollow part, fixed with the frame and main scale is printed on it.

The spindle and thimble are welded, and move together by means of a screw. The circular scale is printed on the thimble as shown. It generally consists of 100 divisions (sometime 50 divisions also)
The main scale has mm marks (Sometimes it also has 1/2 mm marks below mm marks.)
(Usually if pitch of the screw gauge is 1mm then there are 1mm marks on main scale and if pitch is 1/2 mm then there are 1/2 mm marks also)
This instrument can read upto 0.01 mm (10 μm) accuracy that is why it is called micrometer

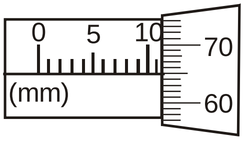
Example 17. Read the normal screwgauge

*Main scale has only mm marks.

*In a complete rotation, the screw advances by 1 mm.

*Circular scale has 100 divisions

Solution :



Soln: Object thickness = 11 mm + 65 ($\frac{1\text{ mm}}{100}$)

= 11.65 mm

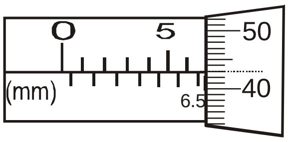
Example 18. Read the screwgauge

* Main scale has $\frac{1}{2}$ mm marks.

* In complete rotation, the screw advances by $\frac{1}{2}$ mm.

* Circular scale has 50 division.

Solution :



Soln: Object thickness = 6.5 - - - -

Object thickness = 6.5 mm + 43 ($\frac{1/2\text{ mm}}{50}$)

= 6.93 mm

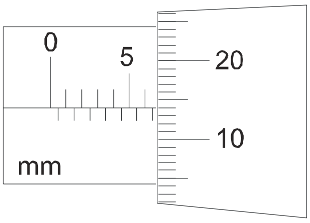
Example 19. Read the screwgauge shown bellow:

* Main scale has $\frac{1}{2}$ mm marks.

* In complete rotation, the screw advances by $\frac{1}{2}$ mm.

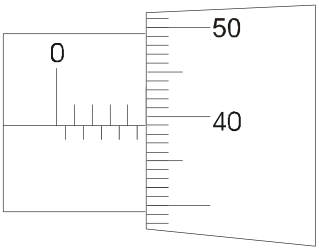
* Circular scale has 50 division.

Solution :



Object thickness = 6.5 mm + 14 $\left(\frac{1/2\text{ mm}}{50}\right)$

= 6.64 mm

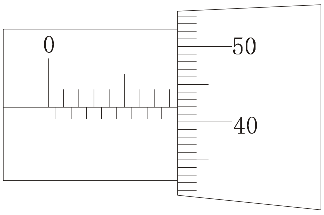


Object thickness = 4.5 mm + 39 $\left(\frac{1/2\text{ mm}}{50}\right)$

= 4.89 mm

Example 20. A wire of resistance R = 100.0 Ω and length l = 50.0 cm is put between the jaws of screw gauge. Its reading is shown in figure. Pitch of the scruegauge is 0.5 mm and there are 50 divisio on circular scale. Find its resistivity in correct significant figures and maximum permissible error in ρ (resistivity).

Solution :



Object thickness = 8 mm + 42 $\left(\frac{1/2\text{ mm}}{50}\right)$

= 8.42 mm

$$R = \frac{\rho\ell}{\pi d^2/4} \quad \Rightarrow \quad \rho = \frac{R\pi d^2}{4\ell} = \frac{(100.0)\ \ (3.14)\ \ (8.42\times10^{-3})}{4(50.0\times10^{-2})} = 1.32\ \ \Omega/m$$

$$\frac{d\rho}{\rho} = \frac{dR}{R} + \frac{2d(D)}{D} + \frac{d\ell}{\ell} = \frac{0.1}{100.0} + 2\times\frac{0.01}{8.42} + \frac{0.1}{50} = 0.00537\ (0.52\%)$$

Example 21. In a complete rotation, spindle of a screw gauge advances by $\frac{1}{2}$ mm. There are 50 divisions on circular scale. The main scale has $\frac{1}{2}$ mm marks → (is graduated to $\frac{1}{2}$ mm or has least count = $\frac{1}{2}$ mm)

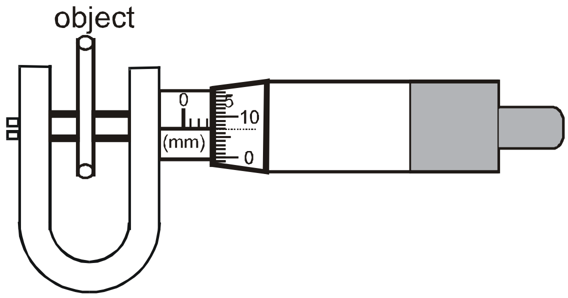
If a wire is put between the jaws, 3 main scale divisions are clearly visible, and 20 division of circular scale co-inside with the reference line. Find diameter of wire in correct S.F.

Solution : Diameter of wire (3 × $\frac{1}{2}$ mm) + (20) $\left(\frac{1/2 \text{ mm}}{50}\right)$ = 1.5 + 0.20 = 1.70 mm (The answer should be upto two decimal places because this screwgauges can measure upto 0.01 mm accuracy).

Example 22. In the previous question if the mass of the wire is measured as 0.53 kg and length of the wire is measured by an mm scale and is found to be 50.0 cm, find the density of the wire in correct significant figures.

Solution :
$$\rho = \frac{m}{\left(\frac{\pi d^2}{4}\right)\ell} = \frac{(0.53 \times 10^3) \times 4}{(3.14)\ (1.70 \times 10^{-3})^2 (50 \times 10^{-2})} g/m^3 = 4.7 \times 10^8 \ \ (2 \text{ S.F.})$$

Example 23. Two measure diameter of a wire, a screwgauge is used. The main scale division is of 1 mm. In a complete rotation, the screw advances by 1 mm and the circular scale has 100 devisions. The reading of screwgauge is as shown in figure.



If there is no error in mass measurement, but error in length measurement is 1%, then find max. Possible error in density.

Solution :
$$\rho = \frac{m}{\left(\frac{\pi d^2}{4}\right)\ell}$$

$$\left(\frac{\Delta\rho}{\rho}\right) = 2\frac{\Delta d}{d} + \frac{\Delta \ell}{\ell}$$

Δd = least count of = $\frac{1 \text{ mm}}{100} = 0.01$ mm

and d = 3.07 mm from the figure

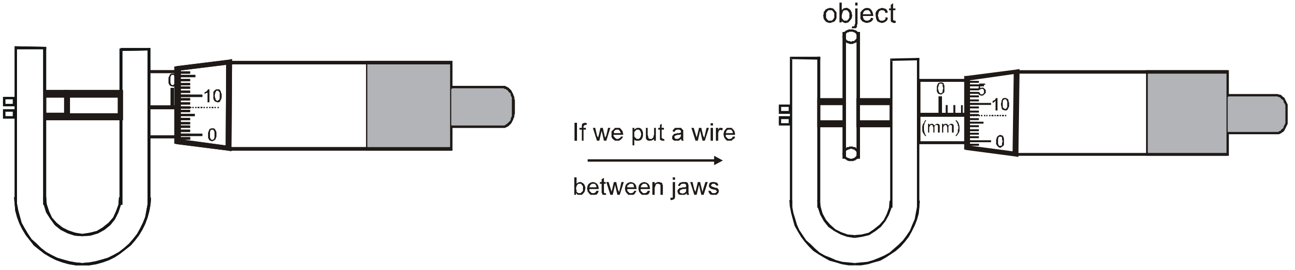
so $\left(\frac{\Delta\rho}{\rho}\right)_{max} = \left(2 \times \frac{0.01}{3.07} + \frac{1}{100}\right) \times 100\%$

$\left(\frac{\Delta\rho}{\rho}\right)_{max}$ = 1.65%.

Zero Error :

If there is no object between the jaws (i.e. jaws are in contact), the screwgauge should give zero reading. But due to extra material on jaws, even if there is no object, it gives some excess reading. This excess.

Reading is called **zero error** :



Excess reading = 0.07 mm
(Zero error)

it gives 3.07 mm

In which there is 0.07 mm excess reading which has to be substructed

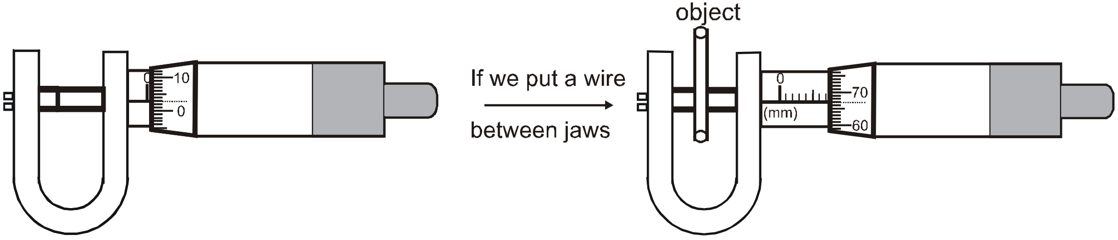
so actual thickness = 3.07 – 0.07 = 3.00 mm

Observed reading

excess reading (zero error)

Actual reading = observed reading – excess reading (zero error)

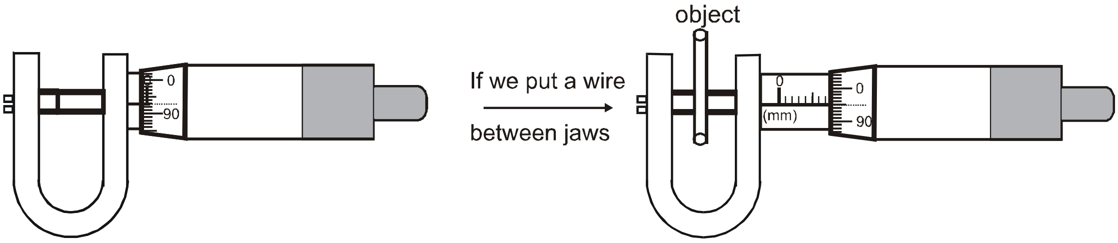
Example 24. Find the thickness of the wire. The main scale division is of 1 mm. In a complete rotation, the screw advances by 1 mm and the circular scale has 100 devisions.



Solution : Excess reading (Zero error) = 0.03 mm It is giving 7.67 mm in which there is 0.03 mm excess reading, which has to be removed (subtracted)

so actual reading = 7.67 - 0.03 = 7.64 mm

Example 25. Find the thickness of the wire. The main scale division is of 1 mm. In a complete rotation, the screw advances by 1 mm and the circular scale has 100 devisions. If no object is placed between the jaws, the zero of main scale is barely visible and 93rd circular devision matches with the main scale line.



Solution : Excess reading (Zero error)
= (–1 mm) + (93) (0.01) = – 0.07mm

It is giving 7.95 mm in which there is -0.07 mm excess reading , which has to be removed (subtracted)
so actual reading = 7.95 -(- 0.07) = 8.02 mm

ZERO CORRECTION :

Zero correction is invert of zero error :

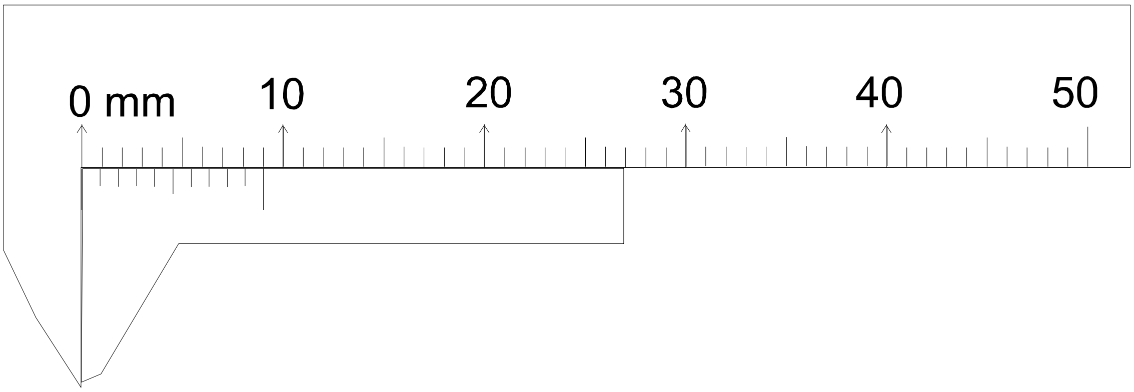
zero correction = - (zero error)

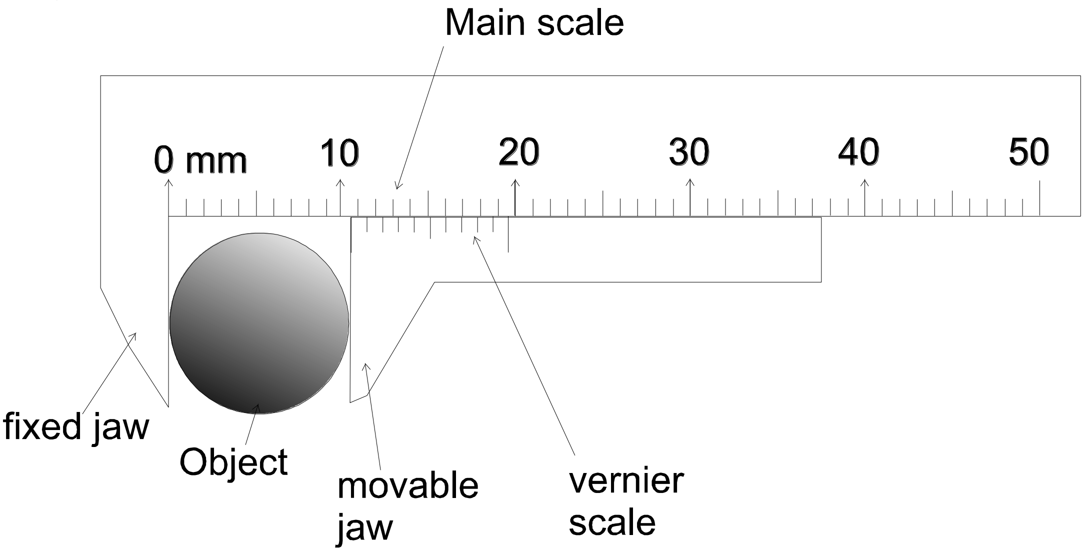
Actual reading = observed reading - zero error
= observed reading + Zero correction

EXPERIMENT # 2

Vernier callipers

It is used to measure accurately upto 0.1 mm.





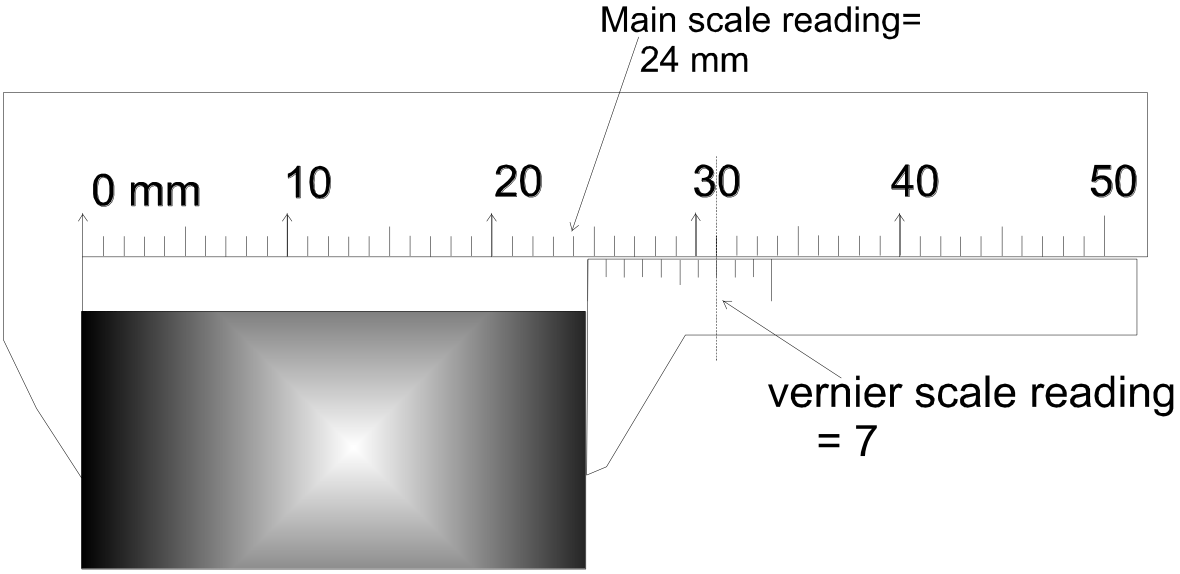
*On the upper plate, main scale is printed which is simply an mm scale.

*On the lower plate, vernier scale is printed, which is a bit compressed scale. Its one part is of 0.9 mm.

(10 vernier scale divisions = 9 mm ⇒ 1 vernier scale division = 0.9 mm)

The object which is to be measured, is fitted between the jaws as shown.

How to read Vernier Callipers:



Thickness of the object = 24. - - - - - - -

= 24 mm + 7 (0.1 mm)

Formula says

Thickness of the object = Main Scale Reading + Vernier Scale Reading least count

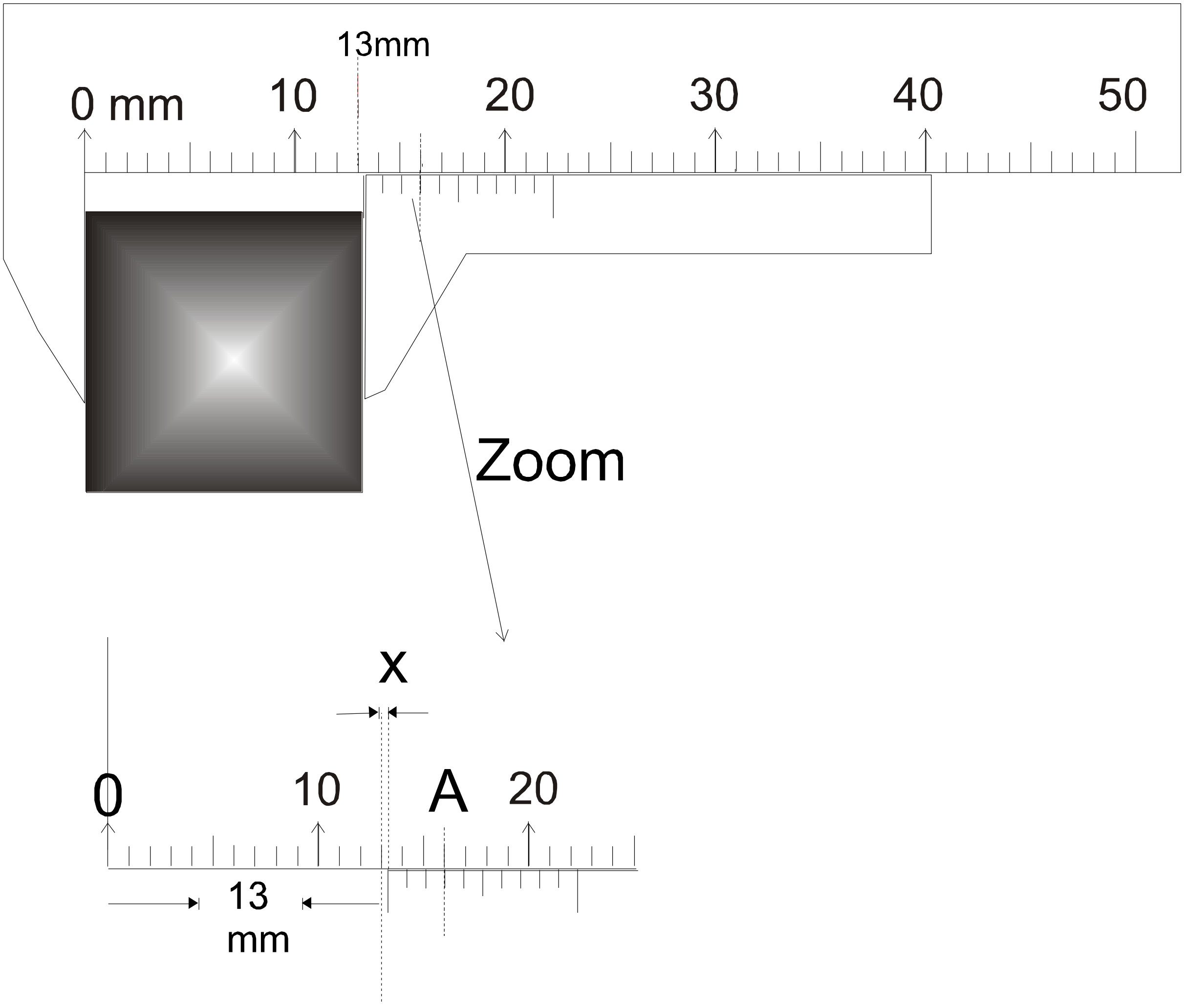
Vernier Scale Reading → Mark on vernier scale which exactly co-insides with some mark of main scale

least count → [1 main scale devision - 1 vernier scale devision]

= 1 mm - 0.9 mm

= 0.1 mm

Now lets see How the slight difference between 1 MSD and 1 VSD reflects as least count



Required length = 13 mm + x = ?

at point ‘A’ , main scale and vernier scale are matching

so length OA along main Scale = length OA along Vernier Scale

13 mm +3 (Main scale division) = (13 mm + x) + 3 (vernier Scale division)

Get 13 mm + x = 13 mm + 3 (Main scale division - vernier Scale division)

= 13 mm + 3 (1 mm – 0.9 mm)

= 13 mm + 3 (0.1 mm) = 13.3 mm

↓ ↓ ↓

(main scale reading) + (vernier scale reading) (Least count)

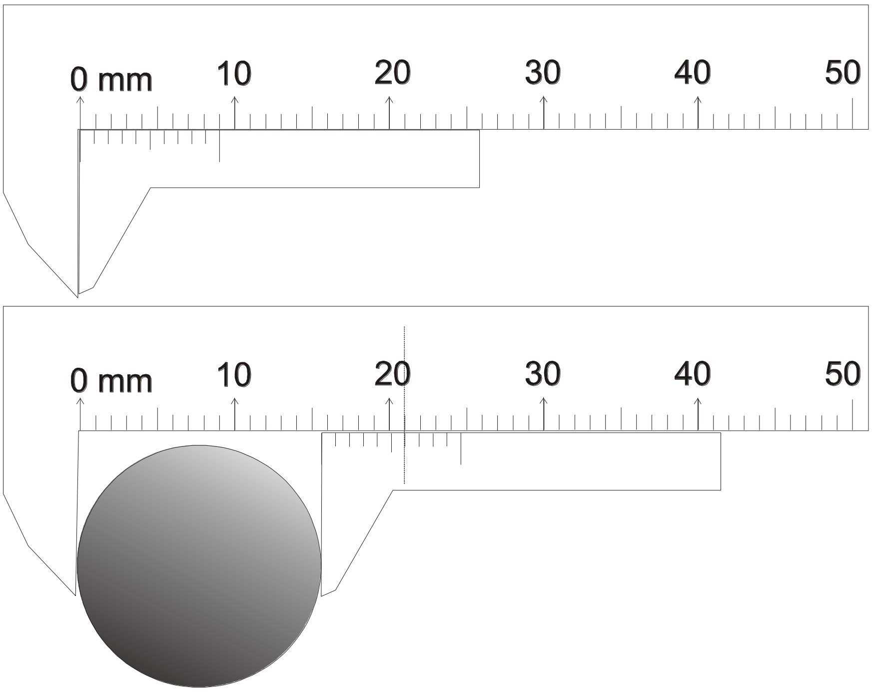
↓

(1 Main scale division – 1 vernier Scale division)

Hence the slight difference between 1 MSD (1 mm) and 1 VSD (0.9 mm) reflects as least count (0.1 mm)

$$\begin{matrix}\text{Thicknes of object}\\ =\\ \text{Reading of vernier callipers}\end{matrix} = \begin{pmatrix}\text{main}\\ \text{scale}\\ \text{reading}\end{pmatrix} + \begin{pmatrix}\text{vernier}\\ \text{scale}\\ \text{reading}\end{pmatrix}\begin{pmatrix}\text{Least}\\ \text{count}\end{pmatrix}$$

Example 26. Read the vernier. 10 division of vernier scale are matching with 9 divisions of main scale.



Solution : 10 vernier scale divisions = 9 mm

1 vernier scale division = 0.9 mm

$\Rightarrow$ least count = (Main scale division - vernier Scale division)

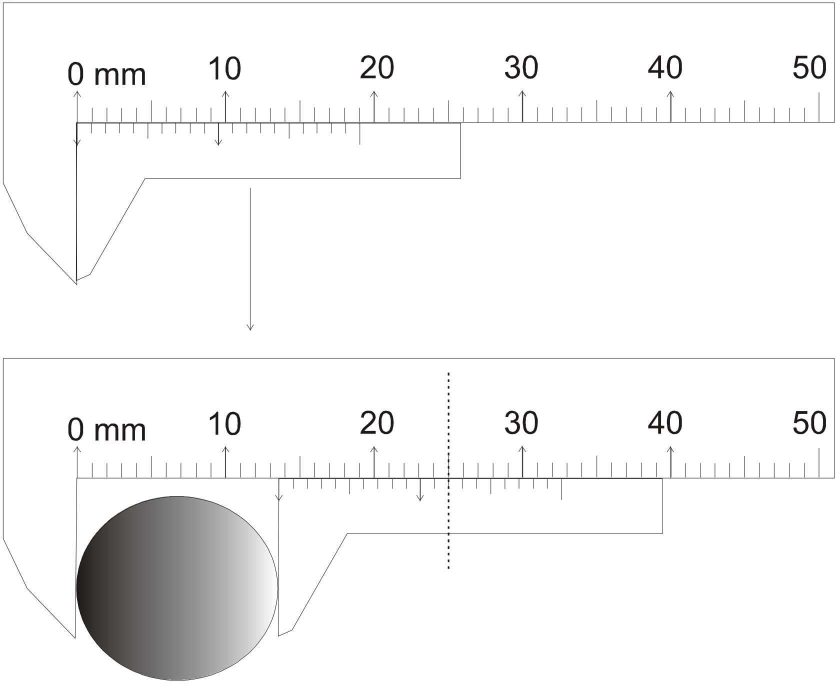
= 1 mm - 0.9 mm (from figure)

= 0.1 mm

Thickness of the object = (main scale reading) + (vernier scale Reading) (least count)

So thickness of the object = 15 mm + (6) (0.1mm) = 15.6 mm **Ans.**

Example 27. Read the special type of vernier. 20 division of vernier scale are matching with 19 divisions of main scale.



Solution : 20 vernier scale divisions = 19 mm

1 vernier scale division = $\frac{19}{20}$ mm

where least count = (Main scale division - vernier Scale division)

= 1 mm – 19/20 mm (from fig.)

= 0.05 mm

Thickness of the object = (main scale reading) + (vernier scale Reading) (least count)

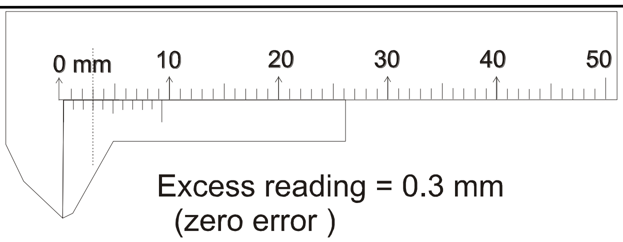
So thickness of the object = 13 mm + (12) (0.05mm)

= 13.60 mm **Ans.**

Zero Error:

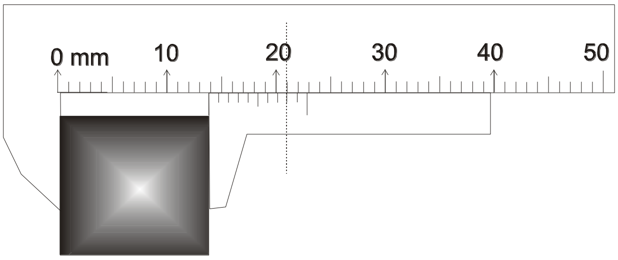
If there is no object between the jaws (ie. jaws are in contact), the vernier should give zero reading. But due to some extra material on jaws, even if there is no object between the jaws, it gives some excess Reading. This excess reading is called **zero error**

Example 28. In the vernier caliperse, 9 main scale divisions matches with 10 vernier scale divisions. The thickness of the object using the defected vernier calliperse will be :



Excess reading = 0.3 mm
(zero error)

If we put an object
between the jaws



It gives 13.8 mm reading

In which there is 0.3 mm excess reading,
which has to be removed (substructed)

So actual thickness = 13.8 - 0.3 = 13.5 mm

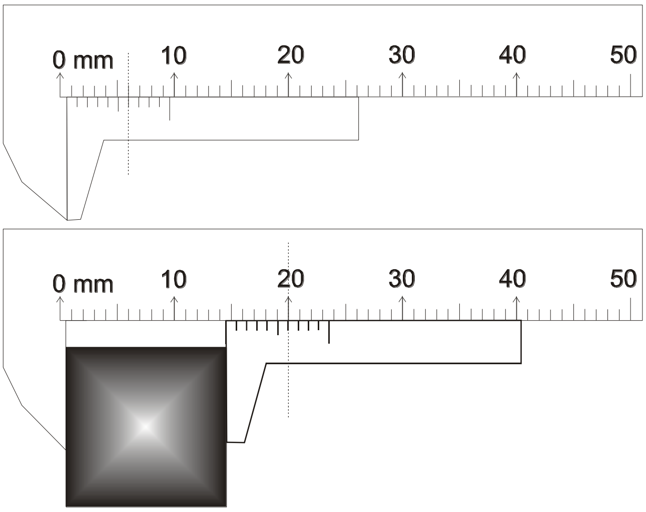
Observed reading

excess reading (zero error)

So we can formulate it as

Actual reading = observed reading - excess reading (Zero error)

Example 29. In the vernier caliperse, 9 main scale divisions matches with 10 vernier scale divisions. The thickness of the object using the defected vernier calliperse will be :



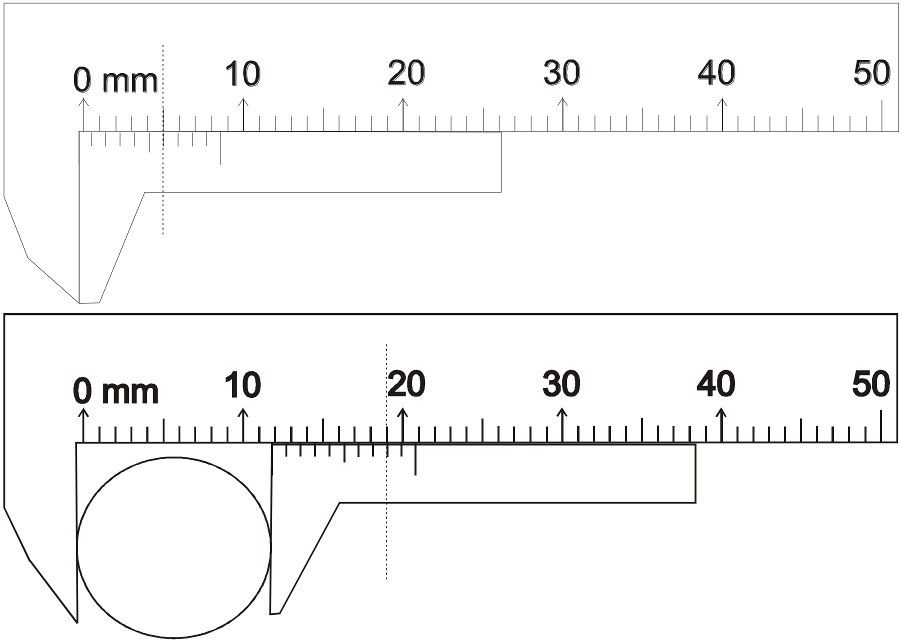
Solution : From first figure, Excess reading (zero error) = 0.6 mm

If an object is placed, vernier gives 14.6 mm in which there is 0.6 mm excess reading, which has to be subtracted. So actual thickness = 14.6 – 0.6 = 14.0 mm we can also do it using the formula

Actual reading = observed reading - excess reading (Zero error)

= 14.6 – 0.6 = 14.0 mm **Ans.**

Example 30. The least count of main scale is 1mm. In the vernier caliperse, 9 main scale divisions matches with 10 vernier scale divisions. When no object is placed between the jaws, the zero of vernior scale is slightly behind the zero of main scale. When a sphere is placed between the jaws, the reading of the vernier is shown in the figure. The thickness of the object using the defected vernier calliperse will be :



Solution : Zero error = main scale reading + (vernier scale reading) (least count)
= –1 mm + 6 (0.1 mm) = – 0.4 mm
observed reading = 11.8 mm
So actual thickness = 11.8 – (–0.4) = 12.2 mm **Ans.**

Zero Correction :

Zero correction is invert of zero error.

Zero correction = – (zero error)

Actual reading = observed reading - excess reading (Zero error)

= observed Reading + zero corraction

In example 28, zero error was 0.6 mm, so zero correction will be – 0.6 mm

In example 29, zero error was -0.4 mm, so zero correction will be + 0.4 mm

Example 31. The main scale of a vernier callipers reads 10 mm in 10 divisions. 10 divisions of Vernier scale coincide with 9 divisions of the main scale. When the two jaws of the callipers touch each other, the fifth division of the vernier coincides with some main scale divisions and the zero of the vernier is to the right of zero of main scale. When a cylinder is tightly placed between the two jaws, the zero of vernier scale lies slightly behind 3.2 cm and the fourth vernier division coincides with a main scale division. The diameter of the cylinder is.

Solution : Zero error = 0.5 mm = 0.05 cm.
Observed reading of cylinder diameter = 3.1 cm + (4) (0.01 cm) = 3.14 cm
Actual thickness of cylinder = (3.14) – (0.05) = 3.09 cm **Ans.**

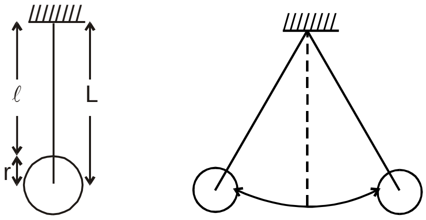
Example 32. In the previous question if the length of the cylinder is measured as 25 mm, and mass of the cylinder is measured as 50.0 gm, find the density of the cylinder (gm/cm^3) in proper significant figures.

Solution : $\rho = \frac{m}{\pi(d^2/4)h}$

$$\rho = \frac{(50.0)\,gm}{3.14 \times (3.09/2)^2 \times (25 \times 10^{-1})cm^3} = 2.7 \text{ gm/cm}^3 \text{ (in two S.F.)}$$ **Ans.**

EXPERIMENT # 3

Determining the value of ‘g’ using a simple pendulum



In this exp. a small spherical bob is hanged with a cotton thread. This arrangement is called sample pendulum. The bob is displaced slightly and allowed to oscillate. To find time period, time taken for 50 oscillations is noted using a stop watch.

Theoretically $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow g = 4\pi^2 \frac{L}{T^2}$ .....(1)

where L = Equivalent length of pendulum = length of thread (ℓ) + radius (r) of bob,

T = time period of the simple pendulum = $\frac{\text{Time taken for 50 oscillations}}{50}$

so ‘g’ can be easily determined by equation ...(1).

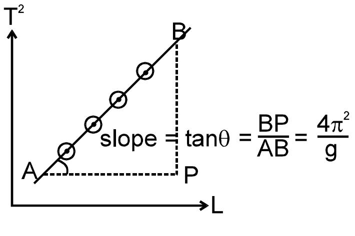
Graphical method to find ‘g’ :

$T^2 = \left(\frac{4\pi^2}{g}\right)L$ ....(2) so, $T^2 \propto L$

* Find T for different values of L.

* Plot T^2 v/s L curve. From equation (2), it should be a straight line, with slope = $\left(\frac{4\pi^2}{g}\right)$.

Find slope of T^2 v/s L graph and equate it to $\left(\frac{4\pi^2}{g}\right)$ and get ‘g’.



Example 33. In certain observation we got ℓ = 23.2 cm, r = 1.32 cm, and time taken for 10 oscillation was 10.0 sec. Estimate the value of ‘g’ in proper significant figure. (take $\pi^2 = 10$)

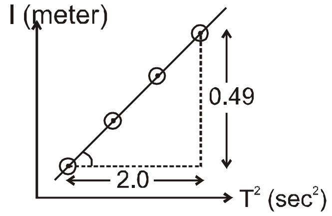
Solution : Equivalent length of pendulum L = 23.2 cm + 1.32 cm
= 24.5 cm (according to addition rule of S.F.)

And time period $T = \frac{10.0}{10} = 1.00$ (Three significant figures)

get $g = 4\pi^2 \frac{L}{T^2} = 4 \times 10 \; \frac{24.5 \text{ cm}}{(1.00)^2}$ (in 3 S.F.)

$$= 4 \times 10 \times \frac{24.5 \times 10^{-2} m}{(1.00)^2 \sec^2} = 9.80 \text{ m/sec}^2$$ **Ans.**

Example 34. For different values of L, we get different values of 'T'. The curve between L v/s T^2 is shown. Estimate 'g' from this curve. (Take $\pi^2 = 10$)



Solution : $L = \left(\frac{g}{4\pi^2}\right) T^2$ so slope of curve between L v/s T^2 = $\left(\frac{g}{4\pi^2}\right)$

Slope = $\frac{0.49}{2} = \frac{g}{4\pi^2} \Rightarrow$ g = 9.8 m/sec² **Ans.**

Maximum permissible error in 'g' due to error in measurement of ℓ, r and T.

$$g = 4\pi^2 \frac{\textcircled{L} \longrightarrow \ell + r}{\textcircled{T}^2 \longrightarrow t/50} \qquad g = 4\pi^2 \frac{(\ell + r)}{(t/50)^2} = 4\pi^2 (2500) \frac{\ell + r}{t^2}$$

$$\ln g = \ln 4\pi^2 (2500) + \ln (\ell + r) - 2 \ln (t) \qquad \left(\frac{\Delta g}{g}\right)_{max} = \frac{\Delta \ell + \Delta r}{\ell + r} + 2\frac{\Delta t}{t}$$

Example 35. In certain observation we got ℓ = 23.2 cm, r = 1.32 cm, and time taken for 10 oscillation was 10.0 sec. Find maximum permissible error in (g)

Solution : ℓ = 23.2 → $\Delta\ell$ = 0.1 cm

r = 1.32 cm → Δr = 0.01 cm

t = 10.0 sec → Δt = 0.1 sec

$$\left(\frac{\Delta g}{g}\right)_{max} = \left(\frac{0.1 \ \text{cm} + 0.01 \ \text{cm}}{23.2\text{cm} + 1.32\text{cm}} + 2\frac{0.1\text{sec}}{10.0\,\text{sec}}\right) \times 100\% = 2.44\ \%.$$

Example 36. Time is measured using a stop watch of least count 0.1 second. In 10 oscillation, time taken is 20.0 second. Find maximum permissible error in time period.

Solution : $T = \frac{\text{Total time}}{\text{Total oscillation}} = \frac{t}{10}$

$\Rightarrow \ \Delta T = \frac{\Delta t}{10} = \frac{0.1}{10}$

ΔT = 0.01 second.

Example 37. A student performs an experiment for determination of $g\left(= \frac{4\pi^2 \ell}{T^2}\right)$, "$\ell$" ≈ 1m, and he commits an error of "$\Delta\ell$". For T he takes the time of n oscillations with the stop watch of least count Δt. For which of the following data, the measurement of g will be most accurate ?

(A) ΔL = 0.5, Δt = 0.1, n = 20 (B) ΔL = 0.5, Δt = 0.1, n = 50

(C) ΔL = 0.5, Δt = 0.02, n = 20 (D) ΔL = 0.1, Δt = 0.05, n = 50

Answer. **(D)**

Solution : Here T = $\frac{\text{total time}}{\text{total oscillation}} = \frac{t}{n}$ so dT = $\frac{dt}{n}$

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T}$$

(A) $\frac{\Delta g}{g} = \frac{0.5}{1} + 2\frac{0.1/20}{T}$ (B) $\frac{\Delta g}{g} = \frac{0.5}{1} + 2\frac{0.1/50}{T}$

(C) $\frac{\Delta g}{g} = \frac{0.5}{1} + 2\frac{0.02/20}{T}$ (D) $\frac{\Delta g}{g} = \frac{0.1}{1} + 2\frac{0.05/50}{T}$

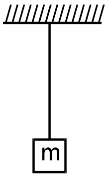
So % error in g will be minimum in option (D)

EXPERIMENT # 4

Determining Young's Modulus of a given wire by ''Searle's Method'' :

An elementary method :

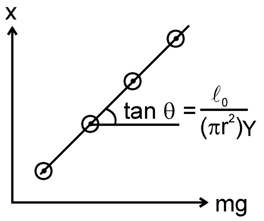
To determine Young's Modulus, we can perform an ordinary experiment. Lets hang a weight 'm' from a wire



from Hook's law: $\frac{mg}{A} = Y\left(\frac{x}{\ell_0}\right)$ x = $\left(\frac{\ell_0}{\pi r^2 Y}\right)$ mg

If we change the weight, the elongation of wire will increase proportionally.

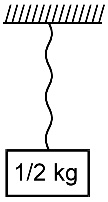
If we plot elongation v/s mg, we will get a straight line.



By measuring its slope and equating it to $\left(\frac{\ell_0}{\pi r^2 Y}\right)$, we can estimate Y.

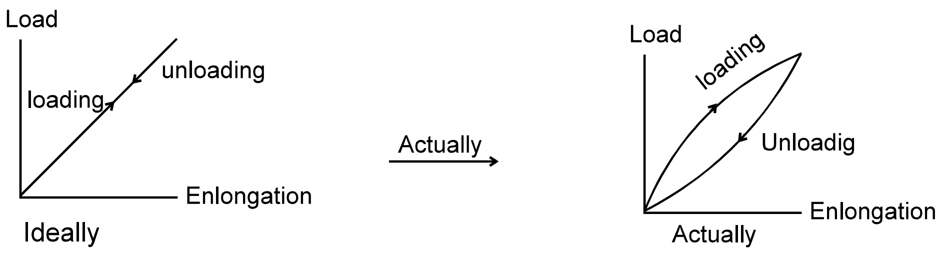
Limitations in this ordinary method

(1) For small load, there may be some bends or kinks in wire.

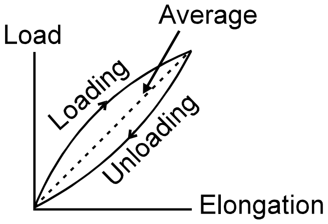


So we had batter start with some initial wt (say 2 kg). So that wire become straight.

(2) There is slight difference in behavior of wire under loading and unloading

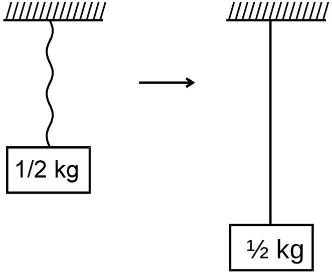


So we had better take average during loading and unloading. The average load will be more and more linear or accurate.

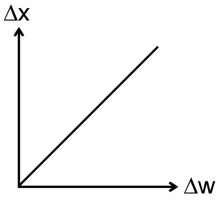


Modification done in "Searle's Method".

To keep the experimental wire straight and kink free, we start with some dead weight (2 kg)



Now we gradually add more and more weight. The extra elongation (Δx) will be proportional to extra weight (Δw).



$$x = \frac{\ell_0}{\pi r^2 Y} w \quad \Rightarrow \quad \Delta x = \frac{\ell_0}{\pi r^2 Y} (\Delta w)$$

so let's plot Δx v/s Δw, the slope of which will be = $\left(\frac{\ell_0}{\pi r^2 Y}\right)$

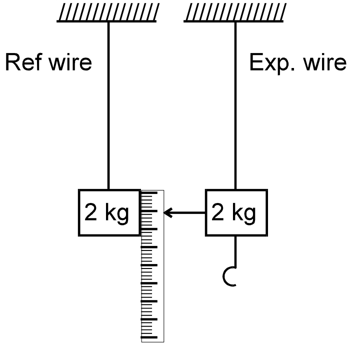
Measurement of Young's modulus.

To measure extra elongation, compared to initial loaded position, we use a reference wire, also carrying 2 kg load (dead weight). This method of measuring elongation by comparison, also cancels the side effect of tamp and yielding of support.

Observations:

(i) Initial Reading = x_0 = 0.540 mm. (Micrometer Reading without extra load)

(ii) Radius of wire = 0.200 mm. (using screw gauge)

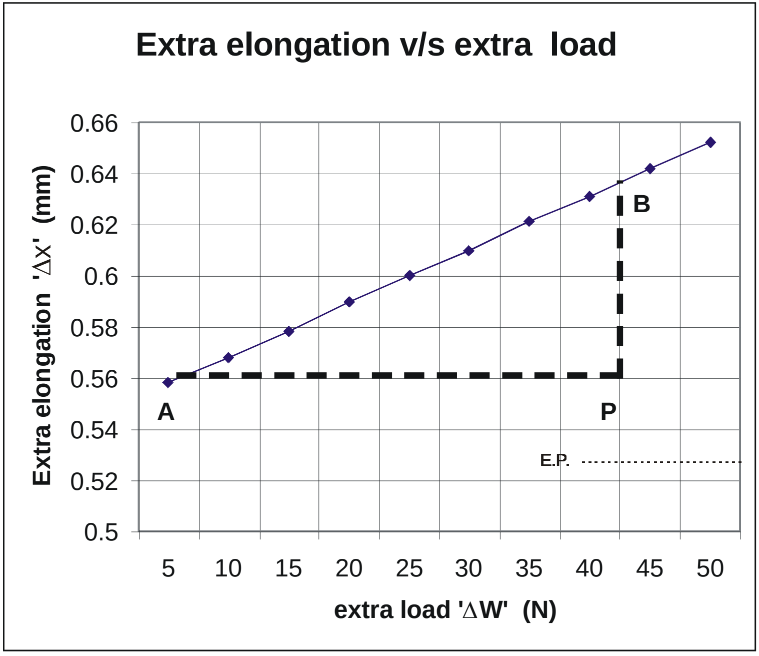


Measurement of extra extension due to extra load.

S.No.	Extra load on hanger Δm (kg)	Micrometer reading		Mean reading (x) (p + q)/2 (mm)	Δx extra elongation $(x - x_0)$ (mm)
		Load increasing (p) (mm)	Load decreasing (q) (mm)		
1	0.5	0.555	0.561	0.558	0.018
2	1.0	0.565	0.571	0.568	0.028
3	1.5	0.576	0.580	0.578	0.038
4	2.0	0.587	0.593	0.590	0.050
5	2.5	0.597	0.603	0.600	0.060
6	3.0	0.608	0.612	0.610	0.070
7	3.5	0.620	0.622	0.621	0.081
8	4.0	0.630	0.632	0.631	0.091
9	4.5	0.641	0.643	0.642	0.102
10	5.0	0.652	0.652	0.652	0.112

Method-1

Plot Δx v/s Δw $(=\Delta m\ g)$



* slope $= \dfrac{BP}{AP} =$ ....

$= \dfrac{\ell}{Y(\pi r^2)}$ $\Rightarrow$ Y = ...

Method-2

Between observation (1) $\longrightarrow$ (6)

and (2) $\longrightarrow$ (7)

and (3) $\longrightarrow$ (8) 2.5 kg extra weight is added

and (4) $\longrightarrow$ (9)

and (5) $\longrightarrow$ (10)

So elongation from observation (1)$\longrightarrow$(6), (2)$\longrightarrow$(7), (3)$\longrightarrow$(8), (4)$\longrightarrow$(9), and (5)$\longrightarrow$ (10) will be due to extra 2.5 kg wt.

So we can find elongation due to 2.5 kg wt from $x_6 - x_1$, $x_7 - x_2$, $x_8 - x_3$, or $x_{10} - x_5$ and hense we can find average elongation due to 2.5 kg wt.

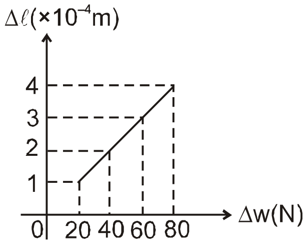
S.No.	Extra load on hanger Δm (kg)	Micrometer reading		Mean reading (x) (p + q)/2 (mm)	Δx extra elongation due to 2.5 kg extra load (mm)
		Load increasing (p) (mm)	Load decreasing (q) (mm)		
1	0.5	0.555	0.561	0.558	0.052
2	1.0	0.565	0.571	0.568	0.053
3	1.5	0.576	0.580	0.578	0.053
4	2.0	0.587	0.593	0.590	0.052
5	2.5	0.597	0.603	0.600	0.052
6	3.0	0.608	0.612	0.610	
7	3.5	0.620	0.622	0.621	
8	4.0	0.630	0.632	0.631	
9	4.5	0.641	0.643	0.642	
10	5.0	0.652	0.652	0.652	

for Δw = 2.5 g, average elongation = Δx = 0.052 mm

$\Delta x = \left(\frac{\ell_0}{\pi r^2 Y}\right)(\Delta w)$ where Δw = Δm g = 25 N and (Δx) average = 0.5 cm

Putting the values find Y = ...

Example 38. The adjacent graph shows the extra extension (Δx) of a wire of length 1m suspended from the top of a roof at one end with an extra load Δw connected to the other end. If the cross sectional area of the wire is 10^{-6} m^2, calculate the Young's modulus of the material of the wire. **[JEE- 2003]**



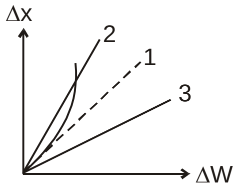
(A) 2×10^{11} N/m^2 (B) 2×10^{-11} N/m^2 (C) 3×10^{13} N/m^3 (D) 2×10^{16} N/m^2

Answer : **(A)**

Solution : $\Delta\ell = \left(\frac{\ell_0}{AY}\right)\Delta w$, slope $= \frac{\ell_0}{AY} = \frac{1\times10^{-4}}{20} \Rightarrow \frac{1}{(10^{-6})Y} = \frac{1\times10^{-4}}{20}$

$Y = 20 \times 10^{10} = 2 \times 10^{11}$ N/m^2

Example 39. In the experiment, the curve between Δx and Δw is shown as dotted line (1). If we use an another wire of same material, but with double length and double radius. Which of the curve is expected.



(A) 1 (B) 2 (C*) 3 (D) 4

Answer : **(C)**

Solution : Initially slope $= \frac{\Delta x}{\Delta w} = \frac{\ell_0}{(\pi r^2)(Y)}$

in second case (slope)^1 $= \frac{(2\ell_0)}{\pi(2r)^2 Y} = \frac{1}{2}\frac{\ell_0}{(\pi r^2)Y}$

so slope will be halved, **Ans. will be (3)**

Example 40. **Assertion :** In Searle's experiment to find young's modulus, a reference wire is also used along with the experiment wire.

Reason : Reference wire neutralizes the effect of temperature, yielding of support and other external factors

(A) If both Assertion and Reason are true and the Reason is a correct explanation of Assertion
(B) If both Assertion and Reason and true but Reason is not a correct explanation of Assertion.
(C) If Assertion is true but Reason is false.
(D) If both Assertion and Reason are false.

Answer : **(A)**

Example 41. If we use very thin and long wire

(A) Sensitivity $\left(\frac{\text{output}}{\text{input}} = \frac{\Delta x}{\Delta w}\right)$ of experiment will increase.
(B) Young's modulus will remain unchanged
(C) Wire may break or yield during loading.
(D) All of the above.

Answer : **(D)**

Maximum permissible error in 'Y' due to error in measuring m, ℓ_0, r, x :

$$Y = \frac{\ell_0}{\pi r^2 x}\,mg$$

If there is no tolerance in mass ; max permissible error in Y is $\left(\frac{\Delta y}{Y}\right)_{max} = \frac{\Delta \ell_0}{\ell_0} + 2\frac{\Delta r}{r} + \frac{\Delta x}{x}$

Example 42. In Searle's experiment to find Young's modulus the diameter of wire is measured as d = 0.050 cm, length of wire is ℓ = 125 cm and when a weight, m = 20.0 kg is put, extension in the length of wire was found to be 0.100cm. Find maximum permissible error in Young's modulus (Y).

Use : $Y = \frac{mg\ell}{(\pi/4)d^2x}$. Least count for mass, length, diameter and extension measurement are respectively 0.1 kg, 1 cm, 0.001 cm and 0.001 cm.

Solution : $\frac{mg}{\pi d^2/4} = Y\left(\frac{x}{\ell}\right) \Rightarrow Y = \frac{mg\ell}{(\pi/4)\ d^2x}$ ....(1)

$$\left(\frac{dY}{Y}\right)_{max} = \frac{\Delta m}{m} + \frac{\Delta \ell}{\ell} + 2\frac{\Delta d}{d} + \frac{\Delta x}{x}$$

Δm = 0.1 kg ; $\Delta\ell$ = 1 cm ; Δd = 0.001 cm ; Δx = 0.001 cm

$$\left(\frac{dY}{Y}\right)_{max} = \left(\frac{0.1\text{kg}}{20.0\text{kg}} + \frac{1\text{cm}}{125\,\text{cm}} + \frac{2\times 0.001\text{cm}}{0.05\,\text{cm}} + \frac{0.001\text{cm}}{0.100\,\text{cm}}\right)\times 100\% = 6.3\ \%$$

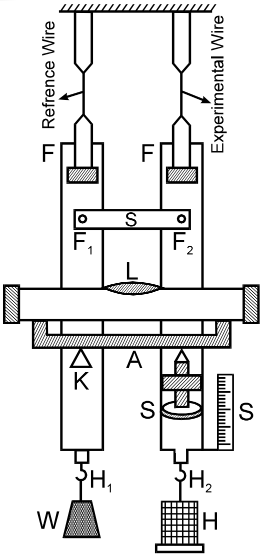
Detailed Apparatus and method of searl's experiment

Searle's Apparatus (Static Method)

The figure shows a Searle's apparatus. It consists of two metal frames **F_1** and **F_2** hinged together so that they can have only vertical relative motion. A spirit level **L** is supported at one end on rigid cross bar frame whose other end rests on the tip of a micrometer screw S, which moves vertically through rigid cross bar.

If there is any relative motion between the two frames, the spirit level no longer remains horizontal and the bubble is displaced. To bring the bubble back to its original position, the screw has to be moved up and down. The distance through which the screw has to be moved gives the relative motion between the two frames.

The frames are suspended by two identical long wires of the steel from the same rigid horizontal support. The **wire B** is an experimental wire and the **wire A** acts as a reference wire. The two frames are provided with two hooks **H_1** and **H_2** at their lower ends. The hook **H_1** carries a constant weight **W** to keep the wire taut. To the hook **H_2**, a hanger is attached over which slotted weights can be put to apply the stretching force.



Procedure :

(i) Measure the length of the experimental wire from the point where it leaves the fixed support to the point where it is fixed in the frame.

(ii) The diameter of the experimental wire is measured with the help of a screw gauge at about five different places and at each place in two mutually perpendicular directions.

(iii) Find the pitch and the least count of the micrometer and adjust it such that the bubble in the spirit level is exactly in the center. The initial reading of the micrometer is noted.

(iv) The load on the hanger $\mathbf{H_2}$ is gradually increased in steps of 0.5 kg. Observe the reading on the micrometer at each stage after leveling the instrument with the help of the spirit level. To avoid the backlash error, all the final adjustments should be made by moving the screw in the upward direction only. If at any time the screw is raised too much, lower it below the central position and then raise it slowly to the proper position.

(v) Unload the wire by removing the weights in the same order and take the reading on the micrometer screw each time. The reading taken for a particular load while loading the wire or unloading the wire, should agree closely.

EXPERIMENT#5

Determining specific heat capacity of an unknown liquid using calorimeter :

Figure shows the Regnault's apparatus to determine the specific heat capacity of a unknown liquid.

A solid sphere of known specific heat capacity s_1 having mass m_1 and initial temperature θ_1, is mixed with the unknown liquid filled in a calorimeter. Let masses of liquid and calorimeter are m_2 and m_3 respectively, specific heat capacities are s_2 and s_3 and initially they were at room temperature θ_2.

When the hot sphere is dropped in it, the sphere looses heat and the liquid calorimeter system takes heat. This process continues till the temperature of all the elements becomes same (say θ).

Heat lost by hot sphere = $m_1s_1(\theta_1 - \theta)$

Heat taken by liquid & calorimeter = $m_2s_2(\theta - \theta_2) + m_3s_3(\theta - \theta_2)$

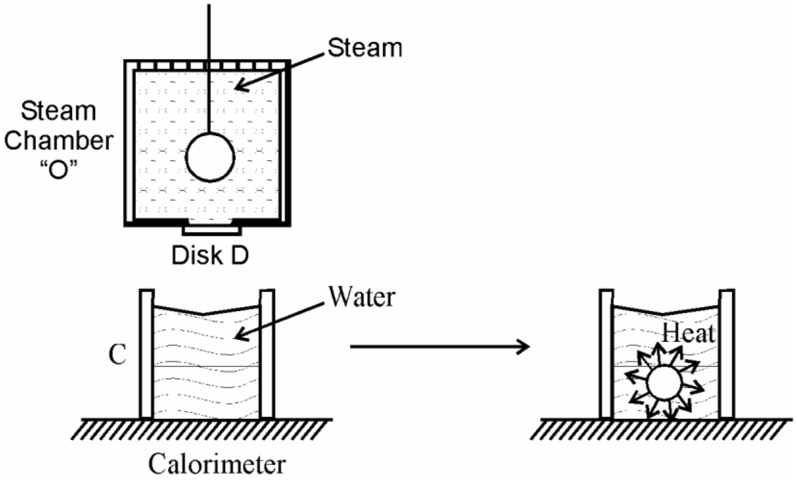
If there were no external heat loss

Heat given by sphere = Heat taken by liquid-Calorimeter system

$$m_1s_1(\theta_1 - \theta) = m_2s_2(\theta - \theta_2) + m_3s_3(\theta - \theta_2)$$

Get $s_2 = \dfrac{m_1s_1(\theta_1-\theta)}{m_2(\theta-\theta_2)} - \dfrac{m_3s_3}{m_2}$

By measuring the final (steady state) temperature of the mixture, we can estimate s_2 : specific heat capacity of the unknown liquid.To give initial temperature (θ_1) to the sphere, we keep it in steam chamber ("O"), hanged by thread. Within some time (say 15 min) it achieves a constant temperature θ_1.



Now the calorimeter, filled with water (part C) is taken below the steam chamber, the wooden removable disc D is removed, and the thread is cut. The sphere drops in the water-calorimeter system and the mixing starts.

If sp. heat capacity of liquid (s_2) were known and that of the solid ball (s_1) is unknown then we can find

$$s_1 = \frac{(m_1s_2 + m_3s_3)(\theta - \theta_2)}{m_1(\theta_1 - \theta)}$$

Example 43. The mass, specific heat capacity and initial temperature of the sphere was 1000 gm, 1/2 cal/gm°C and 80°C respectively. The mass of the liquid and the calorimeter are 900 gm and 200 gm, and initially both were at room temperature 20°C. Both calorimeter and the sphere are made of same material. If the steady-state temperature after mixing is found to be 40°C, then the specific heat capacity of unknown liquid, is

(A) 0.25 cal/g^{o}C (B) 0.5 cal/g^{o}C (C) 1 cal/g^{o}C (D) 1.5 cal/g^{o}C

Answer : **(C)**

Solution : $S_2 = \frac{(1000)\ (1/2)\ (80^\circ - 40^\circ)}{900\ \ (40^\circ - 20^\circ)} - \frac{(200)\ \ (1/2)}{900}$ = 1 cal/gm °C

Example 44. If accidentlly the calorimeter remained open to atmosphere for some time during the experiment, due to which the steady state temperature comes out to be 30^{o}C, then total heat loss to surrounding during the experiment, is (Use the specific heat capacity of the liquid from previous question).

(A) 20 kcal (B) 15 kcal (C) 10 kcal (D) 8 kcal

Answer : **(B)**

Solution : Heat given by the sphere = (1000) (1/2) (80 – 30) = 25,000 cal

Heat absorbed by the water calorimeter system

= (900) (1) (40 – 30) + (200) (1/2) (40 – 30) = 10,000 cal.

So heat loss to surrounding = 15,000 cal

Example 45. If the loss in gravitational potential energy due to falling the sphere by h height and heat loss to surrounding at constant rate $\dot{H}$ are also taken to account, the energy equation will modify to -

(A) $m_1s_1(\theta_1 - \theta) + \frac{m_1gh}{J} = m_2s_2(\theta - \theta_2) + m_3s_3(\theta - \theta_2) - \dot{H}\ t$

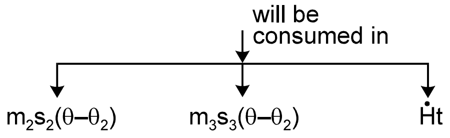
(B) $m_1s_1(\theta_1 - \theta) - \frac{m_1gh}{J} = m_2s_2(\theta - \theta_2) + m_3s_3(\theta - \theta_2) + \dot{H}\ t$

(C) $m_1s_1(\theta_1 - \theta) + \frac{m_1gh}{J} = m_2s_2(\theta - \theta_2) + m_3s_3(\theta - \theta_2) + \dot{H}\ t$

(D) $m_1s_1(\theta_1 - \theta) - \frac{m_1gh}{J} = m_2s_2(\theta - \theta_2) + m_3s_3(\theta - \theta_2) - \dot{H}\ t$

Answer : **(C)**

Solution : Heat generated = $m_1\ s_1\ (\theta_1 - \theta) + \frac{m_1gh}{J}$



Maximum Permissible error in S_1 due to error in measuring θ_1, θ_2 and θ :

To determine the specific heat capacity of unknown solid,

we use $s_{solid} = \frac{m_1s_1 + m_2s_2}{m_1}\left(\frac{\theta_{ss} - \theta_2}{\theta_1 - \theta_{ss}}\right)$

$$s = \frac{m_1s_1 + m_2s_2}{m_1}\left(\frac{\theta_{ss} - \theta_2}{\theta_1 - \theta_{ss}}\right) \quad \Rightarrow \quad \frac{ds}{s} = \frac{d(\theta_{ss} - \theta_2)}{(\theta_{ss} - \theta_2)} - \frac{d(\theta_1 - \theta_{ss})}{\theta_1 - \theta_{ss}}$$

$$\left(\frac{\Delta s}{s}\right) = \frac{\pm\Delta\theta \mp \Delta\theta}{\theta_{ss} - \theta_2} + \frac{\mp\Delta\theta \pm \Delta\theta}{\theta_1 - \theta_{ss}}$$

$$\Rightarrow \left(\frac{\Delta s}{s}\right)_{max} = 2\Delta\theta\left(\frac{1}{\theta_{ss} - \theta_2} + \frac{1}{\theta_1 - \theta_{ss}}\right) = 2\Delta\theta\left(\frac{\theta_1 - \theta_2}{(\theta_{ss} - \theta_2)(\theta_{ss} - \theta_1)}\right)$$

If mass and sp. heat capacities of water and calorimeter is precisely known, and least count of temprature is same for all measurment. Then $\Delta\theta = \Delta\theta_1 = \Delta\theta_2$

$\left(\frac{\Delta s}{s}\right)_{max}$ will be least when $(\theta_{ss} - \theta_2)$ $(\theta_{ss} - \theta_1)$is max i.e. $\theta_{ss} = \frac{\theta_1 + \theta_2}{2}$

If m_1, s_1, m_2, s_2 are precisely known, the maximum permissible % error in s_{solid} will be least when steady state temperature $\theta_{ss} = \frac{\theta_1 + \theta_2}{2}$

Example 46. In the exp. of finding sp. heat capacity of an unknown sphere (S_2), mass of the sphere and calorimeter are 1000 gm and 200 gm respectively and sp. heat capacity of calorimeter is equal to $\frac{1}{2}$ cal/gm/ºC. The mass of liquid (water) used is 900 gm. Initially both the water and the calorimeter were at room temp 20.0ºC while the sphere was at temp 80.0ºC initially. If the steady state temp was found to be 40.0ºC, estimate sp. heat capacity of the unknown sphere (S_2).
(use S_{water} = 1 cal/g/ºC). Also find the maximum permissible error in sp. heat capacity of unknown sphere (S_2 mass and specific heats of sphere and calorimeter are correctly known.)

Solution : To determine the specific heat capacity of unknown solid,

We use $s_{solid} = \frac{m_1s_1 + m_2s_2}{m_1}\left(\frac{\theta_{ss} - \theta_2}{\theta_1 - \theta_{ss}}\right)$ and get s_{solid} = 1/2 cal/g/ºC

$$\left(\frac{\Delta s}{s}\right)_{max} = 2\Delta\theta\left(\frac{1}{\theta_{ss} - \theta_2} + \frac{1}{\theta_1 - \theta_{ss}}\right) = 2\ (0.1^\circ C)\left(\frac{1}{40.0 - 20.0} + \frac{1}{80.0 - 40.0}\right) = 1.5\%$$

Electrical calorimeter

Figure shows an electrical calorimeter to determine specific heat capacity of an unknown liquid. First of all, the mass of empty calorimeter (a copper container) is measured and suppose it is 'm_1'. Then the unknown liquid is poured in it. Now the combined mass of calorimeter + liquid system is measured and let it be 'm_2'. So the mass of liquid is $(m_2 - m_1)$. Initially both were at room temperature (θ_0).

Now a heater is immersed in it for time interval 't'. The voltage drop across the heater is 'V' and current passing through it is 'I'. Due to heat supplied, the temperature of both the liquid and calorimeter will rise simultaneously. After t sec; heater was switched off, and final temperature is θ_f. If there is no heat loss to surroundings

Heat supplied by the heater = Heat absorbed by the liquid + heat absorbed by the calorimeter

$(VI)t = (m_2 - m_1)\ S_\ell\ (\theta_f - \theta_0) + m_1\ S_c\ (\theta_f - \theta_0)$

The specific heat of the liquid $S_\ell = \frac{\frac{(VI)\ t}{\theta_f - \theta_0} - m_1S_C}{(m_2 - m_1)}$

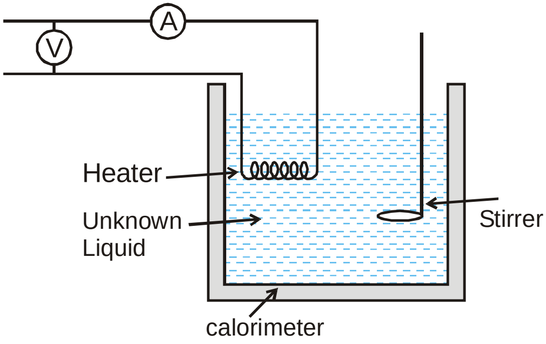


Figure 1

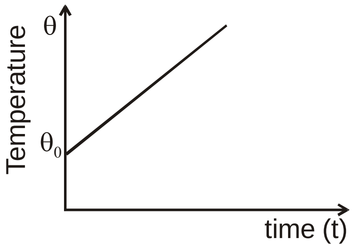


Figure 2
Temperature vs time graph assuming no heat losses to surrounding.

Radiation correction : There can be heat loss to environment. To compensate this loss, a correction is introduced.

Let the heater was on for t sec, and then it is switched off. Now the temperature of the mixture falls due to heat loss to environment. The temperature of the mixture is measured t/2 sec. after switching off. Let the fall in temperature during this time is ε

Now the corrected final temperature is taken as

$$\theta'_f = \theta_f + \varepsilon$$

Example 47. In this experiment voltage across the heater is 100.0 V and current is 10.0A, and heater was switched on for t = 700.0 sec. Initially all elements were at room temperature θ_0 = 10.0°C and final temperature was measured as θ_f = 73.0°C. Mass of empty calorimeter was 1.0 kg and the combined mass of calorimeter + liquid is 3.0 kg. The specific heat capacity of the calorimeter $S_c = 3.0 \times 10^3$ J/kg°C. The fall in temperature 350 second after switching off the heater was 7.0°C. Find the specific heat capacity of the unknown liquid in proper significant figures.

(A) 3.5×10^3 J/kg°C (B) 3.50×10^3 J/kg°C

(C) 4.0×10^3 J/kg°C (D) 3.500×10^3 J/kg°C

Solution : Corrected final temperature = θ_f = 73.0° + 7.0° = 80.0°

$$S_\ell = \frac{\frac{(100.0)\ \ (10.0)\ \ (700.0)}{80.0-10.0} - (1.0)\ \ (3.0\times10^3)}{3.0-1.0}$$

= 3.5×10^3 J/kg°C (According to addition and multiplication rule of S.F.)

Example 48. If mass and specific heat capacity of calorimeter is negligible, what would be maximum permissible error in S_ℓ. Use the data mentioned below. $m_1 \to 0$, $S_c \to 0$, m_2 = 1.00 kg, V = 10.0 V, I = 10.0 A, t = 1.00×10^2 sec., θ_0 = 15°C, Corrected θ_f = 65°C

(A) 4% (B) 5% (C) 8% (D) 12%

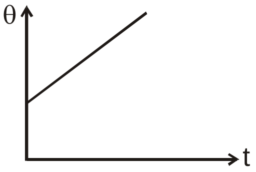
Solution : If $m_1 \to 0$, $S_c \to 0$

$$S_\ell = \frac{VIt}{m_2(\theta_f - \theta_0)}$$

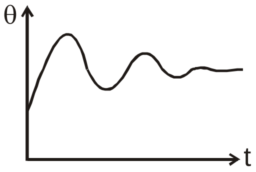
$$\frac{\Delta S_\ell}{S_\ell} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta t}{t} + \frac{\Delta m_2}{m_2} + \frac{\Delta\theta_f + \Delta\theta_0}{\theta_f - \theta_0} = \frac{0.1}{10.0} + \frac{0.1}{10.0} + \frac{0.01\times10^2}{1.00\times10^2} + \frac{0.01}{1.00} + \frac{1+1}{50} = 8\%$$

Example 49. If the system were loosing heat according to Newton's cooling law, the temperature of the mixture would change with time according to (while heater was on)

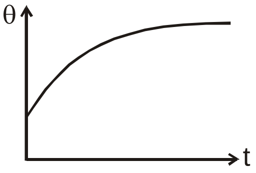
(A)



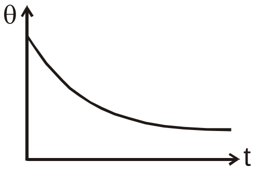
(B)



(C*)



(D)



Solution : As the temperature increases, heat loss to surrounding increases. After some time the rate at which heat is lost becomes equal to rate at which heat is supplied and an equilibrium or steady state is achieved. Hence temperature becomes constant after some time.

$\therefore$ C is correct.

EXPERIMENT # 6

Determining speed of sound using resonance tube method :

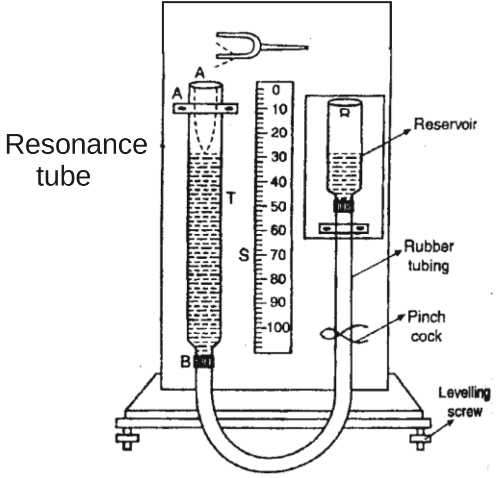


Figure shows the experiment to find velocity of sound in air using Resonance tube method.

Principle : Resonance tube is a kind of closed organ pipe.

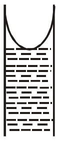
So its natural freq. will be

$$\frac{V}{4\ell_{eq}}, \frac{3V}{4\ell_{eq}}, \frac{5V}{4\ell_{eq}} \text{ .... or } \quad \text{generally } f_n = (2n-1)\frac{V}{4\ell_{eq}}$$

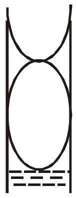
If it is forced with a tuning fork of frequency f_0 ; for resonance, Natural freq = forcing freq.

$$(2n-1)\frac{V}{4\ell_{eq}} = f_0 \quad \Rightarrow \quad \ell_{eq} = (2n-1)\frac{V}{4f_0}$$

For the first Resonance $\ell_{eq} = \frac{V}{4f_0}$ = (corresponding to 1st mode)



For the second Resonance $\ell_{eq} = \frac{3V}{4f_0}$ = (corresponding to 2nd mode)



Working : Resonance tube is a 100 cm tube. Initially it is filled with water. To increase the length of air column in the tube, water level is lowered. The air column is forced with a tuning fork of frequency f_0. Let at length ℓ_1, we get a first resonance (loud voice) then

$$\ell_{eq1} = \frac{V}{4f_0} \quad \Rightarrow \quad \ell_1 + \varepsilon = \frac{V}{4f_0} \quad \text{.........(i)} \quad \text{where } \varepsilon \text{ is end correction}$$

If we further lower the water level, the noise becomes moderate. But at ℓ_2. We, again get a loud noise (second resonance) then

$$\ell_{eq2} = \frac{3V}{4f_0} \quad \Rightarrow \quad \ell_2 + \varepsilon = \frac{3V}{4f_0} \quad \text{.........(ii)}$$

For (i) and (ii), $V = 2f_0(\ell_2 - \ell_1)$

Observation table :

Room temp. in begnning = 26°C, Room temp. at end = 28ºC

		Position of water level (cm)			
Freq. of tuning fork in (Hz) (f_0)	Resonance	Water level is falling	Water level is rising	Mean resonant length	Speed of sound $V = 2f_0(l_2 - l_1)$
340 Hz	1st Resonance	23.9	24.1	$l_1 = 24.0$	V = ……….
	2nd Resonance	73.9	74.1	$l_2 = 74.0$	

***** $\boldsymbol{\ell_3} = 2\ell_2 - \ell_1$

*** end correction** $(e) = \dfrac{\ell_2 - 3\ell_1}{2}$

*** e = 0.3d (d = diameter of tube)**

Example 50. Speed of sound calculated is roughly

(A) 340 m/sec (B) 380 m/sec (C) 430 m/sec (D) None of these

Solution : $\ell_1 = 24.0$ cm ; $\ell_2 = 74.0$ cm

$v = 2f_0 (\ell_2 - \ell_1) = 2(340)(0.740 - 0.240) = (2)(340)(0.500) = 340$ m/sec.

Example 51. In the previous question, speed of sound at 0ºC is roughly

(A) 324 m/sec (B) 380 m/sec (C) 430 m/sec (D) None of these

Solution : $v \alpha \sqrt{T} \Rightarrow \dfrac{V_{27^\circ}}{V_{0^\circ}} = \sqrt{\dfrac{300}{273}}$ $V_{0^\circ} = V_{27^\circ}\sqrt{\dfrac{273}{300}} = 340\sqrt{\dfrac{273}{300}} = 324$ m/sec.

Example 52. What should be minimum length of tube, so that third resonance can also be heard.

(A) $\ell_3 = 421$ (B) $\ell_3 = 214$ (C) $\ell_3 = 124$ (D) None of these

Solution : $\ell_1 + \varepsilon = \dfrac{V}{4f_0}$ $\ell_2 + \varepsilon = \dfrac{3V}{4f_0}$ solve both equations and get $\varepsilon = 1$cm for third resonance,

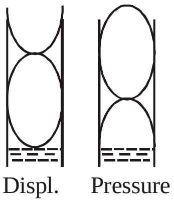
$\ell_3 + \varepsilon = \dfrac{5V}{4f_0}$ get $\ell_3 = 124$cm

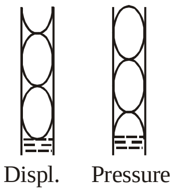
Example 53. From equation (i) and (ii) end correction can be calculated. Estimate the diameter of the tube using formula ($\varepsilon \approx 0.3d$)

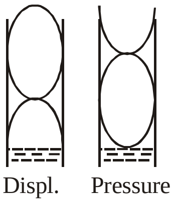
(A) 2.5 cm (B) 3.3 cm (C) 5.2 cm (D) None of these

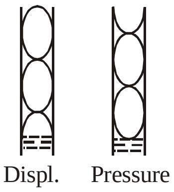
Solution : $\varepsilon = 1 \text{ cm} = 0.3\ d = \dfrac{1\text{cm}}{0.3} = 3.3$ cm

Example 54. For the third resonance, which option shows correct mode for displacement variation and pressure variation,

(A) 

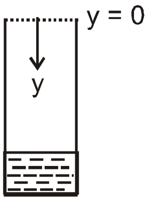
(B) 

(C) 

(D) 

Solution : **(B)**

Example 55. The equation of standing wave for the second resonance can be



(A) $P_{ex} = 2A \sin 2\pi (y + 1\text{cm}) \cos 2\pi (340)\, t$ (B) $P_{ex} = 2A \sin 2\pi (y - 1\text{cm}) \cos 2\pi (340)\, t$

(C) $P_{ex} = 2A \cos 2\pi (y + 1\text{cm}) \cos 2\pi (340)\, t$ (D) $P_{ex} = 2A \cos 2\pi (y - 1\text{cm}) \cos 2\pi (340)\, t$

Solution : (A) $k = \dfrac{2\pi}{\lambda} = \dfrac{2\pi}{1} = 2\pi$ $\omega = 2\pi f = (2\pi)(340)$

first node will be formed at y = –1 instead of y = 0 so eqn. of standing wave is

$P_{ex} = 2A \sin 2\pi(y + 1\text{cm}) \cos 2\pi(340)\, t$

Example 56. Taking the open end of tube as $y = 0$, position of pressure nodes will be

(A) $y = -1$ cm, $y = 49$ cm (B) $y = 0$ cm, $y = 50$ cm

(C) $y = 1$ cm, $y = 51$ cm (D) None of these

Solution : **(A)**

Max Permissible Error in speed of sound due to error in f_0, ℓ_1, ℓ_2 :

for Resonance tube experiment

$$V = 2f_0 (\ell_2 - \ell_1)$$

$$\ln V = \ln 2 + \ln f_0 + \ln (\ell_2 - \ell_1)$$

max. permissible error in speed of sound = $\left(\frac{\Delta V}{V}\right)_{max} = \frac{\Delta f_0}{f_0} + \frac{\Delta\ell_2 + \Delta\ell_1}{(\ell_2 - \ell_1)}$

Example 57. If a tuning fork of (340 Hz ± 1%) is used in the resonance tube method, and the first and second resonance lengths are 24.0 cm and 74.0 cm respectively. Resonant length is measured by a scale having 1 mm marks. Find max. permissible error in speed of sound.

Solution : $\Delta\ell_1 = 0.1$ cm, $\Delta\ell_2 = 0.1$ cm,

$f_0 = (340 \text{ Hz} \pm 1\%)$ $\frac{\Delta f_0}{f_0} = 1\% = \frac{1}{100}$

$$\left(\frac{\Delta V}{V}\right)_{max} = \frac{\Delta f_0}{f_0} + \frac{\Delta\ell_2 + \Delta\ell_1}{\ell_2 - \ell_1} = \frac{1}{100} + \frac{0.1 + 0.1}{74.0 - 24.0} = \frac{1}{100} + \frac{0.2}{50.0} = 0.014$$

EXPERIMENT # 7

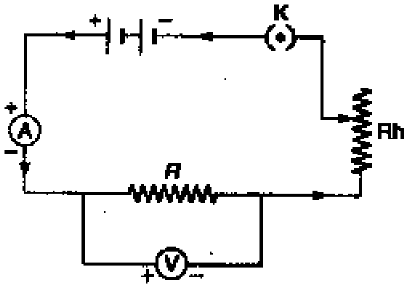
Verification of Ohm's law using voltmeter and ammeter

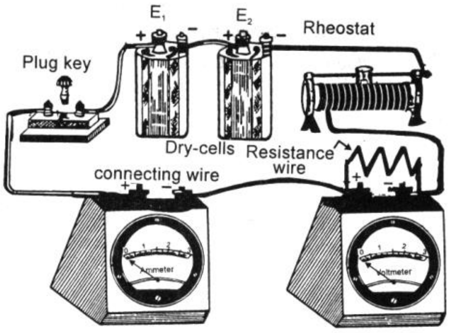
Ohm's law states that the electric current I flowing through a conductor is directly proportional to the potential difference (V) across its ends provided that the physical conditions of the conductor (such as temperature, dimensions, etc.) are kept constant. Mathematically.

$$V \propto I \text{ or } V = IR$$

Here R is a constant known as resistance of the conductor and depends on the nature and dimensions of the conductor.

Circuit Diagram : The circuit diagram is as shown below :

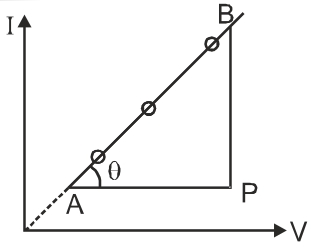




Procedure : By shifting the rheostat contact, reading of ammeter and voltmeter are noted down. At least six set of observations are taken. Then a graph is plotted between potential difference (V) across R and current (I) through R. The graph comes to be a straight line as shown in figure.

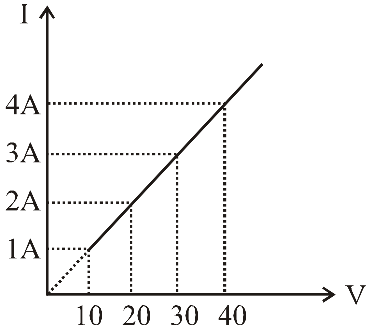
Result : It is found from the graph that the ratio V/I is constant. Hence, current voltage relation ship is established, i.e., $V \propto I$. It means Ohm's law is established.

as $I = \left(\frac{1}{R}\right)V$, find the slope of I – V curve and equate it to $\frac{1}{R}$.



slope = $\frac{BP}{AP}$ = $\frac{1}{R}$ Get R = ...

Example 58. If emf of battery is 100 v, then what was the resistance of Rheostat adjusted at 2nd reading (I = 2A, V = 20V).

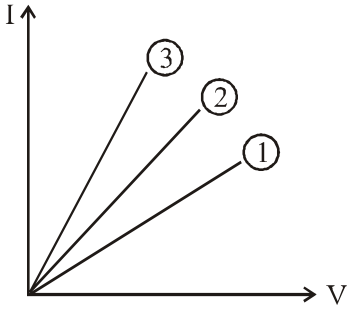


(A) 10Ω (B) 20Ω (C) 30Ω (D) 40Ω

Solution : From the curve slope = $\frac{I}{v} = \frac{1}{R} = \frac{1}{10}$ R = 10 Ω

for second reading $I = \frac{Emf}{R+R_{rh}}$ $2 = \frac{100}{10+R_{rh}}$ ⇒ R_{rh} = 40Ω

Example 59. If three wires of same material but different dimension were used in place of unknown resistance, we get these I-V curve



Match the column according to correct curve :

Wire dimension	**Corresponding curve**
(p) ℓ = 1m, radius = 1 mm	(i) Curve (1)
(q) ℓ = 1m, radius = 2 mm	(ii) Curve (2)
(r) $\ell = \frac{1}{2}$ m, radius = $\frac{1}{2}$ mm	(iii) Curve (3)

(A) (p)-(ii); (q)-(iii); (r)-(i) (B) (p)-(iii); (q)-(ii); (r)-(i)
(C) (p)-(i); (q)-(ii); (r)-(iii) (D) None of these

Solution : $R = \frac{\rho\ell}{A} = \frac{\rho\ell}{\pi r^2}$ for case(p) $R \propto \frac{(1)}{(1)^2}$ for case (q) $R \propto \frac{(1)}{(2)^2}$

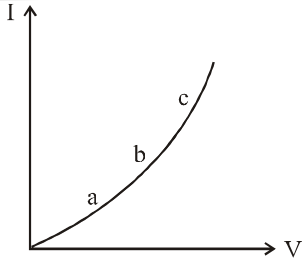
for case (r) $R \propto \frac{(1/2)}{(1/2)^2}$ so $R_r > R_p > R_q$

and slope of I – v cure = $\frac{I}{v} = \frac{1}{R}$

so $slope_r < slope_p < slope_q$

⇒ q → line (3), p → line (2), r → line (1)

Example 60. I v/s V curve for a non-ohmic resistance is shown. The dynamic resistance is maximum at point



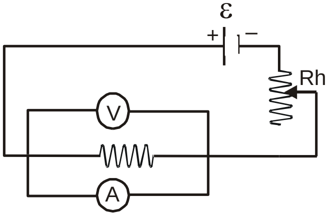
(A) a (B) b (C) c (D) same for all

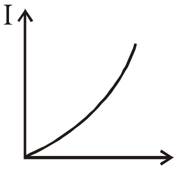
Answer : **(A)**

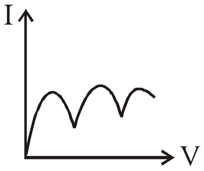
Solution : Dynamic resistance $R = \frac{dv}{dI} = \frac{1}{dI/dv} = \frac{1}{\text{slope}}$

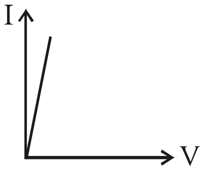
At Pt. a, slope is min, So R is max

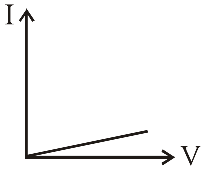
Example 61. If by mistake, Ammeter is connected parallel to the resistance then I-V curve expected is (Here I = reading of ammeter, V = reading of voltmeter)



(A)


(B)


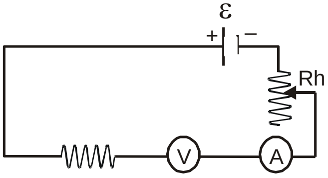
(C)


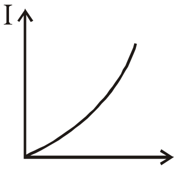
(D)


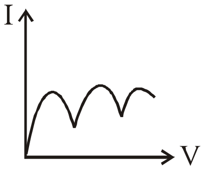
Answer : **(C)**

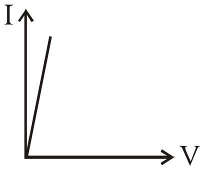
Solution : As ammeter has very low resistance most of current will pass through the ammeter so reading of ammeter (I) will be very large. Voltmeter has very high resistance so reading of voltmeter will be very low.

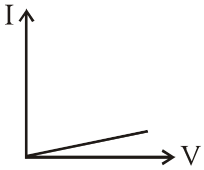
Example 62. If by mistake, voltmeter is connected in series with the resistance then I-V curve expected is (Here I = reading of ammeter, V = reading of voltmeter)



(A)


(B)


(C)


(D)


Answer : **(D)**

Solution : Due to high resistance of voltmeter, reading of ammeter will be very low

We can find the specific resistance of a material using ohm's law experiment.

$$\rho = \frac{RA}{L} = \frac{\pi D^2}{4L}\frac{V}{I}$$

$$\ln \rho = \ln \frac{\pi}{4} + 2 \ln D - \ln L + \ln V - \ln I$$

$$\frac{d\rho}{\rho} = 2\frac{dD}{D} - \frac{dL}{L} + \frac{dV}{V} - \frac{dI}{I}$$

$$\frac{\Delta\rho}{\rho} = \pm 2\frac{\Delta D}{D} \mp \frac{\Delta L}{L} \pm \frac{\Delta V}{V} \mp \frac{\Delta I}{I}$$

$$\left(\frac{\Delta\rho}{\rho}\right)_{max} = \text{max of } \left(\pm 2\frac{\Delta D}{D} \mp \frac{\Delta L}{L} \pm \frac{\Delta V}{V} \mp \frac{\Delta I}{I}\right)$$

$$\left(\frac{\Delta\rho}{\rho}\right)_{max} = +2\ \frac{\Delta D}{D} + \frac{\Delta L}{L} + \frac{\Delta V}{V} + \frac{\Delta I}{I} = \text{max. permissible error in } \rho.$$

Example 63. In the Ohm's experiment, when potential difference 10.0 V is applied, current measured is 1.00 A. If length of wire is found to be 10.0 cm, and diameter of wire is 2.50 mm, then the maximum permissible error in resistivity will be -

(A) 1.8% (B) 10.2% (C) 3.8% (D) 5.75%

Solution : $\left(\frac{\Delta\rho}{\rho}\right)_{max} = 2\left(\frac{0.01}{2.50}\right) + \left(\frac{0.1}{10.0}\right) + \left(\frac{0.1}{10.0}\right) + \left(\frac{0.01}{1.00}\right) = 3.8\%$

Example 64. If % error in length, diameter, current and voltage are same than which of the following affects %error in measurement of resistivity, the most :

(A) length measurement (B) voltage measurement

(C) current measurement (D) diameter measurement

Solution : $\left(\frac{\Delta\rho}{\rho}\right)_{max}$ = is mostly affected by % error in diameter

Example 65. From some instruments, current measured is I = 10.0 Amp., potential difference measured is V = 100.0 V, length of wire is 31.4 cm, and diameter of wire is 2.00 mm (all in correct significant figure). The resistivity of wire (in correct significant figure) will be - (use $\pi = 3.14$)

(A) $1.00 \times 10^{-4}\ \Omega$-m (B) $1.0 \times 10^{-4}\ \Omega$-m (C) $1 \times 10^{-4}\ \Omega$-m (D) $1.000 \times 10^{-4}\ \Omega$-m

Solution : $\rho = \frac{\pi D^2}{4L}\ \frac{V}{I} = \frac{(3.14)\ (2.00 \times 10^{-3})^2}{4(0.314)}\left(\frac{100.0}{10.0}\right)$

and answer should be in three S.F. so $\rho = 1.00 \times 10^{-4}\ \Omega$ -m

Example 66. In the previous question, maximum permissible error in resistivity and resistance measurement will be (respectively)

(A) 2.14%, 1.5% (B) 1.5%, 2.45% (C) 2.41%, 1.1% (D) None of these

Solution : $\left(\frac{\Delta R}{R}\right)_{max} = \frac{\Delta i}{i} + \frac{\Delta v}{v} = \frac{0.1}{10.0} + \frac{0.1}{100.0} = 1.1\% \Rightarrow \left(\frac{d\rho}{\rho}\right)_{max} = 2.42\%$

EXPERIMENT # 8

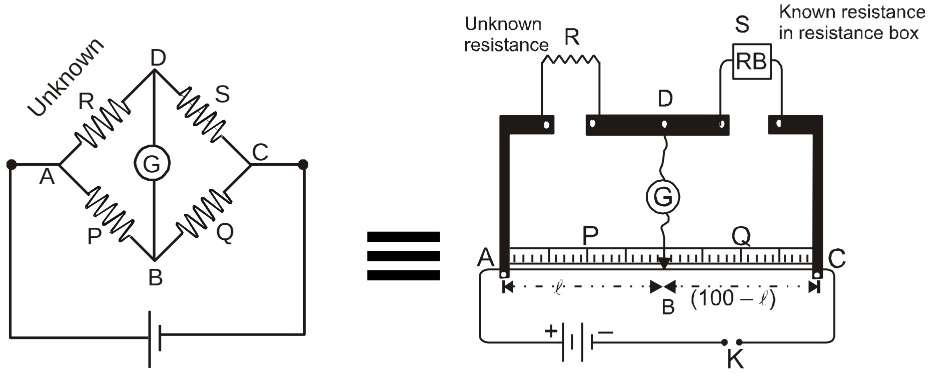
METER BRIDGE

Meter bridge is a simple case of wheatstone-Bridge and is used to find the unknown Resistance. The unknown resistance is placed in place of R, and in place of S, a known resistance is used, using R.B. (Resistance Box). There is a 1m long resistance wire between A and C. The jockey is moved along the wire. When $R(100 - \ell) = S(\ell)$ then the Bridge will be balanced, and the galvanometer will gives zero defflection. "ℓ" can be measured by the meter scale.

The unknown resistance is $R = S\frac{\ell}{100 - \ell}$ ....(1)

If length of unknown wire is L and diameter of the wire is d, then specific resistance of the wire

$$\rho = \frac{R\left(\frac{\pi d^2}{4}\right)}{L} \qquad \text{from eq.(1)} \;\; \rho = \frac{\pi d^2}{4L}\left(\frac{(\ell)}{100-\ell}\right) S$$



Example 67. If resistance S in RB = 300Ω, then the balanced length is found to be 25.0 cm from end A. The diameter of unknown wire is 1mm and length of the unknown wire is 31.4 cm. The specific resistivity of the wire should be

(A) 2.5×10^{-4} Ω-m (B) 3.5×10^{-4} Ω-m (C) 4.5×10^{-4} Ω-m (D) None of these

Answer : **(A)**

Solution : $\frac{R}{300} = \frac{25}{75} \Rightarrow R = 100 \Rightarrow \rho = \frac{R\pi d^2}{4L} = 2.5 \times 10^{-4}\ \Omega$ -m

Example 68. In the previous question. If R and S are interchanged, the balanced point is shifted by

(A) 30 cm (B) 40 cm (C) 50 cm (D) None of these

Solution : If R and S wave interchanged, $\ell = 75$, $100 - \ell = 25$

Balance point will be shifted by 75 – 25 = 50 cm

Example 69. In a meter bridge, null point is at $\ell = 33.7$ cm, when the resistance S is shunted by 12Ω resistance the null point is found to be shifted by a distance of 18.2 cm. The value of unknown resistance R should be

(A) 13.5Ω (B) 68.8Ω (C) 3.42Ω (D) None of these

Answer : **(B)**

Solution : $\frac{R}{S} = \frac{33.7}{100-33.7} \Rightarrow \frac{R}{\left(\frac{12\times S}{12+S}\right)} = \frac{(33.7+18.2)}{100-(33.7+18.2)}$

solving get R = 6.86 Ω

End Corrections

In meter Bridge circuit, some extra length comes (is found under metallic strips) at end point A and C. So some additional length (α and β) should be included at ends for accurate result. Hence in place of ℓ we use $\ell + \alpha$ and in place of $100 - \ell$, we use $100 - \ell + \beta$ (where α and β are called end correction). To estimate α and β, we use known resistance R_1 and R_2 at the place of R and S in meter Bridge.

Suppose we get null point at ℓ_1 distance then

$$\frac{R_1}{R_2} = \frac{\ell_1+\alpha}{100-\ell_1+\beta} \qquad \text{......(i)}$$

Now we interchange the position of R_1 and R_2, and get null point at ℓ_2 distance then

$$\frac{R_2}{R_1} = \frac{\ell_2+\alpha}{100-\ell_2+\beta} \qquad \text{......(ii)}$$

Solving equation (i) and (ii) get, $\alpha = \frac{R_2\ell_1 - R_1\ell_2}{R_1 - R_2}$ and $\beta = \frac{R_1\ell_1 - R_2\ell_2}{R_1 - R_2} - 100$

These end corrections (α and β) are used to modify the observations

Example 70. If we used 100Ω and 200Ω resistance in place of R and S, we get null deflection at ℓ_1 = 33.0cm. If we interchange the Resistance, the null defflection was found to be at ℓ_2 = 67.0 cm. The end correction α and β should be :

(A) α = 1cm, β = 1cm (B) α = 2cm, β = 1cm (C) α = 1cm, β = 2cm (D) None of these

Answer : **(A)**

Solution :

$$\alpha = \frac{R_2\ell_1 - R_1\ell_2}{R_1 - R_2} = \frac{(200)(33)-(100)(67)}{100-200} = 1 \text{ cm}$$

$$\beta = \frac{R_1\ell_1 - R_2\ell_2}{R_1 - R_2} - 100 = \frac{(33)(100)-(200)(67)}{100-200} - 100 = 1 \text{ cm}$$

Example 71. Now we start taking observation. At the position of R, unknown resistance is used, and at position of S, 300Ω resistance is used. If the balanced length was found to be ℓ = 26cm, estimate the unknown resistance.

(A) 108Ω (B) 105.4Ω (C) 100Ω (D) 110Ω

Answer : **(A)**

Solution :

$$\frac{\ell_{eq}}{(100-\ell)_{eq}} = \frac{R}{300}$$

$$\frac{R}{(300)} = \frac{26+1}{(100-26)+1} = \frac{27}{75}\,,\quad R = \frac{300\times 27}{75} = 108\ \Omega.$$

Example 72. If the unknown Resistance calculated without using the end correction, is R_1 and with using the end corrections is R_2 then (assume same end correction)

(A) $R_1 > R_2$ when balanced point is in first half (B*) $R_1 < R_2$ when balanced point is in first half

(C*) $R_1 > R_2$ when balanced point is in second half (D) $R_1 > R_2$ always

Solution :

$$R_1 = S\left(\frac{\ell}{100-\ell}\right),\quad R_2 = S\left(\frac{\ell+\alpha}{100-\ell+\beta}\right)$$

If balance point is in first half say l = 40

$$R_1 = S\left(\frac{40}{60}\right) \qquad R_2 = S\left(\frac{41}{61}\right) \qquad \text{so } R_2 > R_1$$

If balance point is in second half say l = 70

$$R_1 = S\left(\frac{70}{30}\right) \qquad R_2 = S\left(\frac{71}{31}\right) \qquad \text{so } R_2 < R_1.$$

Maximum Permissible Error in ρ :

The specific resistivity of wire, from meter bridge is $\rho = \frac{\pi D^2 S}{4L}\frac{\ell}{100-\ell}$

Assume that known resistance in RB(S), and total length of wire is precisely known, then lets find maximum permissible error in ρ due to error in measurement of ℓ (balance length) and D (diameter of wire).

$$\ln \rho = \ln\left(\frac{\pi S}{4L}\right) + 2\ln D + \ln \ell - \ln(100-\ell) \qquad \text{(assume there is no error in S and L)}$$

$$\frac{d\rho}{\rho} = 2\frac{dD}{D} + \frac{d\ell}{\ell} - \frac{d(100-\ell)}{(100-\ell)} = 2\frac{dD}{D} + \frac{d\ell}{\ell} + \frac{d\ell}{100-\ell}$$

$$\left(\frac{\Delta\rho}{\rho}\right)_{max} = 2\frac{\Delta D}{D} + \frac{\Delta\ell}{\ell} + \frac{\Delta\ell}{100-\ell}$$

$$\left(\frac{\Delta\rho}{\rho}\right)_{max} \text{ due to error in } \ell \text{ only is} = \frac{\Delta\ell}{\ell} + \frac{\Delta\ell}{100-\ell} = \frac{\Delta\ell(100)}{\ell(100-\ell)}$$

$\left(\frac{\Delta\rho}{\rho}\right)_{max}$ will be least when $\ell(100-\ell)$ is maximum , i.e. ℓ = 50 cm

So % error in resistance (resistivity) will be minimum if the balance point is at the mid point of meter bridge wire.

EXPERIMENT # 9

POST OFFICE BOX

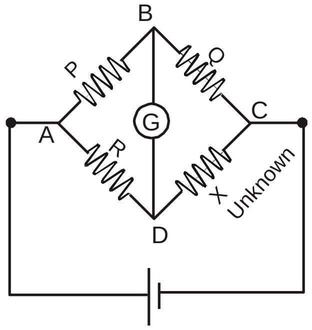


Figure-1

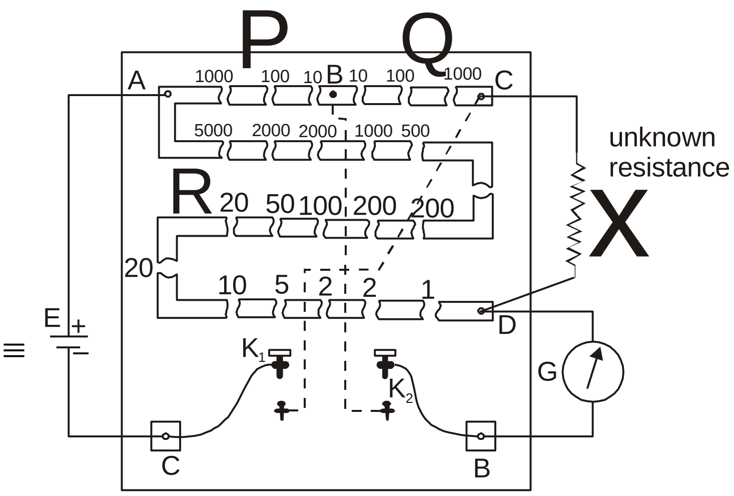


Figure-2

In a wheat stone's Bridge circuit, If $\frac{P}{Q} = \frac{R}{X}$ then the bridge is balanced. So unknown resistance $X = \frac{P}{Q}$ R = $\frac{R}{(P/Q)}$. To realize the wheat stone's Bridge circuit, a pox office Box is described.

Resistance P and Q are set in arms AB and BC where we can have 10Ω , 100 Ω or 1000 Ω resistance, to set any ratio $\frac{P}{Q}$.

These arms are called ratio arms. Initially we take Q = 10 Ω and P = 10 Ω to set $\frac{P}{Q}$ = 1. The unknown resistance (X) is connected between C and D and battery is connected across A and C (Just like wheat stone's Bridge).

Now put Resistance in part A to D such that the Bridge gets balanced. For this keep on increasing the resistance with 1Ω interval, check the deflection in Galvanometer by first pressing key K_1 key then Galvanometer key K_2.

Suppose at R = 4Ω , we get deflection toward left and at R = 5Ω , we get deflection toward right. So we can say that for bridge balance. R should be between 4 to 5.

Now X = $\frac{R}{(P/Q)} = \frac{R}{(10/10)}$ = R = 4 to 5.

So we can estimate that X should be between 4Ω and 5Ω.

To get closer X, in the second observation, lets choose $\frac{P}{Q}$ = 10 e.i. $\left(\frac{P = 100}{Q = 10}\right)$.

Suppose Now at R = 42. We are getting deflection toward left, and at R = 43, deflection is toward right. So R $\in$ (42, 43).

Now X = $\frac{R}{(P/Q)} = \frac{R}{(100/10)} = \frac{1}{10}$R where R $\in$ (42,43)

So we can estimate that X$\in$ (4.2, 4.3). Now to get further closer, choose $\frac{P}{Q}$ = 100. As we increas the $\frac{P}{Q}$ ratio, R will be divided by a greater number, so the answer will be upto more decimal places so answer will be more accurate.

The observation table is shown below.

No. of Obs.	Resistance in the Ratio arms		Resistance in arm AD (R) (Ohm)	Direction of deflection left or righ	Unknown resistance $X = \frac{Q}{P} \times R$ (Ohm)
	AB(P) (Ohm)	BC(Q) (Ohm)			
1.	10	10	4	Left	(4 – 5)
			5	Right	
2.	100	10	40	Left (large)	(4.2 – 4.3)
			50	Right (large)	
			42	Left	
			43	Right	
3.	1000	10	420	Left	4.25
			424	Left	
			425	No deflection	
			426	Right	

Example 73. If the length of wire is (100.0 cm), and radius of wire, as measured from screw gauge is (1.00 mm) then the specific resistance of wire material is

(A) $13.35 \times 10^{-6}\ \Omega$-m (B) $13.4 \times 10^{-6}\ \Omega$-m (C) $13.352 \times 10^{-6}\ \Omega$-m (D) $16.5 \times 10^{-6}\ \Omega$-m

Answer. **(B)**

Solution : From observation table R = 4.25 Ω

$$\rho = \frac{(R)\pi r^2}{\ell} = \frac{4.25 \times 3.14 \times (1.00)^2 \times 10^{-6}}{(100.0 \times 10^{-2})}$$

$= 13.3 \times 10^{-6}\ \Omega$–m (**Ans.** in three S.F.)

Example 74. **Assertion :** To locate null deflection, the battery key (K_1) is pressed first and then the galvanometer key (K_2).

Reason : If first K_2 is pressed, and then as soon as K_1 is pressed, current suddenly try to increase. So due to self induction, a large stopping emf is generated in galvanometer, which may damage the galvanometer.

(A) If both Assertion and Reason are true and the Reason is a correct explanation of Assertion.
(B) If both Assertion and Reason and true but Reason is not a correct explanation of Assertion.
(C) If Assertion is true but Reason is false.
(D) If both Assertion and Reason are false.

Answer : **(A)**

Example 75. What is the maximum and minimum possible resistance, which can be determined using the PO Box shown in above figure-2

(A) 1111 kΩ , 0.1 Ω (B) 1111 kΩ , 0.01 Ω (C) 1111 kΩ , 0.001 Ω (D) None of these

Answer : **(B)**

Solution : $X = \frac{Q}{P}R \Rightarrow (X)_{max} = \frac{(Q)_{max}}{(P)_{min}} (R)_{max} = \frac{1000}{10} (11110) = 1111\ k\Omega$

$(X)_{min} = \frac{(Q)_{min}}{(P)_{max}} \quad (R)_{min} = \frac{10}{1000}\ \frac{10}{1000} \quad (1) = 0.01\ \Omega.$

Example 76. In a certain experiment if $\frac{Q}{P} = \frac{1}{10}$ and in R, if 192 Ω if used we are getting deflection toward right, at 193 Ω, again toward right but at 194 Ω, deflection is toward left. The unknown resistance should lie between

(A) 19.2 to 19.3 Ω (B) 19.3 to 19.4 Ω (C) 19 to 20 Ω (D) 19.4 to 19.5 Ω

Answer : **(B)**

Solution : $X = \frac{Q}{P}(R) = \frac{1}{10}(193 \leftrightarrow 194) = 19.3 \leftrightarrow 19.4$

Example 77. If By mistake, Battery is connected between B and C Galvanometer is connected across A and C then

(A) We cannot get balanced point.
(B) Experiment will be less accurate
(C) Experiment can be done in similar manner.
(D) Experiment can be done in similar manner but now, K_2 should be pressed first, then K_1.

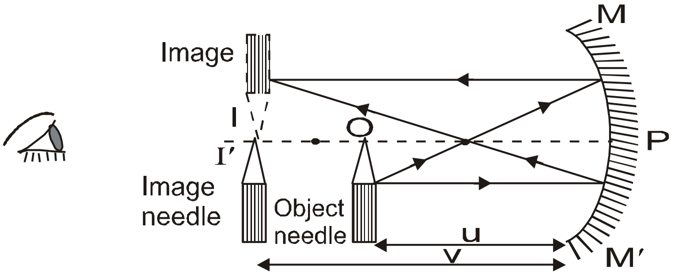
Answer : **(D)**

EXPERIMENT # 10

TO FIND FOCAL LENGTH OF A CONCAVE MIRROR USING U-V METHOD.

Principle : For different u, we measure different v, and find f using mirror’s formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$.

In this experiment, a concave mirror is fixed at position MM’ and a knitting needle is used as an object, mounted in front of the concave mirror. This needle is called object needle (O in fig)



First of all we make a rough estimation of f. For estimating f roughly, make a sharp image of a far away object (like sun) on a filter paper. The image distance of the far object will be an approx estimation of focal length).

Now, the object needle is kept beyond f, so that its real and inverted image (I in fig) can be formed. You can see this inverted image in the mirror by closing your one eye and keeping the other eye along the pole of the mirror.

To locate the position of the image, use a second needle, and shift this needle such that its peak Coincide with the image. The second needle gives the distance of image (v), so it is called “image needle” (I' in figure). Note the object distance ‘u’ and image distance ‘v’ from the mm scale on optical bench and find focus distance from that

Similarly take 4-5 more observations.

Determining ‘f’ from u – v observation:

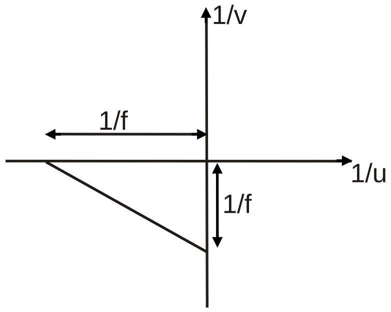
Using Mirror Formula :

(i) Use mirror formula : $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$ to find focal length from each u – v observation. Finally take average of all.

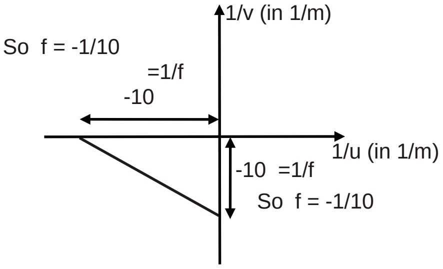
(ii) From $\frac{1}{v}$ v/s $\frac{1}{u}$ curve :

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1/u}{1/f}+\frac{1/v}{1/f} = 1 \leftrightarrow \frac{x}{a}+\frac{y}{b} = 1$$

So curve between $\frac{1}{v}$ v/s $\frac{1}{u}$ should be a straight line having x and y intercepts = $\frac{1}{f}$ and $\frac{1}{f}$



from the observations of u and v, plot $\frac{1}{v}$ v/s $\frac{1}{u}$ curve as a straight line, find the x and y



intercepts, and equate them to $\frac{1}{f}$ and $\frac{1}{f}$.

(iii) **From u – v curve :**

Relation between u and v is

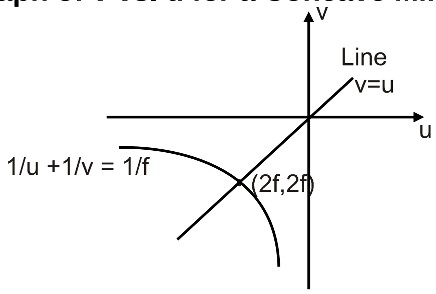
$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \qquad .....(1)$$

So curve between v v/s u is a rectangular hyperbola as shown in figure.

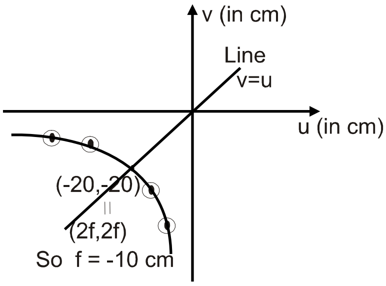
If we draw a line bisecting both the axis, i.e. line

$$u = v \qquad .....(2)$$

Graph of v vs. u for a Concave Mirror



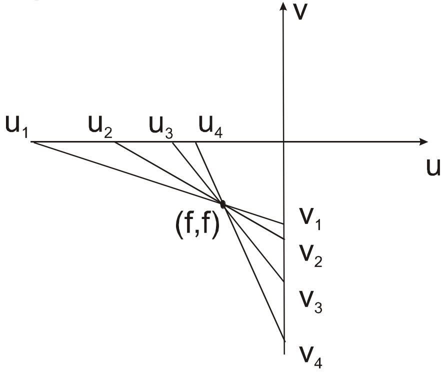
then their intersection points should be v = 2f, u = 2f (By solving equation (1) and equation (2)) from u – v data, plot v v/s u curve, and draw a line bisecting the axis. Find the intersection point and equate them to (2f, 2f).



(iv) **From intersection of lines joining u_n and v_n :**

Indicate u_1, u_2, u_3 .... u_n on x-axis, and v_1, v_2, v_3 .... v_n on y-axis. If we join u_1 with v_1, u_2 with v_2, u_3 with v_3 and .... so on. All line intersects at a common point (f, f).

Graph of v vs. u for a Concave Mirror



EXPLANATION

Line joining u_1 and v_1 is

$$\frac{x}{u_1} + \frac{y}{v_1} = 1 \qquad .....(1)$$

where, $\frac{1}{u_1}+\frac{1}{v_1}=\frac{1}{f}$ = or $\frac{f}{u_1}+\frac{f}{v_1}$ = 1 .....(1')

Line joining u_2 and v_2 is

$\frac{x}{u_2}+\frac{y}{v_2}$ = 1 .....(2)

where $\frac{f}{u_2}+\frac{f}{v_2}$ = 1 .....(2')

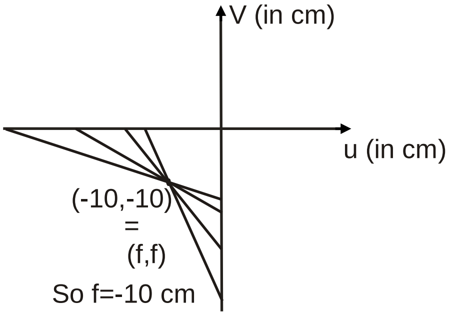
Similarly Line joining u_n and v_n is

$\frac{X}{V_n}+\frac{y}{u_n}$ = 1 .....(3)

where $\frac{f}{u_n}+\frac{f}{v_n}$ = 1 .....(3')

From equation (1'), (2'), (3'), we can say that x = f and y = f will satisfy all equations (1), (2), (3). So point (f, f) will be the common intersection point of all the lines.

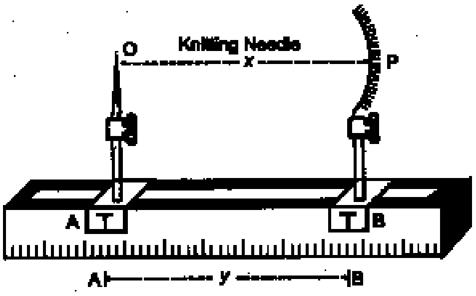
From u – v datas draw u_1, u_2 ...... u_n on x-axis and v_1, v_2, ... v_n datas on y-axis. Join u_1 with v_1, u_2 with v_2 .... u_n with v_n. Find common intersection point and equate it to (f, f).



INDEX ERROR

In u – v method, we require the distance between object or image from the pole (vertex) of the mirror (actual distance).

But practically we measure the distance between the indices A and B. (Observed distance), which need not exactly coincide with object and pole, there can be a slight mismatch called index error, which will be constant for every observation.



Determination of index correction.

Index error = Observed distance – Actual distance

(Just like zero error in screw gauge, it is the excess reading).

To determine index error, mirror and object needle are placed at arbitrary position. For measuring actual distance, a knitting needle is just fitted between the pole of mirror and object needle "O". The length of knitting needle will give the actual object distance while the separation between indices A and B at that instant is the observed distance.

So index error is -

e = Observed distance – Actual distance

= Separation between indices A and B – Length of knitting needle

once we get e, in every observation, we get

Actual distance = Observed distance (separation between the indices) – Excess reading (e)

*There is an another term, **Index correction** which is inverse of index error.

Index correction = – index error

Example 78. To find index error for u, when a knitting needle of length 20.0 cm is adjusted between pole and object needle, the separation between the indices of object needle and mirror was observed to be 20.2 cm. Index correction for u is -

(A) –0.2 cm (B) 0.2 cm (C) –0.1 cm (D) 0.1 cm

Answer : **(B)**

Solution : Index error (Excess reading) = Observed reading – Actual reading = 20.2 – 20.0 = 0.2cm

Example 79. To find index error for v, when the same knitting needle is adjusted between the pole and the image needle, the separation between the indices of image needle and mirror was found to be 19.9 cm. Index error for v is

(A) 0.1 cm (B) –0.1 cm (C) 0.2 cm (D) –0.2 cm

Answer : **(B)**

Solution : e = 19.9 cm – 20.0 cm = –0.1 cm

Example 80. In some observation, the observed object distance (Separation between indices of object needle and mirror) is 30.2 cm, and the observed image distance is 19.9 cm. Using index correction from previous two questions, estimate the focal length of the concave mirror!

Solution : u = 30.2 – 0.2 (excess reading)

= 30.0 cm.

v = 19.9 – (–0.1) (excess reading)

= 20.0 cm.

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow f = 12.0 \text{ cm.}$$

Maximum permissible error in f due to imperfect measurement of u & v:

In this experiment, from a set (u, v), focus distance f can be calculated from equation.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \qquad \Rightarrow \qquad \frac{df}{f^2} = \frac{du}{u^2} + \frac{dv}{v^2}$$

$$\left(\frac{\Delta f}{f^2}\right) = \pm \frac{\Delta u}{u^2} \pm \frac{\Delta v}{v^2} \Rightarrow \left(\frac{\Delta f}{f^2}\right)_{max} = + \frac{\Delta u}{u^2} + \frac{\Delta v}{v^2} \Rightarrow (\Delta f)_{max} = \left(\frac{\Delta u}{u^2} + \frac{\Delta v}{v^2}\right) \times f^2$$

Example 81. In u – v method to find focal length of a concave mirror, if object distance was found to be 10.0 cm and image distance was also found to be 10.0 cm then find maximum permissible error in f, due to error in u and v measurement. (Least count of the scale on optical banch is 1 mm.)

Solution : $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{(-10)} + \frac{1}{(-10)} = \frac{1}{f} \Rightarrow |f| = 5$ cm

$$(\Delta f)_{max} = \left(\frac{\Delta u}{u^2} + \frac{\Delta v}{v^2}\right) \times f^2 \Rightarrow (\Delta f)_{max} = \left(\frac{0.1}{10^2} + \frac{0.1}{10^2}\right) \times 5^2 = 0.05 \text{ cm}$$

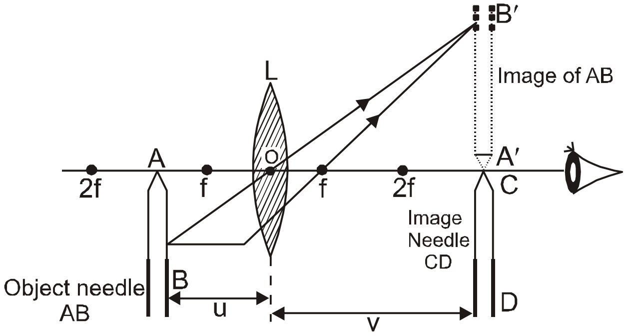
so, f = (5 ± 0.05) cm

EXPERIMENT # 11

To find focal length of a convex lens using u-v method.

Principle : For different u, we measure different v, and find f using lens's formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$.

Procedure : In this experiment, a convex lens is fixed at position L and a knitting needle is used as an object, mounted in front of the concave mirror. This needle is called object needle (AB in fig)



First of all we make a rough estimation of f. For estimating f roughly, make a sharp image of a far away object (like sun) on a filter paper. The image distance of the far object will be an approx estimation of focal length.

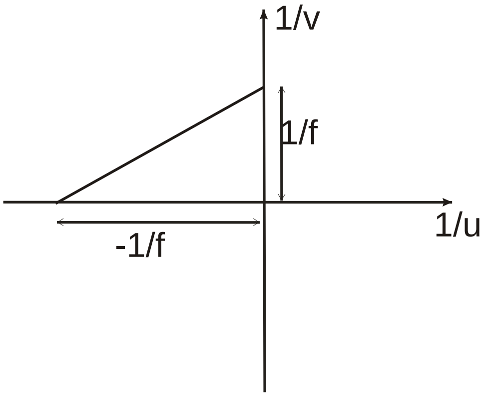
Now, the object needle is kept beyond f, so that its real and inverted image (I in fig) can be formed.
To locate the position of the image, use a second needle, and shift this needle such that its peak coincide with the image. The second needle gives the distance of image (v), so it is called “image needle” (CD in figure). Note the object distance ‘u’ and image distance ‘v’ from the mm scale on optical bench.
Similarly take 4-5 more observations.
Determining ‘f’ from u – v observation:
Using lens Formula :

(i) Use lens formula : $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ to find focal length from each u – v observation. Finally take average of all.

(ii) From $\frac{1}{v}$ v/s $\frac{1}{u}$ curve :

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1/u}{-1/f}+\frac{1/v}{1/f} = 1 \leftrightarrow \frac{x}{a}+\frac{y}{b} = 1$$

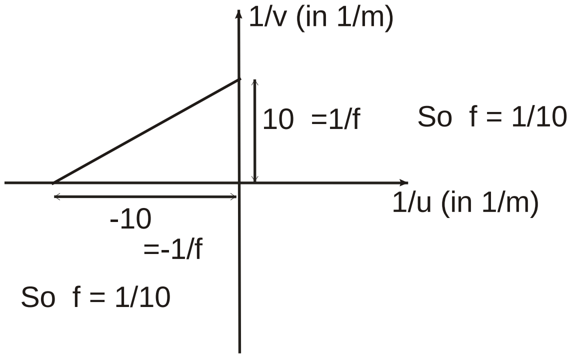
So curve between $\frac{1}{v}$ v/s $\frac{1}{u}$ should be a straight line having x



and y intercepts = $-\frac{1}{f}$ and $\frac{1}{f}$

Graph of $\frac{1}{v}$ vs. $\frac{1}{u}$ for a convex lens

from the observations of u and v, plot $\frac{1}{v}$ v/s $\frac{1}{u}$ curve as a straight line, find the x and y intercepts, and equate them to – $\frac{1}{f}$ and $\frac{1}{f}$.



(iii) From u – v curve :

Relation between u and v is

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \qquad ....(1)$$

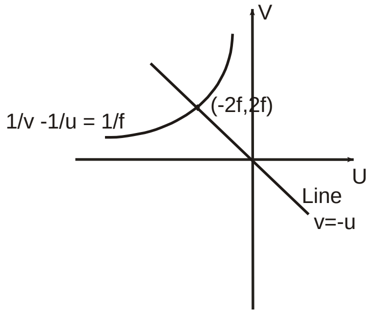
So curve between v v/s u is a rectangular hyperbola as shown below.

If we draw a line bisecting both the axis, i.e. line

$u = -v$ ....(2)

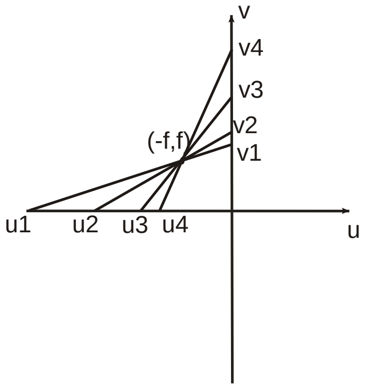
then their intersection points should be V = 2f, u = – 2f (By solving equation (1) and equation (2))from u – v data, plot v v/s u curve, and draw a line y = –x. Find the intersection point and equate them to (–2f, 2f).

Graph of v vs. u for a Convex lens



(iv) **From intersection of lines joining u_n and v_n :**

Indicate u_1, u_2, u_3 .... u_n on x-axis, and v_1, v_2, v_3 .... v_n on y-axis. If we join u_1 with v_1, u_2 with v_2, u_3 with v_3 and .... so on. All line intersects at a common point (–f, f).



from u – v datas draw u_1, u_2 ...... u_n on x-axis and v_1, v_2, ... v_n datas on y-axis. Join u_1 and v_1, u_2 with v_2 .... u_n and v_n. Find common intersection point and equate it to (–f, f)

Index error and max permissible error is similar to the concave mirror

EXPERIMENT # 12

Object

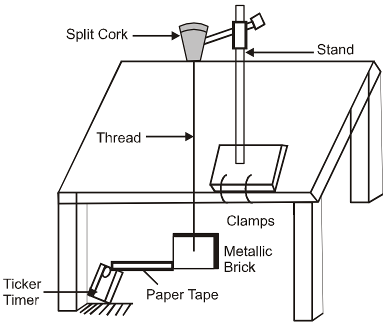
To study dissipation of energy of a simple pendulum by plotting a graph between square of amplitude and time.

Appratus

Ticker timer, paper tape, meter scale, thread, clamp, metallic brick as bob, clamps, split cork and a spring balance.

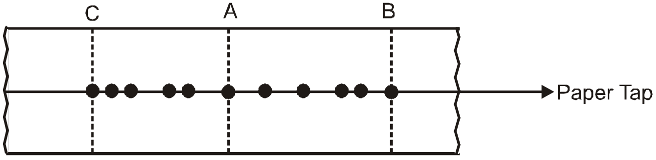
Principle

The energy of a simple harmonic oscillator is directly proportional to its amplitude. When the bob of a simple pendulum is set into vibrations, its amplitude goes on decreasing with time due to friction of air and friction at the point of support. Such vibration whose amplitude decreases with time due to some dissipative force are called damped vibrations. The vibrations of simple pendulum are also damped vibrations. At any time t the energy $E_t = E. e^{-\lambda t}$, where λ is the decay constant and energy E is given by $E = \frac{1}{2} KA^2$ where A is the amplitude and K is force constant.



Method

1. Find the mass of the metallic brick by the spring balance.
2. Fix the clamp stand on the edge of the table with the help of clamps.
3. The one end of the thread with the metallic brick and pass the other end of the thread through the split cork hold the cork in the clamp stand.
4. Fix the ticker timer at the same height above the ground on the brick is attach the paper tape at the centre of the brick with the help of the cello tape.
5. Pull the brick towards the ticker timer and taut the paper tape. Start the ticker timer and release the brick.
6. As the brick reaches the outer extreme switch off the ticker timer.
7. Remove the paper tape. The pattern of dots obtained on the tape will be as shown below.



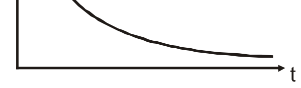
8. Mark the central dot A and the extreme dots B and C corresponding to the extreme positions of the metallic brick.
9. Measure the distance of the dots from the central dot A.

Observations :

Least count of spring balance = ... kg
Corrected mass of the metallic block = m = ... kg
Time period of ticker-timer (one tick) = ... sec
Length of simple pendulum, = L = ... m

Side from dot	S. no. of dot from central dot (A)	Displacement from central dot A (m) = Amplitude	$(\text{Amplitude})^2$	Time Interval t = No. of dot x time period
Right	1 2 3			
Left	1 2 3			

Graph



From the graph it is clear that Energy $\propto$ $(\text{Amp})^2$ and the energy of the pendulum decreases with time.

Precaution

1. An inextensible and string thread should be used for making the pendulum.
2. The lower faces of the split cork should lie in the same horizontal plane.
3. The amplitude of oscillation should be kept small.
4. The experiment should be performed at place which in free from any air disturbance.

5. The metallic brick should be suspended close to the ground.
6. The metallic brick should move along the reference line without any jerky motion.

Result

The sum of the kinetic energy and potential energy of the bob (metallic block) of the simple pendulum is constant within the limits of the experimental error. This shows that the energy is being transferred from kinetic to potential and vice versa. From the above graph it is proved that there is dissipation of energy during SHM of simple pendulum.

Precaution

1. Pendulum support should be rigid
2. The amplitude should remain small.
3. Pendulum should be sufficiently long (about 2 metres).
4. Pulling string should be used to avoid spinning of the metallic block
5. Paper tape should be attached to the centre of the bottom of the block.

Source of Error

1. The support may not be fully rigid.
2. Movement of metallic block may not be proper.

EXPERIMENT # 13

Object

To determine the mass of a given body using a metre scale by principle of moments

Appratus

A metre scale, a broad heavy wedge with sharp edge, a weight box, a body of unknown mass

Principle

Metre scale as a beam balance :

(a) **Introduction :** Like a physical balance, a metre scale can be used as a beam balance making use of the same principle of moments. Besides it has adjustable power arm and weight arm about fulcrum whose length can be adjusted.

(b) **Diagram :**

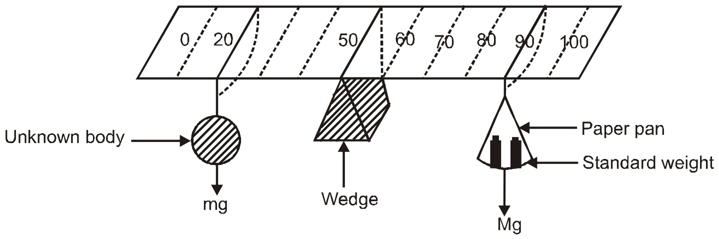


Figure (b) Metre-scale balance. Power and weight arms of unequal length.

(c) Construction (Arrangement) : The metre scale is balanced by putting its 50 cm mark over the sharp edge of a heavy broad wedge works as fulcrum. In this position the weight of the metre scale and reaction of the wedge, balance each other.

(b) Working : The body is tied to a strong and light thread loop and suspended on the left of the wedge on some fixed mark. (Say 20 cm in diagram)

A light paper pan is suspended by a strong and light thread on the right. Weights are put on the pan. The position of the loop of the pan and weight in it are so adjusted that the metre scale becomes horizontal again. Position of thread of the loops and the amount of weights in the pan are noted. Mass of the body is calculated using following theory.

(e) Theory : If m and M be the mass of the body and mass of the weight used and a_1 and a_2 be the distance of their loops from wedge. Then, power (mass) arm = a_1, weight arm = a_2

or $m = \frac{Ma_2}{a_1}$, which can be calculated.

(f) Two different methods :

(i) Arm lengths fixed and equal and weight adjustable.

The thread loops are suspended at position forming both arm of equal length. Weight in the paper pan are adjusted till the metre scale becomes horizontal. (figure (a))

In this case $a_1 = a_2 = a$

Hence, $mga_1 = Mga_2$

or $m = M$

A physical balance makes use of this method.

(ii) Masses and power arm fixed and weight arm adjustable.

Mass is suspended at a fixed distance a_1.

Length of power arm is adjusted by moving weight loop thread in and out till the metre scale becomes horizontal (figure (b))

In this case $a_1 = a$, $a_2 = A$

Hence $mga_1 = Mga_2$, becomes $mg\,a = MgA$ or $m = M\frac{A}{a}$

PROCEDURE

(i) First method

1. Arrange the metre scale horizontally by supporting it at the sharp edge of the broad heavy wedge at 50 cm mark.
2. Suspend the body of unknown mass by a loop thread at a fixed mark on the left of the wedge.
3. Suspended paper pan at same distance on the right of the wedge with some weights in it.
4. Adjust the weights in paper pan till the metre scale becomes horizontal.
5. Note the mass of the weights in the pan.
6. Repeat steps 2 to 5, three time by increasing the length of the arms in equal steps keeping the lengths equal.
7. Record the observations as given below in table.

OBSERVATION AND CALCULATIONS

S.No.	Length of weight (or power) arm a (cm)	Mass of Weight in the Paper pan M (g)	Unknown mass (body) m(g)
1	30	$M_1 = 20$	$m_1 = M_1 = 20$
2	35	$M_2 = 20$	$m_1 = M_2 = 20$
3	40	$M_3 = 20$	$m_3 = M_3 = 20$

(**Note :** Observations are as sample)

Mean mass, $m = \frac{m_1 + m_2 + m_3}{3}$ g = ...g

It will be found that $M_1 = M_2 = M_3 = m$ in all cases.

RESULT

The unknown mass of the body, m = 20 g

(ii) Second method

1, 2. Step 1 and 2 of first method.

3. Suspend the paper pan on the right of the wedge with some known weight in it.
4. Adjust the distance of the paper pan till the metre scale becomes horizontal.
5. Note the position of the paper pan and thus length of the weight arm.
6. Repeat steps 2 to 5, three times by increasing the mass of the weights by equal amount.
7. Record the observations as given below in table.

OBSERVATION AND CALCULATIONS

Fixed length of power arm = a = 25 cm

S.No.	Mass of weight in the paper pan M(g)	Length of the Weight arm A(cm)	Unknown mass body m(g)
1	20	$A_1 = 30$	$m_1 = \frac{M_1A_1}{a} = 24$
2	30	$A_2 = 20$	$m_2 = \frac{M_2A_2}{a} = 24$
3	40	$A_3 = 15$	$m_3 = \frac{M_3A_3}{a} = 24$

(**Note :** Observations are as sample)

Mean mass, $m = \frac{m_1 + m_2 + m_3}{3}$ g = ...g

It will be found that $m_1 = m_2 = m_3 = m$ in all cases.

RESULT

The unknown mass of the body, m = 24 g

PRECAUTIONS :

1. The wedge should be broad and heavy with sharp edge.

2. Metre scale should have uniform mass distribution.
3. Threads used for loops should be thin, light and strong.

SOURCES OF ERROR

1. The wedge may not be sharp.
2. Metre scale may have faulty calibration.
3. The threads used for loops may be thick and heavy.

EXPERIMENT # 14 (i)

AIM

To determine the surface tension of water by capillary rise method.

APPARATUS

Three capillary tubes of different radii and a tipped pointer clamped in a metallic plate with a handle, travelling microscope, clamp and stand, a fine motion adjustable height stand, a flat bottom open dish, clean water in a beaker, thermometer.

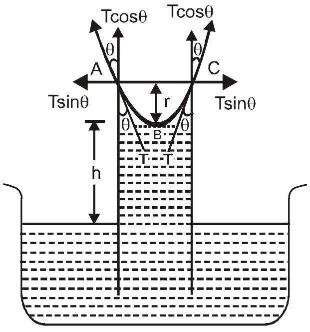
THEORY

Rise of liquid level in a capillary tube (Ascent formula) :

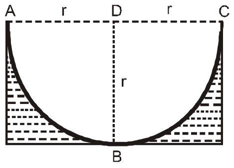
Let a capillary tube be dipped in a liquid which makes concave meniscus in the tube. Due to surface tension, the tube molecules exert a force T on the liquid molecules in the unit length of the circle of contact of the liquid surface with the tube. This force acts at an angle θ (angle of contact) with the wall of the vessel [fig. (a)]. Components T sin θ perpendicular to the wall of the tube cancel for the whole circle. Component T cos θ along the wall of the tube on all molecules becomes $2\pi rT\cos\theta$.

It is this upward force that pulls the liquid upward in the capillary tube. The liquid rises in the capillary tube upto a height till the weight of the liquid risen equals this force.

Let the liquid rise upto a height h (as measured for the lower meniscus B) and let the meniscus ABC have hemispherical shape [Fig. (b)].



(a)



(b)

Volume of liquid in meniscus above B (figure b)

Then, volume of the liquid risen upto lower meniscus = $\pi r^2 h$.

Volume of cylinder of radius and height r – Volume of hemisphere of radius r

$$= \pi r^2 . r - \frac{1}{3}\ \pi r^3 = \pi r^3\left[h + \frac{r}{3}\right]$$

Total volume of the liquid risen = $\pi r^2 h + \pi r^3 = \pi r^2$

If liquid has a density ρ, then mass of liquid risen = $\pi r^2 = \left[h + \frac{r}{3}\right]\rho$

and weight of the liquid risen = $\pi r^2\left[h + \frac{r}{3}\right]\rho g$

For equilibrium, $\pi r^2\left[h + \frac{r}{3}\right]\ \rho g = 2\pi rT\cos\theta$ or $h = \frac{2T\cos\theta}{r\rho g} - \frac{r}{3}$

[From above we find that $h \propto \frac{1}{r}$, i.e., liquid rises more in a capillary tube of small radius]

Also, $T = \frac{(h + r/3)r\rho g}{2\cos\theta}$

Measuring height h of liquid risen in capillary tube and knowing other quantities, surface tension of liquid (T), can be calculated.

[In practice, $\frac{r}{3}$ is neglected as compared to h, then T = $\frac{hr\rho g}{2\cos\theta}$]

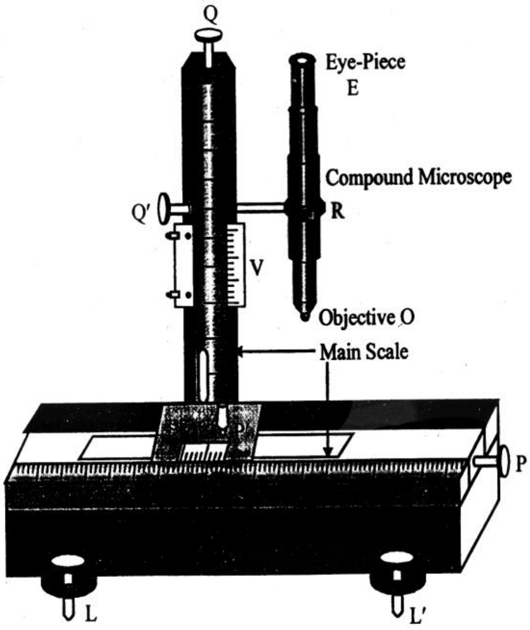


Fig. Travelling microscope

A travelling microscope is device which is used for the accurate measurement of very small distances. Basically, it is a compound microscope fixed on a strong metallic horizontal platform which can be balanced with the help of levelling screws L and L’ [Fig. (2)]. The compound microscope has ability to slide or travel both along horizontal and vertical levels. Due to the horizontal or vertical travelling of the microscope we have named it as a travelling microscope.

The compound microscope consists of two convex lenses called objective O which is placed closed to the object and eye-piece E placed near the eye of an observer. The objective O is simple convex lens small aperture and a small focal length. These two lenses are placed in two distinct tubes placed coaxially. To focus object the tubes can be moved by using a rack and pinion arrangement R. The microscope has a crosswire in front of eye-piece which serves as a reference mark. The object to be seen is placed in front of the objective and the image is viewed through the eye piece. The image formed is virtual, magnified and inverted.

The distance through which the microscope moves can be read with the help of a vernier scale (V) moves with the microscope along with the scale engraved on the frame work. The horizontal movement of microscope is done with the help of screw P in the [Fig. (2)] and the vertical movement of microscope is done with the help of screw Q whereas the horizontal and vertical shifting for fine adjustment microscope can be done with the help of fine screws P’ and Q’

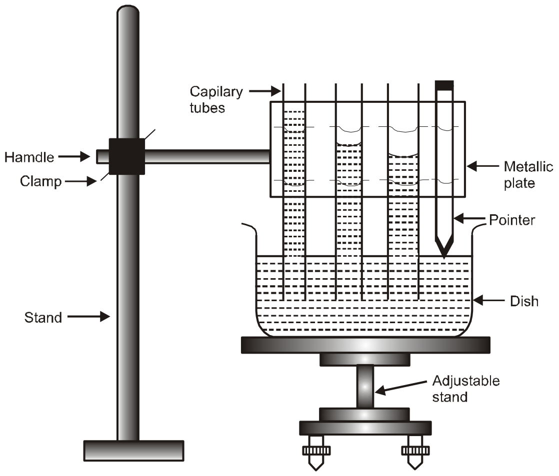


Fig. (3): Measurement of surface tension by capillary rise method

(a) Setting the apparatus

1. Place the adjustable height stand on the table and make its base horizontal by levelling screws.
2. Take dirt and grease free water in an open dish with flat bottom and put it on the top of the stand.
3. Take three capillary tubes of different radii (ranging from 0.05 mm to 0.15 mm)
4. Clean and dry them, clamp the capillary tubes in a metallic plate in order of increasing radius. Also clamp a pointer after third capillary tube.
5. Clamp the horizontal handle of the metallic plate in a vertical stand, so the capillary tubes and the pointer become vertical.
6. So adjust the height of metallic plate that the capillary tubes dip in water in open dish.
7. Adjust the position of the pointer, such that its tip just touches the water surface.

(b) Measurement of capillary rise

8. Find the least count of the travelling microscope for the horizontal and the vertical scale. Record the same in the note-book.
9. Raise the microscope to a suitable height, keeping its axis horizontal and pointed towards the capillary tubes.
10. Bring the microscope in front of first capillary tube (which has maximum rise).
11. Make the horizontal cross wire just touch the central part of the concave meniscus (seenconvex through microscope [fig 4 (b)])
12. Note the reading of the position of the microscope on the vertical scale.
13. Now move the microscope horizontally and bring it in front of the second capillary tube.
14. Lower the microscope and repeat steps 11 and 12.
15. Repeat steps 13 and 14 for third capillary tube.
16. Lower the stand so that pointer tip becomes visible.
17. Move the microscope horizontally and bring it in front of the pointer.
18. Lower the microscope and make the horizontal cross wire touch the tip of the pointer. Repeat step 12.

(3) Measurement of the internal diameter of the capillary tube.

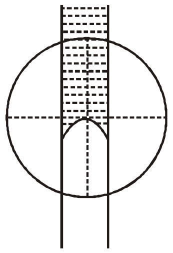


Fig. 6.4(a)

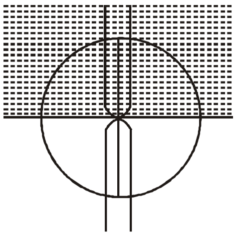


Fig. 6.4(b)

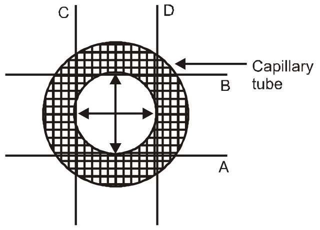


Fig. 6.4(c)

19. Place the first capillary tube horizontally on the adjustable stand.
20. Focus the microscope on the end dipped in water. A white circle (inner bore) surrounded by a green circular strip (glass cross-section) will be seen [fig.4(3)].
21. Make horizontal cross-wire touch the inner circle at A. Note microscope reading on vertical scale.
22. Raise the microscope to make the horizontal cross-wire touch the circle at B. Note the reading (the difference gives the vertical internal diameter AB of the capillary tube).
23. Move the microscope on horizontal scale and make the vertical cross wire touch the inner circle at C. Note microscope reading on horizontal scale.
24. Move the microscope to the right to make the vertical cross-wire touch the circle at D. Note the reading (the difference gives the horizontal diameter CD of the capillary tube).
25. Repeat steps 19 to 24 for other two capillary tubes.
26. Note temperature of water in dish.
27. Record your observations as given below.

OBSERVATION

Least count of travelling microscope (L.C.) = ...cm.

Table for height of liquid rise

Serial No. of Capillary tube	Reading of Meniscus			Reading of Pointer Tip			Height $h_1 - h_2$ = h (cm)
	M.S.R. N (cm)	V.S.R. n×(L.C.) (cm)	Total Reading N+n(L.C.) h_1(cm)	M.S.R N (cm)	V.S.R n×(L.C.) (cm)	Total Reading N+n(L.C.) h_2(cm)	
(1)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)	(4)
1. 2. 3.							

Table for internal diameter of the capillary tube

Serial No. of Capillary tube	Microscope Reading for cross Wire in position				Internal Diameter			Internal radius $\frac{d}{2}$ = r (cm)
	(A) (cm)	(B) (cm)	(C) (cm)	(D) (cm)	Vertical AB (cm)	Horizontal CD (cm)	Mean $\frac{AB+CD}{2}$ d(cm)	
(1)	(2a)	(2b)	(2c)	(2d)	(3a)	(3b)	(3c)	(4)
1. 2. 3.								

Temperature of water, (t) = ... ºC

Density of water at observed temperature, ρ = ... (g cm^{-3})

Angle of contact of water in glass, $\theta = 8^{o}$

i.e., cos θ = 0.99027 taken as 1.

CALCULATIONS

From formula, $T = \frac{r(h + r/3)\rho g}{2\cos\theta}$

Put values of h (column 4-first table) and r (column 4-second table) for each capillary tube separately and find the value of T (in dynes cm^{-1}).

Find mean value, $T = \frac{T_1 + T_2 + T_3}{3}$ = ...dynes cm^{-1}.

RESULT

The surface tension of water at tºC = ...dynes cm^{-1}.

PRECAUTIONS

1. Capillary tube and water should be free from grease.
2. Capillary tube should be set vertical.
3. Microscope should be moved in lower direction only to avoid back lash error.
4. Internal diameter of capillary tube should be measured in two mutually perpendicular directions.
5. Temperature of water should be noted.

SOURCES OF ERROR :

Water and capillary tube may not be free from grease.

EXPERIMENT # 14 (ii)

Aim

To study the effect of the detergent on surface tension by observing capillary rise.

Apparatus

Three capillary tubes of different radii and a tipped pointer clamped in a metallic plate with a handle, travelling microscope, clamp and stand, a fine motion adjustable height stand, a flat botom open dish, clean water in a beaker, thermometer.

Theory

A detergent when added to distilled water reduces surface tension of water. If we use same capillary tube to studey the rise of pure distilled water and then the rise of detergent mixed water (solution), we shall find that the rise will be lesser in case of solution. If quantity of detergent (solution concentratio) is increased, rise will be still lesser.

Procedure

1. Set the apparatus as in previous Experiment.

2. Find the rise of pure distilled (grease free) water through the capillary tube following all the stps of previous Experiment.
3. Take a known volume of distilled water from same sample.
4. Dissolve a small known mass of a detergent in the water to make a dilute solution.
5. Find the rise of the solution in same capillary tube. The rise will be less than that for pure water.
6. Add double mass of detergent in same volume of water to have a solution with double concen tration.
7. Find the rise of this concentrated solution in same capillary tube. The rise will be still lesser.
8. Repeat with solution of same detergent having increased concentration. Rise will decrease as concentration increases.
   [Note : Do not make solution too much concentrated to effect density]

Observation

The rise in capillary tube decreases with addition of detergent in pure water with more addition of detergent, rise becomes lesser and lesser.

Result

The detergent reduces the surface tension of water.

1. Capillary tube and water should be free from grease.
2. Capillary tube should be set vertical.
3. Microscope should be moved in lower direction only to avoid back lash error.
4. Internal diameter of capillary tube should be measured in two mutually perpendicular directions.
5. Temperature of water should be noted.

Sources of Error

Water and capillary tube may not be free from grease.

EXPERIMENT # 15

AIM

To determine the coefficient of viscosity of a given viscous liquid by measuring the terminal velocity of a given spherical body.

APPARATUS

A half metre high, 5 cm broad glass cylindrical jar with millimetre graduations along its height, transparent viscous liquid, one steel ball, screw gauge, stop clock/watch, thermometer, clamp with stand.

THEORY

Terminal velocity :

(a) **Definition :** The maximum velocity acquired by the body, falling freely in a viscous medium, is called terminal velocity.

(b) **Expression :** Considering a small sphere of radius r of density ρ falling freely in a viscous medium (liquid) of density σ. The forces acting on it are :

The weight of the sphere acting downward = $\frac{4}{3}\pi r^3 \rho g$

The upward thrust = Weight of the liquid displaced by the sphere = $\frac{4}{3}\pi r^3 \sigma g$

The effective downward force,

$$mg = \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

Upward force of viscosity, $F = 6\pi\eta r v$

When the downward force is balanced by the upward force of viscosity, the body falls down with a constant velocity, called terminal velocity.

Hence, with terminal velocity,

$$6\pi\eta r v = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

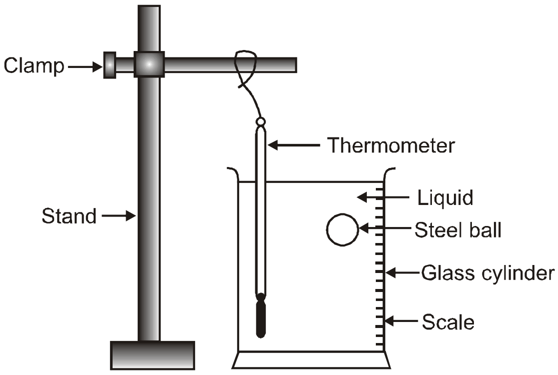
or Terminal velocity, $v = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$

This is the required expression.

Terminal velocity = $\frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$ or $\eta = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{v}$

knowing r, ρ and σ, and measuring v, η can be calculated.

DIAGRAM



PROCEDURE :

1. Clean the glass jar and fill it with the viscous liquid, which must be transparent.
2. Check that the vertical scale along the height of the jar is clearly visible. Note its least count.
3. Test the stop clock/watch for its tight spring. Find its least count and zero error (if any)
4. Find and note the least count and zero error of the screw gauge.
5. Determine mean radius of the ball.
6. Drop the ball gently in the liquid. It falls down in the liquid with accelerated velocity for about one-third of the height. Then it falls with uniform terminal velocity.
7. Start the stop clock/watch when the ball reaches some convenient division (20 cm, 25 cm,.....).
8. Stop the stop clock/watch just when the ball reaches lowest convenient division (45 cm).
9. Find and note the distance fallen and time taken by the ball.
10. Repeat steps 6 to 9 two times more.
11. Note and record temperature of the liquid.
12. Record your observations as given ahead.

OBSERVATIONS :

Least count of vertical scale =.......mm.

Least count of stop clock/watch =.......s.

Zero error of stop clock/watch =.......s.

Pitch of the screw (p) = 1 mm.

Number of divisions on the circular scale = 100

Least count of screw gauge (L.C.) = $\frac{1}{100}$ = 0.01 mm

Zero error of screw gauge (e) =......mm.

Zero correction of screw gauge (C) (– e) =.......mm

Diameter of spherical ball

(i) Along one direction, D_1 = ...mm

(ii) In perpendicular direction, D_2 = ...mm

Terminal velocity of spherical ball

Distance fallen S = ...mm

Time taken, t_1 = ...s

t_2 = ...s

t_3 = ...s

CALCULATIONS

Mean diameter D = $\frac{D_1 + D_2}{2}$ mm

Mean radius r = $\frac{D}{2}$ mm = ...cm

Mean time t = $\frac{t_1 + t_2 + t_3}{3}$ = ...s

Mean terminal velocity, v = $\frac{S}{t}$ = cm s^{-1}

From formula, $\eta = \frac{2r^2(\rho - \sigma)g}{9v}$ C.G.S. units.

RESULT

The coefficient of viscosity of the liquid at temperature (θ^oC) = ...C.G.S. units

PRECAUTIONS

1. Liquid should be transparent to watch motion of the ball.
2. Balls should be perfectly spherical.
3. Velocity should be noted only when it becomes constant.

SOURCES OF ERROR

1. The liquid may be have uniform density.
2. The balls may not be perfectly spherical.
3. The noted velocity may not be constant.

EXPERIMENT # 16

AIM

To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

APPARATUS

Newton's law of cooling apparatus (a thin-walled copper calorimeter suspended in a double walled enclosure) two thermometers, clamp and stand, stop clock/watch.

THEORY

Newton was the first person to investigate the heat lost by a body in air. He found that the rate of loss of heat is proportional to the excess temperature over the surroundings. This result, called Newton's law of cooling, is approximately true in still air only for a temperature excess of 20 K or 30 K.

Consider a hot body at a temperature T placed in surroundings at temperature T_0.

Rate of loss of heat $= -\frac{dQ}{dt}$

Using Newton's law of cooling, $-\frac{dQ}{dt} \propto (T - T_0)$

or $\frac{dQ}{dt} = -k(T - T_0)$ where k is constant of proportionality whose value depends upon the area and nature of surface of the body.

If the temperature of the body falls by a small amount dT in time dt, then

$dQ = mcdT$

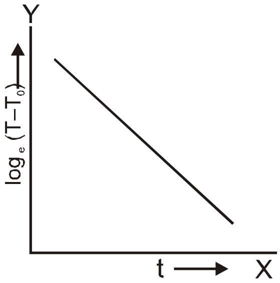
where m is the mass of the body and c is the specific heat of the material of the body.

Now, $mc\frac{dT}{dt} = -k(T - T_0)$

or $\frac{dT}{dt} = -\frac{k}{mc}(T - T_0)$

or $\frac{dT}{dt} = -K(T - T_0)$ $\left[\text{Here}, K = \frac{k}{mc} = \text{constant}\right]$

The negative sign indicates a decrease in temperature with time.



Again, $\frac{dT}{T - T_0} = -K\,dt$

Integrating, $\int \frac{1}{T - T_0}\,dT = -K\int dt$

or $\log_e(T - T_0) = -Kt + C$ ....(1)

This is the equation of a straight line having negative slope (– K) and intercept C on Y-axis, Figure shows the graph of $\log_e(T - T_0)$ versus time t. While t has been treated as the x-variable, $\log_e(T - T_0)$ has been treated as the y-variable.

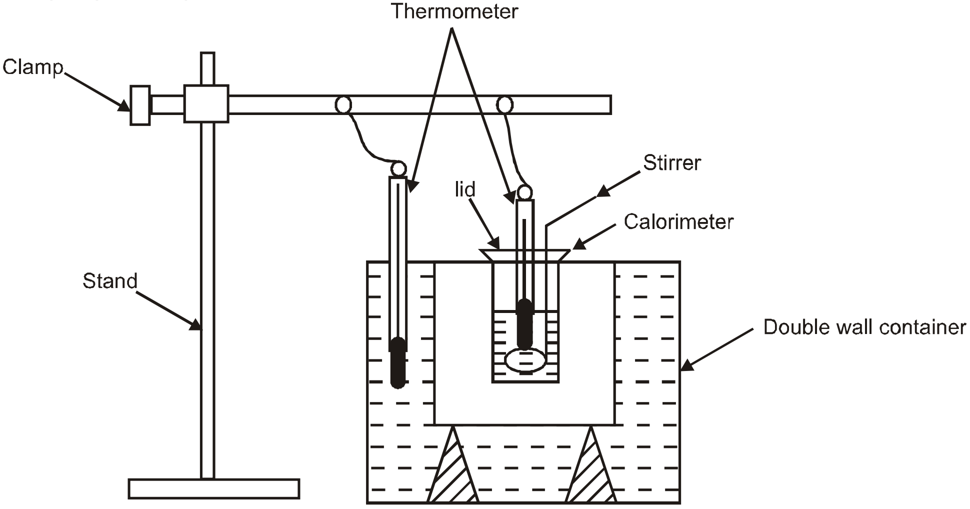
If T_m is the maximum temperature of hot body, then at t = 0 from equation (i)

$\log(T_m - T_0) = C$

$\therefore$ $\log(T - T_0) - \log(T_m - T_0) = -kt$

$\log\left(\frac{T - T_0}{T_m - T_0}\right) = -kt \Rightarrow \frac{T - T_0}{T_m - T_0} = e^{-kt}$

so $(T - T_0) = (T_m - T_0)\,e^{-kt}$



PROCEDURE

1. Fill the space between double wall of the enclosure with water and put enclosure on a laboratory table.
2. Fill the calorimeter two-third with water heated to about 80ºC.
3. Suspend the calorimeter inside the enclosure along with a stirrer in it. Cover it with a wooden lid having a hole in its middle.
4. Suspend from clamp and stand, one thermometer in enclosure water and the other in calorimeter water.
5. Note least count of the thermometers.
6. Set the stop clock/watch at zero and note its least count.
7. Note temperature (T_0) of water in enclosure.
8. Start stirring the water in calorimeter to make it cool uniformly.
9. Just when calorimeter water has some convenient temperature reading (say 70ºC), note it and start the stop clock/watch.
10. Continue stirring and note temperature after every 5 minutes. The temperature falls quickly in the beginning.
11. Note enclosure water temperature after every five minutes.

12. When fall of temperature becomes slow note temperature at interval of two minutes for 10 minutes and then at interval of 5 minutes.

13. Stop when fall of temperature becomes very slow.

14. Record your observations as given ahead.

OBSERVATIONS

Least count of enclosure water thermometer = ...ºC

Least count of calorimeter water thermometer = ...ºC

Least count of stop clock/watch = ...s.

Table for time and temperature

Serial No. of Obs. (1)	Time for cooling t (min) (2)	Temperature of water in calorimeter (T)ºC (3)	Temperature of water in enclosure (T_0)ºC (4)	Difference of temperature ($T - T_0$)ºC (5)	$\log_{10}(T - T_0)$ (6)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

CALCULATIONS

1. Temperature of water in enclosure will be found to remain same. If not then take its mean is T_0.

2. Find temperature difference ($T - T_0$) and record it in column 5 of the table.

3. Plot a graph between time t (column 2) and temperature T (column 3), taking t along X-axis and T along Y-axis. The graph comes to be as shown in given figure. It is called cooling curve' of the liquid.

Graph between time and temperature (Cooling curve)

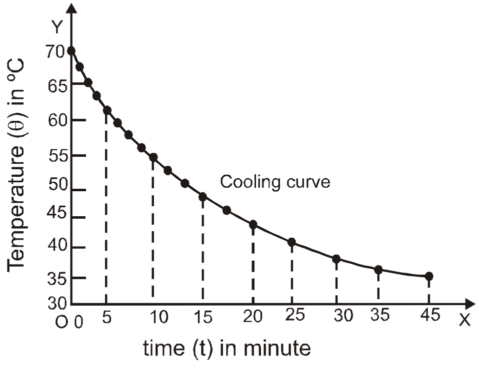
Scale :

X - axis : 1 cm = 5 minutes of t

Y - axis : 1 cm = 5º C of T

RESULT

The temperature falls quickly in the beginning and then slowly as difference of temperature goes on decreasing. This is an agreement with Newton's law of cooling.



PRECAUTIONS

1. Double-walled enclosure should be used to maintain surrounding at a constant temperature.

2. Stirring should remain continuous for uniform cooling

SOURCES OF ERROR

1. Surrounding temperature may change.

2. The stirring of hot liquid may not be continuous.

EXPERIMENT # 17

AIM

To determine specific heat of a given solid (lead shots) by method of mixtures.

APPARATUS

Solid (lead shots), copper calorimeter with copper stirrer and lid, calorimeter jacket (wooden box with coating of insulating material inside), hypsometer, heating arrangement tripod, burner and wire gauze or a hot plate, two Celsius thermometers graduated in 0.2ºC. Water and a physical balance, weight box and milligram fractional weights.

THEORY

The law of mixtures states that when two substances at different temperatures are mixed, i.e., brought in thermal contact with each other, then the heat is exchanged between them, the substance at higher temperature loses heat and that at lower temperature gains heat. Exchange of heat energy continues till both the substances attain a common temperature called equilibrium temperature.

The amount of heat energy lost by the hotter body is equal to the amount of heat energy gained by colder body, provided (i) no heat is lost to the surroundings and (ii) the substances mixed do not react chemically to produce or absorb heat. In brief, the law mixtures is written as :

On mixing of two substances at different temperatures, if no heat is lost to surroundings; at the equilibrium temperature,

Heat gained = Heat lost

For a body of mass m, and specific heat s, when its temperature falls by $\Delta\theta$, the amount of heat lost by it is given as

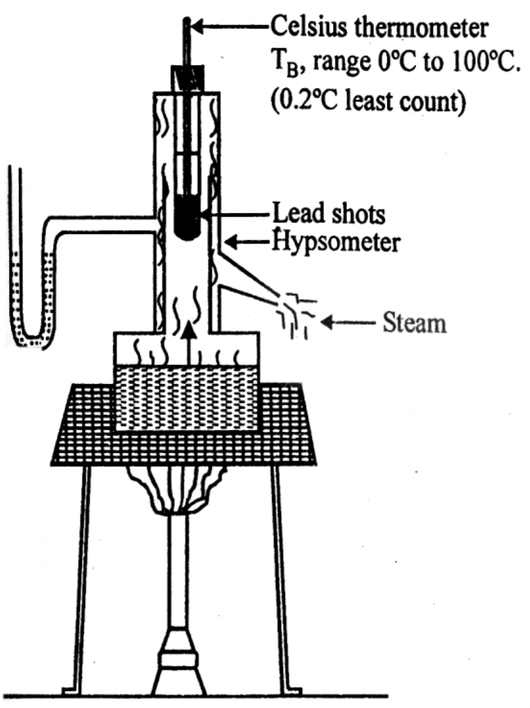
$\Delta Q = m.s\ \Delta\theta$

The same formula is used for the amount of heat gained by colder body where $\Delta\theta$, would be the rise in temperature.

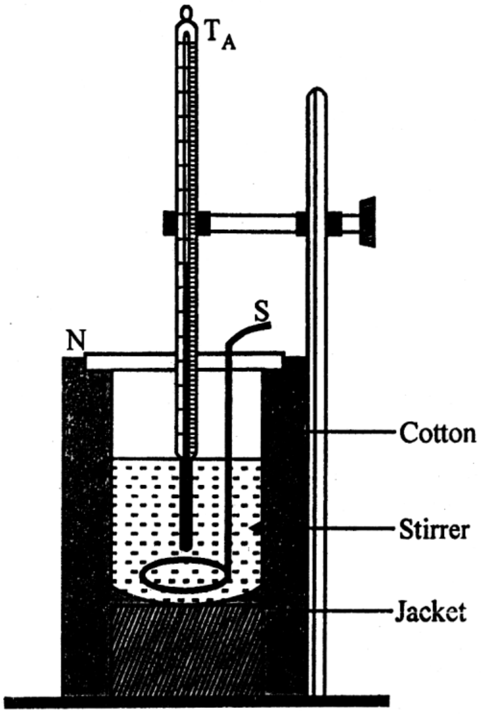
SPECIFIC HEAT

Specific heat of a substance is the amount of heat required to raise the temperature of unit mass of substance through one degree celsius.

S.I. unit of specific heat is $J\ kg^{-1}\ K^{-1}$. Convenient measure of mass in the lab is gram and temperature is ºC. So we express specific heat as $J\ g^{-1}\ {}^{o}C^{-1}$.



Hypsometer for generating steam and heating of given solid



Calorimeter containing known mass of water, stirrer and thermometer placed inside a jacket

PROCEDURE

1. To ensure that two thermometers read the temperature of a body exactly the same, one is compared with the other one which is taken as the standard thermometer. Mark the thermometer used

for measuring temperature of water in calorimeter at room temperature as T_A and the other used in hypsometer as T_B. Suspend them side by side from a clamp stand and note their readings. The error in the temperature measured by thermometer B, is $e = T_B = T_A$

The correction is (– e).

The correction (– e) is algebraically added to readings of temperature recorded by thermometer T_B used hypsometer.

2. Take about 100 grams of lead shots in the tube of hypsometer and add sufficient quantity of water in the hypsometer.

3. Insert the thermometer marked T_B in the tube such that its bulb is surrounded by lead shots and fix the tube inside the mouth of hypsometer.

4. Place the hypsometer on the wire gauze placed on the tripod and start heating it using the burner.

Note : Alternatively, hot plate may be used in place of tripod and burner arrangement.

MEASURING MASSES :

5. Ensure that the physical balance is in proper working condition and on turning the knob, the pointer moves equal divisions on the left and right sides of the zero mark of the scale provided at the back of pointer.

6. Check that the calorimeter is clean and dry. Use a piece of cloth to rub it and shine its surface. Weigh the calorimeter along with stirrer, note the reading as m_c.

7. Weigh the calorimeter with stirrer and lid. Record it as m_1.

8. Place few pieces of ice in a beaker containing water such that its temperature becomes 5 to 7ºC below the room temperature. Fill 2/3 of the calorimeter with cold water from the beaker and ensure that no moisture from air should condense on the surface of the calorimeter, clean the surface if at all the drops appear.

9. Weigh the calorimeter with stirrer, lid and water in it.

10. Place the calorimeter in the jacket. Insert thermometer labelled as A through the lid cover of calorimeter and hold it in a clamp provided on the jacket such that the bulb of thermometer is well immersed in water but does not touch the bottom of the calorimeter.

11. Note and record the temperature of water in the calorimeter.

12. Observe the temperature of the solid in hypsometer at intervals of two minutes till the temperature becomes steady. After the temperature becomes steady for about 5 minutes, record it as θ_2. Apply the correction (–e) to it and write the corrected temperature of solid.

13. Note the temperature of cold water in the calorimeter once again. This is to be taken as the reading for calculations. Immediately after this, remove the cork along with thermometer from the copper tube of hypsometer. Take out the tube, raise the lid of calorimeter and transfer the hot solid quickly to water in the calorimeter without any splash of water.

14. Stir the water in the calorimeter till the temperature of the mixture becomes steady. Note the equilibrium temperature reached by the hot solid and the cold water in the calorimeter.

15. Gently take the thermometer out of the water in the calorimeter. Take care that no water drops come out of the calorimeter along with the thermometer.

16. Take out the calorimeter from the jacket and weigh the calorimeter with stirrer, lid water and solid in it. Record it as m_3.

OBSERVATIONS :

Room temperature reading by thermometer A, T_A = ...ºC
Room temperature reading by thermometer B, T_B = ...ºC
Correction required for thermometer B, $e = T_A - T_B$
Mass of calorimeter + stirrer, m = ...g
Specific heat of the material of calorimeter, copper from tables, s_c = 0.4 J/g/ºC,

Specific heat of water s_w = 4.2 J/g/ºC

Water equivalent of calorimeter, W = m_1 (s_C/s_W)

* when s_W for water is taken as 1 cal/g/ºC

W = m × s_1 otherwise write W as W = m × $\left(\frac{0.4}{4.2}\right)$ g

Mass of calorimeter + stirrer + lid = m_1 = ...g

Mass of calorimeter + lid + cold water = m_2 = ...g

Temperature of cold water in calorimeter, θ_1 = ...ºC

Steady temperature of solid in hypsometer by thermometer B, θ'_2= ....ºC

Corrected temperature of solid, θ_2, $\theta_2 = \theta'_2 + (-e)$ ....ºC

Final, i.e., equilibrium temperature of the mixture θ'_e= ....ºC

Mass of calorimeter + stirrer + lid + water + solid m_3 = ...g

CALCULATION :

(a) Let the specific heat of solid be S J/g/ºC

Mass of clod water in calorimeter, $m_w = m_2 - m_1$ = ...g

Water equivalent of calorimeter + stirrer, W = m × $\frac{s_c}{s_w}$

Rise in temperature of cold water and calorimeter and stirrer, $\theta_e - \theta_1$ = ...ºC

Amount of heat gained by cold water and calorimeter = $(m_w + W) \times s_w \times (\theta_e - \theta_1)$ = ...J ..(1)

where specific heat of water = s_w = 4.2 J/g/ºC

(b) Mass of solid added to cold water, $m_s = m_3 - m_2$ = ...g

Rise in temperature of solid, $\theta_2 - \theta_e$ = ...ºC

Assumed value of specific heat of solid, s = ...J/g/ºC

Heat lost by hot solid = mass × sp. heat × fall of temperature = $(m_3 - m_2)\, s\, (\theta_2 - \theta_e)$ ..(2)

Applying law of mixtures, keeping in view the conditions,

Heat lost = Heat gained

Equating (2) and (1)

$$(m_3 - m_2)\, s\, (\theta_2 - \theta_e) = (m_w + W)\, s_w\, (\theta_e - \theta_1)$$

$$\therefore \quad s = \frac{(m_w + W)}{(m_3 - m_2)} \frac{(\theta_e - \theta_1).s_w}{(\theta_2 - \theta_e)} = \text{.............J/g/ºC}$$

s may be written in S.I. unit as J/kg/ºC, by multiplying the calculated value above by 1000.

RESULT

Specific heat of given (solid), s = ...J/kg/ºC

Value from tables s_t = ...J/kg/ºC

Percentage Error in the value of S = $\frac{s - s_t}{s_t}$ × 100 = ...%

PRECAUTIONS

1. Physical balance should be in proper working condition
2. Sufficient quantity of water should be taken in the boiler of the hypsometer
3. The calorimeter should be wiped clean and its surface should be shining so as to minimise any loss of heat due to radiation.
4. The thermometers used should be of the same range and their least counts be compared before starting the experiment. Cold water in calorimeter should not be so cold that it forms dew droplets on the outer surface of calorimeter. Solid used should not be chemically reactive with water.
5. Hypsometer, burner and heating system should be at sufficient distance from the calorimeter so that calorimeter absorbs no heat from them.
6. The solid should be heated such that its temperature is steady for about 5 to 7 minutes.
7. The solid should be transferred quickly so that its temperature when dropped in water is the same as recorded.
8. Water should not be allowed to splash while dropping the solid in water in the calorimeter.

9. After measuring equilibrium temperature, the thermometer when removed should not have any water droplets sticking to it.
10. Cold water taken in the beaker should be as much below temperature as the equilibrium temperatrue after adding solid is expected to go above it. This is to take care of heat absorbed from surroundings by cold water or that lost by warm water during the course of experiment. It would be of interest to know that this correction had been thought of by count Rumsfort in 19th century.

SOURCES OF ERROR

1. Radiation losses can be minimised but cannot be completely eliminated.
2. During transfer of hot solid into calorimeter, the heat loss cannot be accounted for.
3. Though mercury in the thermometer bulbs have low thermal capacity, it absorbs some heat and lowers the temperature to be measured.

EXPERIMENT # 18 (i)

AIM

To compare electro-Motive-Force's (E.M.Fs) of two primary cells using a potentiometer.

Apparatus

A potentiometer with sliding key (or jockey), a leclanche cell, a Daniel cell, an ammeter, a low resistance Rheostat, a one-way-key, a galvanometer, a resistance box, a battery of 2 to 3 accumulators (or E.M.F. higher than the E.M.F. of individual cell to be compared), a voltmeter, connecting wires : a two-way key and a piece of sand paper.

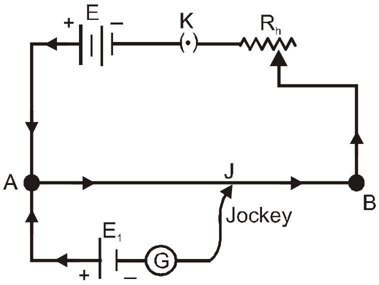


fig. 1

Theory : Potentiometer is an instrument designed for an accurate comparison of potential differences and for measuring small potential differences. In an ordinary form it consists of a long, uniform resistance wire of manganin or constantan stretched over a wooden board usually in 4 turns (or 10 turns) each of 100 cm length. The wire is fixed at its ends to two binding screws. A metre-scale is fitted parallel to the wire and a sliding key or jockey is provided for contact. The working of potentiometer can be understood by considering a simple diagram Let a wire AB be connected to a source of constant potential difference 'E' known as ' Auxiliary battery'. This source will maintain a current in the wire flowing from A to B and there will be a constant fall of potential form the end A to B. This source thus establishes in the wire a potential difference per unit length known as the 'potential Gradient'.

If L be the length of the wire, this potential gradient 'ρ will be E/L volts.

Let one of the cell, whose E.M.F. 'E_1' is to be compared with the E.M.F. 'E_2' of the other cell, be connected with its + ve electrode at A and the other electrode through a galvanometer to a movable contact i.e., jockey J (fig.).

If the fall in potential between A and J due to the current flowing in the wire be equal to the E.M.F. 'E_1' of the cell, the galvanometer will show no deflection when the jockey is pressed at J indicating no current in the galvanometer. This position on the wire AB is possible only when E is greater Than E_1.

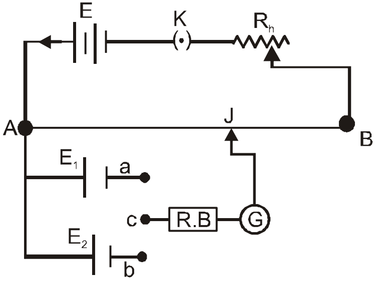


fig. 2

If the point J be at a distance l_1 cm from A, the fall in potential between A and J will ρ l_1 and therefore $\boxed{E_1 = \rho l_1}$ at the null deflection.

If this cell be now replaced by the second cell of E.M.F. 'E_2' and another balance be obtained at a distance l_2 cm from A, then

$$\boxed{E_2 = \rho l_2}$$

$$\therefore \quad \frac{E_1}{E_2} = \frac{\rho l_1}{\rho l_2} = \frac{l_1}{l_2} \quad \text{or} \quad \boxed{\frac{E_1}{E_2} = \frac{l_1}{l_2}}$$

Since the galvanometer shows no deflection at the null point so no current is drawn from the experimental cell and it is thus the actual E.M.F of the cell that is compared in this experiment.

Procedure :

1. Draw a diagram showing the scheme of connections as in fig. 1
2. Remove the insulation from the end of the connecting copper wires and clean the ends with a sand paper.
3. Connect the positive pole of the auxiliary battery (a battery of constant e.m.f) to the zero end (A) of the potentiometer and the negative pole through a one-way-key, an ammeter and a low resistance rheostat to the other end of the potentiometer. Connect the positive pole of the cells E_1 and E_2 to the terminal at the zero and (A) and the negative poles to terminal a and b of the two way key connect the common terminal c of the two way key through a galvanometer (G) and a resistance box (R.B) to the jockey.
4. To test the connections : Introduce the plug in position in the one-way-key (K) in auxiliary circuit and also in between the terminal a and c of the two-way-key. Take out a 2,000 ohms plug from the resistance box (R.B). Press the jockey at the zero end and note the direction of deflection in the galvanometer. Press the jockey at the other end of the potentiometer wire; if the direction of deflection is opposite to that in the first case, the connections are correct. If the direction of deflection is in the same direction then increase the corrent in the auxiliary circuit with a rheostate till the deflaction obtained in the galvanometer is in the opposite direction when the jockey is pressed at the other end.
5. Move the jockey along the wire from the zero end A towards the other end B so as to find a point J_1 where the galvanometer shows no defection. Put in the 2000 ohms plug in the resistance box and find the null point accurately. Note the length 'l_1' of the wire and also the current in the ammeter.
6. Disconnect the cell E_1 and put the cell E_2 in circuit. Again remove 2000 ohms plug from the resistance box and find the corresponding length (l_2) accurately for no deflection of galvanometer keeping the ammeter reading the same.
7. Repeat the observation alternately for each cell again for the same value of current.
8. Increase the current by adjusting the rheostat and obtain in a similar way, four sets of observations. (The rheostat used in the circuit should have a low resistance as compared to the resistance pf the potentiometer wire.)
9. Find the mean of the two observations for each cell and calculate the ratio $\frac{l_1}{l_2}$.
10. Measure the E.M.F of the two cells separately with a voltmeter and compare the ratio $\frac{E_1}{E_2}$ with that obtained from observation with potentiometer.

Observation and Calculations :

S.No.	Ammeter reading	Length of wire with						$\frac{E_1}{E_2} = \frac{l_1}{l_1}$
		Cell E_1 (Leclanche cell)			Cell E_2 (Daniel cell)			
		(i)	(ii)	Mean (l_1)	(i)	(ii)	Mean (l_1)	
1.	...amperes	...cm	...cm	...cm	..cm	...cm	...cm	
2.								
3.								
4.								
5.								

Mean $\frac{E_1}{E_2}$ = ...

E.M.F of leclanche cell (E_1) = ... volts
(By voltmeter)
E.M.F. of Daniel cell (E_2) = ... volts
(By voltmeter)

$\therefore \quad \frac{E_1}{E_2}$ = ...

Result : $\frac{\text{E.M.F of Leclanche cell}}{\text{E.M.F of Daniel cel}}$ = ...

Precaution :

1. The e.m.f. of the auxiliary battery should be constant and always greater than the e.m.f of either of the two cells, whose e.m.f are to be compared.
2. The positive pole of the auxiliary battery and the positive poles of the cell must be connect to the terminal on the zero side of the potentiometer wire otherwise it would be impossible to obtain balance point.
3. The rheostat should be of low resistance and whenever the deflection shown is to the same side when jockey is pressed at all points of the wire, the current must be increased to obtain the balance point at a desired length.
4. The current should remain constant for each set of observation with the two cells.
5. The current should be passed only for the duration it is necessary, otherwise the balance point will keep on changing.
6. The balance points should be obtained at large distances from the zero end.
7. The length should always be measured from the end of the wire where positive poles are connected.
8. The balance point should be found alternately with the two cells.
9. A high resistance should be used in series with the galvanometer. This does not affect the position of the balance point in any way. Near the position of the exact balance point, however, this resistance should be removed. (Note that the same purpose can be served by putting a shunt across the galvanometer)
10. A resistance box should never be used in the auxiliary circuit.
11. To avoid any change in the e.m.f. of a cell due to polarization, the reading should be taken after sufficient intervals of time.

Sources of Error :

(i) The potentiometer wire may not be uniform.

(ii) The resistance of the wire may change due to rise of temperature.

(iii) Contact potentials may not be negligible.

EXPERIMENT # 18 (ii)

Aim

To determine the internal resistance of a primary cell using a potentiometer.

Apparatus

A potentiometer, a Leclanche cell, a battery of three cells, an ammeter, a low resistance rhostat, two one-way key a sensitive galvanometer two resistance boxes, a jockey connecting wires and a piece of sane paper.

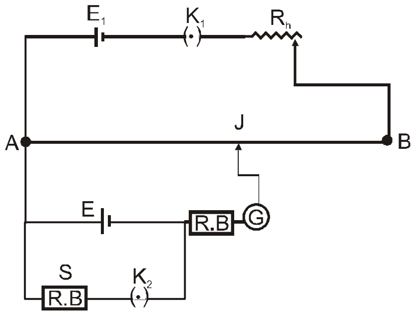


Fig. Internal resistance of a cell

Theory

In the potentiometer circuit of Fig. let ‘l_1’ be the length of the potentiometer wire upto the point X, when balance is obtained with the cell (E) in open circuit i.e., when key K_2 is not closed and ‘l_2’ the length upto Y when the balance is obtained with the cell shunted through a resistance S. Then if E is the e.m.f of the cell and ‘V’ the P.D. between its terminals when shunted, we have according to the principle of the potentiometer,

and $E \propto l_1$ and $V \propto l_2$

$$\therefore \quad \frac{E}{V} = \frac{l_1}{l_2} \qquad .....(i)$$

If 'r' be the internal resistance of the cell and I the current through it when shunted by S, then by Ohm's Law

E = I (S + r) and V = IS

$$\therefore \quad \frac{E}{V} = \frac{S+r}{S} \qquad .....(ii)$$

From (i) and (ii), $\frac{S+r}{S} = \frac{l_1}{l_2}$ or $1 + \frac{r}{S} = \frac{l_1}{l_2}$

hence, $\boxed{r = \frac{(l_1 - l_1)S}{l_2}}$ ....(iii)

Procedure

1. Draw a diagram as shown the scheme of connections in Fig.
2. Remove the insulation from the ends of the copper wires and clean the ends with a sand paper. Connect the positive pole of the auxiliary battery to the zero end (A) of the potentiometer (Fig.) and the negative pole through a one-way key (K_1), an ammeter and a low resistance rheostat to the other end (B) of the potentiometer wire.
3. Connect the positive pole of the cell (E) to the terminal at the zero end (A) and the negative pole the jockey through the galvanometer (G) and resistance box (R.B.)
4. Connect a resistance box S across the cell (E) through a one-ways key (K_2)
5. Insert the plug in key K_1 and adjust a constant current in the potentiometer circuit with the help of rheostat.
6. (i) Move the jockey along the wire so as to find a point where the galvanometer shows no deflection. Insert the 2000 ohms lug and find the null point accurately as at X. Note the length l_1 of the wire and the current in the ammeter. Put in the key K_2 and take out 2 ohm plug from the resistance box S and make all other plugs tight by giving them a slight twist. Find the balance point again as at Y and note corresponding length l_2 Repeat twice for the same value of the current in the auxiliary circuit and same shunt resistance in a similar manner.
   (ii) Remove the plugs from the keys K_1 and K_2. Wait for some time, insert the plug in the key K_1 and find l_1 keeping the current same in a similar manner. Put in the key K_2, take out a resistance of 3or 4 ohms and find the length l_1
   (iii) repeat similarly for S equal to 5 Ω
7. Change the value of current in the external circuit by a slight amount and repeat observations as in Step 6.

Observation

S.No.	Ammeter Reading (amperes)	Position of Null point						Shunt Resistance (S) ohms	Internal Resistance r = (S (l_1–l_2) / (l_2))
		Without shunt			With Shunt				
		(i)	(ii)	Mean (l_1) cm	(i)	(ii)	Mean (l_2) cm		
1. 2. 3									
1. 2. 3									

Result

Internal resistance of Leclanche cell (r) = ... ohms

Percautions

1. The e.m.f. of the auxiliary battery should be constant and always greater than the e.m.f. of either of the two cells, whose e.m.fs. are to be compared.

2. The positive pole of the auxiliary battery and the positive poles of the cells must be connected to the terminal on the zero side of the potentiometer wire otherwise it would be impossible to obtain balance point
3. The rheostat should be of a low resistance and whenever the deflection shown is to the same side when jockey is pressed at all points of the wire, the current must be increased to obtain the balance point at a desired length.
4. The current should remain constant for each set of observations with two cells.
5. The current should be passed only for the duration it is necessary, otherwise the balance point will keep on changing
6. The balance points should be obtained at large distances from the zero end.
7. The internal resistance of a Leclanche cell is not constant but varies with the current drawn from the cell. Hence to get constant readings the resistance from the resistance box S must be varied by a small amount (say 3 to 8 ohms).

[**Note**, To prevent a large current from being passed through the galvanometer either shunt it with a wire or put a large resistance about 2000 ohms in series with it (fig.) But when the balance point is located, to find it more predicely the shunt should be removed or all the plugs of the series resistance box should be inserted].

EXERCISE

1. A student is required to measure emf of a cell, he should use -
(1) Potentiometer (2) Voltmeter (3) ammeter (4) either (1) or (2)

2. A potentiometer is an ideal device of measuring potential difference, because-
(1) it uses a sensitive galvanometer
(2) it does not disturb the potential difference it measures
(3) it is an elaborate arrangement
(4) it has a long wire hence heat developed is quickly radiated

3. Which of the following statements is correct during measurement of emf of cell by potentiometer ?
(1) No current flows through potentiometer wire upto position of null point
(2) At null point in any potentiometer experiment no current flows through whole of potentiometer wire.
(3) No current is drawn from cell when null point is obtained
(4) No current is drawn from bettery when null point is obtained

4. Which of the following statements is not wrong ?
(1) To increase sensitivity of a potentiometer increase current through potentiometer wire.
(2) To increase sensitivity increase external resistance in battery circuit connected to potentiometer.
(3) To increase sensitivity increase battery voltage
(4) To increase sensitivity increase emf of battery.

ANSWERS:

Q.	1	2	3	4
A.	1	2	3	4

EXPERIMENT # 19

AIM : To find the resistance of a galvanometer by half deflection method and find its figure of merit.

Apparatus : A weston type moving coil galvanometer, a cell, two resistance boxes, two one-way key, a voltmeter, connecting wires and a sand paper.

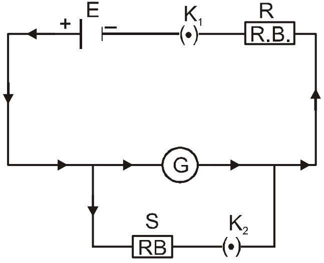


fig. Half deflection method

Theory : The connections for finding the resistance of a galvanometer by the half deflection method are shown in Fig. When the key, K_1 is closed, keeping the key K_2 open, the current I_g through the galvanometer is given by

$I_g = \frac{E}{R+G}$ where E = E.M.F. of the cell.

R = Resistance from the resistance box R.B.
G = Galvanometer resistance.

If θ is the deflection produced, then

$$\frac{E}{R+G} = k\theta \qquad .....(1)$$

If now the key K_2 is closed and the value of the shunt resistance S is adjusted so that the deflection is reduced to half of the first value, then current flowing through the galvanometer I'_g is given by

$$I'_g = \frac{E}{R+\frac{GS}{(G+S)}}\left(\frac{S}{G+S}\right) = \frac{k\theta}{2}$$

or $$I'_g = \frac{ES}{R(G+S)+GS} = \frac{k\theta}{2} \qquad .....(2)$$

Comparing (1) and (2), we get

$$(R + G)\ 2S = R(G + S) + GS$$

or $(R - S)\ G = RS$ or $G = \frac{RS}{R-S}$

If the value of R is very large as compared to S, then $\frac{R}{R-S}$ is nearly equal to unity. Hence

$$\boxed{G \approx S}$$

Figure of Merit :

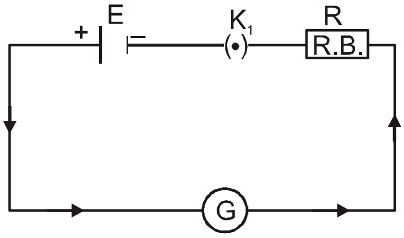
Figure of merit of a galvanometer is that much current sent through the galvanometer in order to produce a deflection of one division on the scale.

If k is the figure of merit of the galvanometer, and 'θ' be the number of divisions on the scale, then current (I_g) through the galvanometer is given by

$$\boxed{I_g = k\theta}$$

Procedure :

1. Draw a diagram showing the scheme of connections as in fig. and make the connections accordingly.
2. Check the connections and show the same to the teacher before passing current.
3. Introduce a high resistance R from the resistance box (R. B), close the key K_1 and adjust the value of R till the deflection is within scale and maximum. Note the deflection and the value of the resistance R.
4. Close the key K_2 and adjust the value of the shunt resistance S so that the deflection is reduced exactly to half the first value. Note this deflection and the value of the resistance S.
5. Repeat the experiment three times taking different deflections of the galvanometer.
6. **To find the figure of merit :**
   - (i) Find the e.m.f. of the cell by a voltmeter. See the positive of the cell the connected to the positive marked terminal of the voltmeter.
   - (ii) Connect the cell E, the galvanometer G, the resistance box R.B. and the key K_1 in series as shown in fig



take out 5,000 ohms plug from the resistance box and make all other plug tight. put in the key K_1 and adjust the value of the resistance R from the resistance box so that a deflection θ, near about 30 divisions is indicated in the galvanometer. Note the deflection θ in the galvanometer and also the value of the resistance R from the resistance box.

   - (iii) Adjust the value of R from the resistance box to get a deflection of about 20 divisions and again note the deflection and the resistance.
   - (iv) Increase the number of cells to two. Find the e.m.f and the value of the resistance R to get a deflection of about 30 and again about 20 divisions as in the previous step.

(i) Resistance of Galvanometer :

S.No.	Resistance R (ohms)	Deflection	Shunt Resistance S (ohms)	Half deflection (θ / 2)	Galvanometer Resistance G = RS / R – S (ohms)
1					
2					
3					
4					

Mean Value of G = ... ohms

(ii) Figure of merit :

Galvanometer resistance (G) = ...Ω

Number of division on the galvanometer scale = ...

S.No.	Number of cell (votls)	e.m.f. (E) of cell (volts)	Resistance in the resistance box (R) (ohms)	Deflection (θ)	Figure of Merit K = E / (R + G)
1	One				
2	One				
3	two				
4	two				

Precautions :

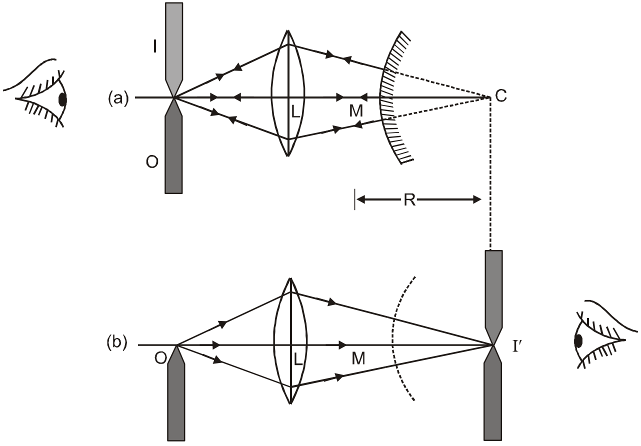
1. The value of ‘R’ should be large
2. To decrease the deflection, the shunt resistance should be decreased and vice-versa.
3. In this method it is assumed that the deflection is proportional to the current. This is possible only in a weston type moving coil galvanometer.
4. The connections must be tight and the ends of connecting wires should be cleaned.

EXPERIMENT # 20 (I)

AIM : To find the focal length of a convex mirror using a convex lens.

Apparatus : An optical bench with four uprights, a convex mirror, a convex lens, a knitting needle and a half meter scale

Theory : Suppose a convex lens L is interposed between a convex mirror M and an object needle O as shown in fig 15 (A). When the relative position of M, L and O are adjusted in such a way that there is no parallax between the object needle O and its image I, then in that position, the rays will fall normally on the convex mirror M. The rays which fall on the mirror normally should meet at the centre of curvature C of the mirror when produced (Fig.).



The distance MC gives the radius of curvature R. Half of the radius of curvature gives the focal length F of the mirror.

Now with out disturbing the positions of the object O and the lens L, the convex mirror is removed and another needle is placed in the position of the image I′ of the object O, formed by the lens L by using parallax method as shown in fig.

Measure MI′ Now f, = $\frac{R}{2}$ = $\frac{MI`}{2}$

Procedure

1. Mount the convex mirror M, a convex lens L and the object needle O on optical bench as shown in fig (a). Look for the inverted image of O through the system of the lens L and the mirror M by adjusting the position of O or L with respect to that of the mirror. When the inverted image is not obtained, a convex lens of larger focal length should be used.

2. Remove the parallax between the object needle O and its inverted image and note the position of O, L and M on the bench scale.
3. Remove the mirror M and do not disturb the lens L and O at all. Take another needle I' and place it on the other side of the lens (fig. (b)).
4. Take five sets of observations for different positions of O and L.
5. Determine the index correction between the mirror M and the image needle I'.

Observation and Calculations :

Index correction

Length of the knitting needle, y = ... cm

Observed distance with the needle between M and I' x = ... cm

∴ Index correction between M and I' = (y – x) = ... cm

Table Determination of Focal Length

No. of Obs	Position of Object needle O	Position of lens L	Position of Mirror M	Position of image needle I'	Observed distance, MI'
		(cm)	(cm)	(cm)	(cm)
1.					
2.					
3.					
4.					
5.					

Mean, M I' = ... cm

Corrected distance, M I' = ... cm

∴ $f = \frac{\text{Corrected } MI'}{2}$ =........ cm

Result :

Focal length of the given convex mirror =........ cm

=........ cm

Precautions :

1. The line joining the pole of the mirror, the centre of the lens L and the tip of the needle, should be parallel to the length of the optical bench.
2. The auxiliary lens L must have sufficiently large focal length.
3. The parallax should be removed tip to tip while removing the parallax, the eye should be kept at the least distance of distinct vision i.e., 25 cm away from the needle.
4. In the second part of the experiment i.e., after removing the mirror M, the position of L and O should not be disturbed at all.

EXPERIMENT # 20 (ii)

AIM

To find the focal length of a convex lens by plotting graphs between u and v and between 1/u and 1/v.

Apparatus

A convex lens of short focal length (say 15 to 20 cm.), two needles, three uprights, one clamp, an optical bench a half meter rod and a knitting needle.

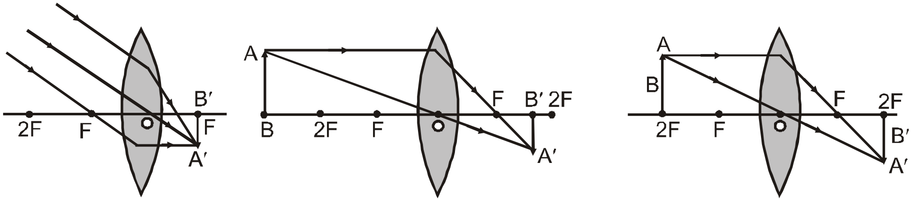
Theory

Position of the image formed by a convex lens depends upon the position of the object with respect to the lens fig.(1) below shows the different positions of the images formed by a convex lens for different object positions. The relation between u, v and f for a convex lens is $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

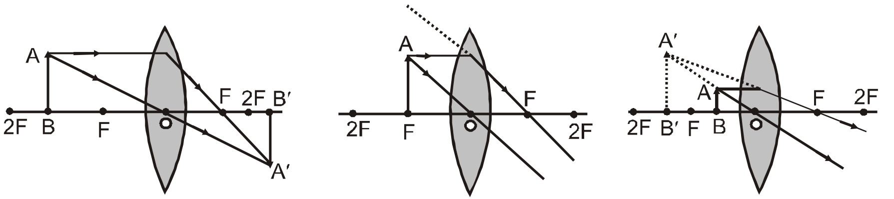
Procedure

1. Find the rough focal length of the given convex lens by focussing a sharp, clear and inverted image of a distance object on a white paper and measuring this distance between the lens and the white paper with a meter scale.
2. If the optical bench is provided with levelling screw, then level it using a spirit level.

3. Mount the convex lens (held in its holder) on the central upright of the optical bench. Also amount the two needles on the remaining two uprights. Arrange the tips of the needles at the same vertical height as the centre of the lens.



(a) Object at infinity (b) Object beyound 2F (c) Object at 2F



(d) Object between 2F and F (e) Object at F (f) Object between F and O

Fig. (1)

S. No.	Figure	Position of		Nature of the image	Size of the image
		the object	the image		
1.	(a)	At infiity	At F	Real and inverted	Highly diminshed
2.	(b)	Beyound 2F	Between F and 2F	Real and inverted	Diminished
3.	(c)	At 2 F	At 2 F	Real and inverted	Same size as object
4.	(d)	Between F and 2F	Beyound 2 F	Real and inverted	Magnified
5.	(e)	At F	At infinity	Real and inverted	Highly magnified (blurred)
6.	(f)	Between F and the lens	On the same side as object	Virtual and errect	Enlarged

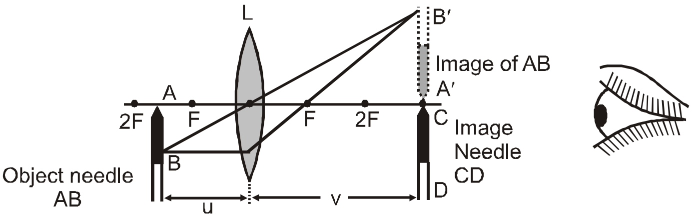


Fig. 2 Two pin method for determining the focal length f of a convex lens. (Arrangement on the optical branch)

4. Mark one needle as AB object needle and the other one CD as image needle and distinguish between them by rubbing tip of one of the needles with a piece of chalk or putting a paper flag on it.
5. Find the index corrections for u and v using a knitting needle.
6. Shift the position of the object needle AB to a distance greater than 2f from the lens. Look from the other side of the lens along its principal axis near the end of the bench. If the setting is correct, an inverted, real image A′B′ is seen. Now adjust the position of the second needle CD such that parallax between the image of the object needle and the image needle is removed. The position of the second needle is so adjusted that parallax is removed tip to tip as shown in fig.2.
7. Note the positions of the lenses, the object needle and the image needle on the bench scale and thus find the observed values of u and v. Apply index corrections to get the corrected values for u and v.
8. Repeat the above steps for 5 different positions of the object by placing it beyond 2F and between F and 2F. Record your observations as detailed below:

Observations :

(i) Approximate focal length of length of the lens f = ... cm

(ii) For index correction

Actual length of the knitting needle x = ... cm

(a) For u

1. Observed distance between the object needle and the lens
When knitting needle is inserted between them, y = ... cm
2. Index error for u, $e_1 = (y - x) =$ .... cm
3. Index correction for u,$- e_1 = (x - y) =$ .... cm

(b) For v

1. Observed distance between the image needle and the lens
   When knitting needle is inserted between them, z = ... cm
2. Index error for v, $e_1 = (z - x)$ = ... cm
3. Index correction for v, $- e_2 = (x - z)$ = ... cm

Table

No. of Obs.	Position of			Object distance u(cm)		Image distance v (cm)		1/u	1/v
	Lens at O (cm)	Object needle at A (cm)	Image needle at C (cm)	Observed (O– A) = u′ (cm)	Corrected u = u′ + (–ei) (cm)	Observed (C– O) = v′ (cm)	Corrected v = v′ + $(-e_2)$ (cm)	(cm^{-1})	(cm^{-1})
1. 2. 3. 4. 5. 6.									

9. Plotting Graphs and Calculations of f

(a) u – v Graph -

(i) Choose a suitable but the same scale to represent u along x-axis and v along y-axis Remember that u is negative and v is positive for a convex lens, according to the coordinate sign convention used these days

(ii) Plot the points for various sets of value of u and v from the observation table. The graph will be a rectangular hyperbola as shown in fig. 15(3).3

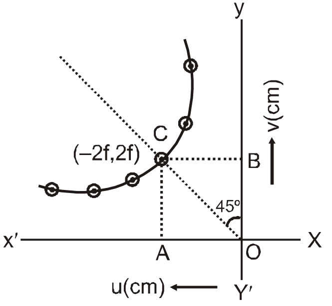


Fig. 15(C).3 Graph of u v/s v for a convex lens (rectangular hyperbola)

Find f from this graph : Draw a line OC bisecting the angle X′ OY and cutting the graph at point C. The coordinates of this point are (–2f, 2f) as shown in fig. Note the distances if the foot of the perpendiculars OA and OB respectively on X and Y axis. Half of these distances given the focal length of the convex lens. Thus

$$f = \frac{OA}{2} = ...cm$$

also $$f = \frac{OB}{2} = ...cm$$

take the mean of these two values of f.

(b) Calculation of f from graph between 1/u and 1/v : Choose a suitable but the same scale to represent $\frac{1}{u}$ along x-axis and $\frac{1}{v}$ along y-axis, taking O as the origin (0,0). Plot the graph between $\frac{1}{u}$ and $\frac{1}{v}$. The graph would be a straight line as shown in figure below making equal intercepts (OA and OB) on them measure AO and OB. Then

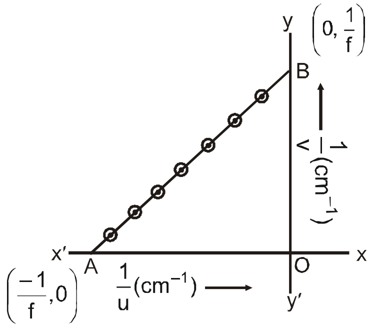


Fig. Graph of 1/u vs. 1/v for a convex lens

$f = \frac{1}{OA} = \frac{1}{OB}$ = ... cm

Result :

The focal length of the given convex lens as determined from the graph of

(i) (u, v) from fig. above =........... cm

(ii) $\left(\frac{1}{u}, \frac{1}{v}\right)$ fig. fig. above =........... cm

Precaution

1. The tips of the needles should be as high as the optical centre of the lens.
2. The uprights carrying the lens and the needles should not be shaky.
3. Parallax should be removed tip to tip.
4. The eye should be placed at such a position that the distance between the image needle and the eye is more than 25 cm.
5. The image and object needles should not be interchanged for different sets of observations.
6. A piece of chalk may be rubbed on the tip of the object needle or a paper flag put on it, so as to distinguish it from the image needle.

EXERCISE

1. By plotting $\frac{1}{v}$ versus $\frac{1}{u}$ focal length of a convex mirror can be found -

(1) No, as it forms a virtual image (2) Yes, only if scale is large
(3) Yes, only if scale is small (4) Yes, only if aperture is small

2. The focal length of which of the following can not be obtained directly-

(1) convex mirror and convex lens (2) convex mirror & concave lens
(3) convex lens and concave mirror (4) concave lens and concave mirror

3. Which of the following statement is false -

(1) The bench correction is always equal to the negative of bench error
(2) larger the distance between the two objects larger the magnitude of parallax
(3) parallax disappear if the positions of two objects coincide
(4) parallax can occur between any two objects

4. The focal length of a convex mirror is obtained by using a convex lens. The following observations are recorded during the experiment

object position = 5 cm
lens = 35.4 cm
Image = 93.8 cm
Mirror = 63.3 cm
Bench error = –0.1 cm

then the focal length of mirror will be -

(1) 7.5 (2) 8.4 cm (3) 15.3 cm (4) none of these

5. For spherical mirrors, graph plotted between $-\frac{1}{V}$ and $-\frac{1}{u}$ is -

(1) straight line with slope 1 (2) straight line with slope - 1
(3) Parabola (4) none

ANSWERS :

Q.	1	2	3	4	5
A.	1	2	2	3	2

EXPERIMENT # 21

AIM

To determine the angle of minimum deviation for a given glass prism by plotting a graph between the angle of incidence and angle of deviation and hence find the refractive index of the material of the prism.

APPARATUS

A drawing board, a sheet of paper, glass triangular prism, pins, a half meter scale, a graph paper and a protractor

THEORY :

Refraction Through a prism (angle of minimum deviation)

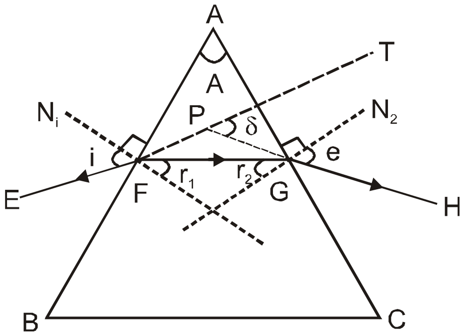


Figure 1 Refraction of light through a prism

Minimum Deviation - In (Fig 1), ABC represents the principal section of a glass prism. Let EF be a ray of light that is incident on the refracting face AB of the prism. The straight path FG represents the refracted ray through the prism and GH represents the emergent ray. FN_1 and GN_2 are drawn normal to the refracting faces AB and AC at points F and G respectively. Incident ray EF Produced to PT, as result of refraction through the prism ABC emerges along GH. The incident ray shown as EF (extruded as dotted line FPT) deviates and follows the path PGH. The angle δ is the angle between the incident ray EFPT (produced) shown dotted and the emergent ray GH (produced backwards) to meet EFT at the point P. This angle δ is known as the angle of deviation. the angle BAC of the prism (i.e., the angle between its two refracting faces) is called the angle of the prism and it is denoted by the letter 'A' It can be proved from simple geometrical considerations that

$$\angle A + \angle\delta = \angle i + \angle e \qquad ....(i)$$

and $A = r_1 + r_2$ ....(ii)

where i = angle of incidence

e = angle of emergence

r_1 = angle of refraction at face AB

r_2 = angle of refraction at face AC.

The relation (i) clearly shows that angle of deviation δ varies with the angle of incidence i.

The variation of angle δ with angle i is represented graphically in Fig 2

It is obvious from Fig 2. That the angle δ decreases with the increase in the value of i initially, till a particular value (i_0) of the angle of incidence is reached. For this value of angle of incidence, the corresponding value of the angle of deviation is minimum and it is denoted by the letter δ_m. This angle of deviation is called the angle of minimum deviation. When a prism is so placed with respect to the incident ray that the angle of deviation produced by it is minimum, then the prism is said to be in the position of minimum deviation. In this position, the following relation holds between the angles.

i.e., $\angle i = \angle e$ and $\angle r_1 = \angle r_2$ ....(iii)

In this position, the incident ray and the emergent ray are symmetrical with respect to the prism and the ray passes through the prism is parallel to its base. Refractive index of material of prism is given as,

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

Where δ_m is the angle of minimum deviation and A is the angle of the prism. Fig. 2 Variation of angle of deviation with angle of incidence for refraction through a prism

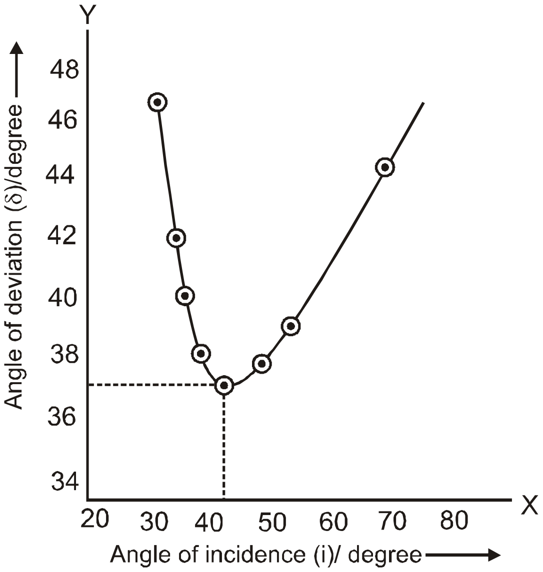


Fig. (2)

PROCEDURE :

1. Fix the sheet of the white paper on the drawing board with cello-tape or drawing pins.

2. Draw a straight line XY nearly at the centre of the sheet parallel to its length. Mark points marked as O at suitable spacing on this line XY and draw normal to the line XY at points O as shown in Fig. 3 Draw straight line PQ corresponding to the incident rays that are drawn at angle of incidence ranging from 30º to 60º, i.e., for angles of 30º, 40º, 50º and 60º using a protractor.

3. Place the prism with one of its refracting surfaces on the line XY and trace its boundary

ABC as shown in Fig. 3.

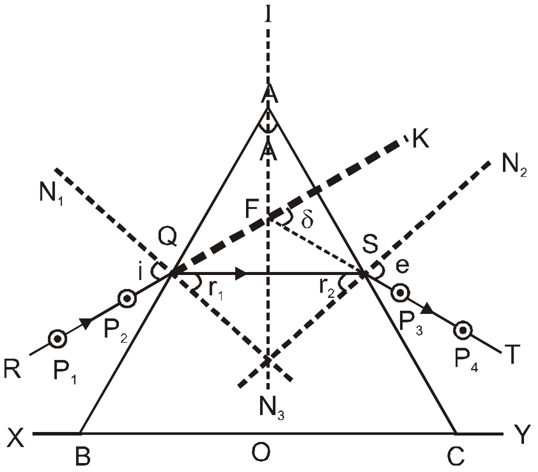


Fig. 3

4. Fix two pins P and Q about 8 cm apart on the incident ray line and view its image with your with your one eye closed from the face BC of the prism. Fix two pins R and S on the paper such that the tips of these pins and the tips of the images of the incident ray pins P and Q all lie on the same straight line.

5. Remove the pins R and S and encircle their pin pricks on the paper. Remove the pins P and Q and also encircle their pin pricks.

6. Join the points (i.e., pin pricks) S and R and produce it backwards to meet the incident ray PQ produced (shown by dotted lines). Thus RS is the emergent ray corresponding to the incident ray PQ. Draw arrow heads to show the direction of the rays.

7. Measure the angle of deviation δ with a protractor.
8. Repeat the steps (3 to 7) for different values of angle of incidence (Fig.3) and measure the corresponding angles of deviation δ. Take at least seven values of angle i ranging from 30º – 60º.

Measurement of refracting angle 'A' of the prism.

1. Draw a line XY on the drawing sheet as depicted in Fig.(4) below.

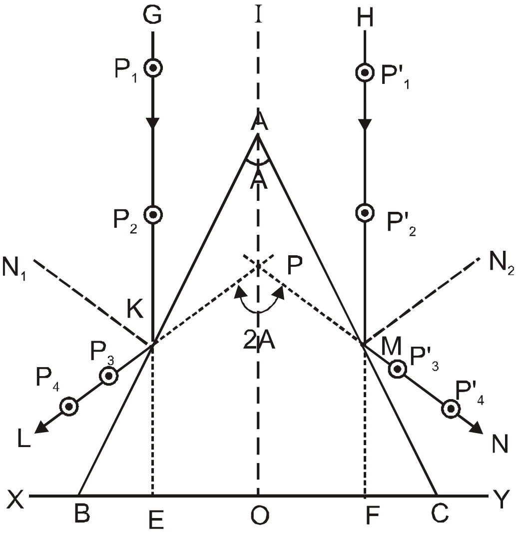


Fig. 4 Measurement of the refracting angle A of the prism.

2. Mark points O in the middle of XY and E and F on either side of O equidistant from E such that OE = OF (say 1 cm each).
3. Draw three vertical lines EG, OI and FH through E, O and F respectively, such that these are parallel to each other.
4. Place the prism with its refracting edge A on the line OI such that BC is along XY. The points E and F would be symmetric with respect to edges B and C.
5. Draw the boundary ABC of the face of prism touching the board.
6. Fix pins P_1 and P_2 vertically, 4 cm apart, observe their refection in the face AB and fix the pin P_3 such that the images of P_1, P_2 and P_3 are in a straight line. Fix another pin P_4 such that prick of P_4 is also in the same straight line. Join the pricks of P_3 and P_4 by line LK and product it backward. KL is reflected ray of incident ray GK.
7. Similarly locate NM by joining $P'_3 P'_4$ as the reflected ray of incident ray HM. Draw NM backward to meet the line LK product backward at point P. The point P should lie on the line OI if observations are correctly taken.
8. The angle LPN is equal to 2∠A (it can be proved geometrically from the figure). Measure the angle LPN and determine ∠A, the angle of prism.

OBSERVATIONS :

(i) Table for angle i and δ

Reading	i	δ
1	30°	
2	35°	
3	40°	
4	45°	
...	...	
8	60°	

(ii) Plotting the graph between ∠i and ∠δ Plot a graph between angles i and δ for various sets of values recorded in the observation table. The graph will be a curve as shown in Fig.2

(iii) For angle 'A' of prism

LPN = ...°= 2A

or Angle A =...........°

CALCULATIONS : Determine the angle of minimum deviation δ_m from the graph.

RESULT : The angle of deviation δ first decreases with the increase in the angle of incidence, attains a minimum value and then increases with further increase in the angle of incidence as indicated in the (δ—i) graph fig. 2

PERCAUTIONS :

1. A sharp pencil should be used for drawing the boundary of the prism.
2. The separation between the pins should not be less than 8 cm.
3. The angle of incidence should lie between 30° to 60°.
4. The same angle of prism should be used for all the observation. So an ink mark should be placed on it to distinguish it as the refracting angle A of the prism.
5. The pins should have sharp tips and fixed vertically and the pin pricks should be encircled immediately after they are removed.
6. Proper arrows should be drawn to indicate the incident, the refracted and the emergent rays.
7. A smooth curve practically passing through all the plotted points should be drawn.

EXPERIMENT # 22

AIM :

To determine the refractive index of a glass slab using a travelling microscope.

APPARATUS :

A piece of paper, a marker, glass slab, travelling microscope, lycopodium powder.

THEORY :

Refraction is a phenomenon of propagation of light from one transparent medium into the other medium such that light deviates from its original path. The ratio of velocity of light in the first medium to that in the second medium is called refractive index of second medium with respect to the first. Usually the first medium is air. The bottom surface of a vessel containing a refracting liquid appears to be raised, such that apparent depth is less than the real depth. Refractive index of refracting liquid is defined as the ratio of real depth to the apparent depth.

Mathematically, Refractive index $\mu = \dfrac{\text{real depth}}{\text{apparent depth}}$

For accurate measurements of depths, a travelling microscope [Fig. 17(a)] is used.

If reading of real depth at the bottom of the slab is r_1, if reading at cross due to refraction is r_2 and at the top of slab if reading is r_3, then

real depth = $r_3 — r_1$, and apparent depth = $r_3 — r_2$

Therefore , refractive index of glass (material of slab) $\mu = \dfrac{r_3 - r_1}{r_3 - r_2}$

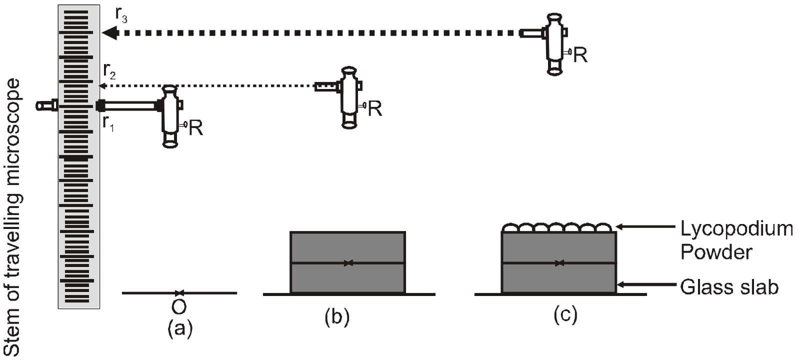


Fig. 17 Travelling microscope taking reading (a) at the cross mark (b) at the cross mark with slab placed on it (c) at powder sprinkled on the top of the slab

PROCEDURE :

For accurate measurement of depth, travelling microscope is used.

1. Note the number of divisions of vernier which coincide with number of full scale divisions.
2. Find the value of each main division and hence least count of the microscope scale as
   (1 M.S.D —V.S.D)
3. Set the microscope in its stand such that it is capable of sliding vertically up and down as the screw attached to rack and pinion is turned.
4. On a sheet of white paper, a cross and place it below the objective of the microscope.
5. Move the microscope very gently. Using the screw, focus the eye piece on cross mark and bring the cross in focus such that the cross wires, coincides with the marked cross on the paper. Note the reading of the microscope as r_1 [Fig. 17(a)]
6. Place the given glass slab on the cross mark. You would observe that the cross mark appears to be raised.
7. Move the microscope gradually and gently upward to bring the cross mark in focus and on cross of cross wires. Record the reading as r_2 [Fig. 17(b)]
8. Sprinkle some fine lycopodium powder on the glass slab and move the microscope upward till the powder particle come into focus. Record the reading on the scale as r_3 [Fig 17(c)]
9. Difference of readings r_3 and r_1 i.e $r_3 — r_1$ gives the real depth whereas $r_3—r_2$ gives the apparent depth.
10. Record your observations as follows and calculate the value of refractive index m.

OBSERVATIONS :

Least count of travelling microscope.

10 Vernier Scale Division = 9 Main Scale Divisions

(Scales may differ from instrument to instrument).

Value of one main scale division = 1mm i.e. 0.1 cm.

10 V.S.D =9 M.S.D (V.S.D. Vernier Scale Division, M.SD. Main Scale Divisions)

$$\therefore \quad 1 \quad \text{V.S.D} = \frac{9}{10} \quad \text{M.S.D}$$

$$\text{L.C} = 1 \text{ M.S.D} — 1\text{V.S.D} = 1\text{M.S.D} — \frac{9}{10} \quad \text{M.S.D} \quad = \quad \frac{1}{10} \quad \text{M.S.D} \quad \text{or} \quad \frac{1}{10} \times 0.1\text{cm} = \ 0.01\text{cm}$$

No. of Obs.	Reading of microscope focussed on								
	Cross mark without slab			Cross mark with slab placed on it			Powder sprinkled on top of slab		
	Main scale reding (N) (cm)	Vernier div. Coinciding n	Reading N + n × L, C. =r_1	Main scale reading (N)	Vernier div. Coinciding n	Reading N + n × L, C. = r_2	Main scale reading (N) (cm)	Vernier div. Coinciding n	Reading N + n × L, C. = r_3 (cm)
1.									
2.									
3.									

Mean values r_1 =.......cm, r_2 =........r_3=......cm

CALCULATIONS :

Real depth = $d_r = r_3 – r_1$ =....... cm.

Apparent depth = $d_a = r_3 – r_2$ =....... cm.

$$\text{refractive index } \mu = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{d_r}{d_a} \quad = ...$$

PERCAUTIONS :

1. Least count of the scale of travelling microscope should be carefully calculated.
2. Microscope once focussed on the cross mark, the focussing should not be disturbed throughout the experiment.
3. Eye piece should be adjusted such that cross wires are distinctly seen.
4. Cross wires, cross should be set on the ink cross mark on the paper.
5. Only a thin latyer of powder should be spread on the top of slab
6. Express your result upto significant figures keeping in view the least count of instrument.

Result

The refractive index of the glass slab by using travelling microscope is determined as ....

EXPERIMENT # 23

AIM

To study the static and dynamic curves of a p–n junction diode in forward bias and to determine its static and dynamic resistances

APPARATUS

A p-n junction diode, a 3V battery, a high resistance rheostat, 0-3 volt voltmeter, one milliammeter, one way key and connecting wires.

THEORY

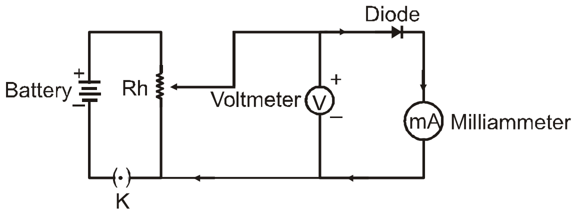
When a junction diode is forward biased, a forward current is produced which increases with increase in bias voltage. This increase is not proportional.

The ratio of forward bias voltage (V) and forward current (I) is called the static resistance of semiconductor diode, i.e., $R = \frac{V_F}{I_F}$.

In case of a varying bias voltage and varying forward current, the ratio of change in forward bias voltage (ΔV) and corresponding change in forward current (ΔI) is called the dynamic resistance $\left(r = \frac{\Delta V_F}{\Delta I_F}\right)$.

To find the static and dynamic resistance of semiconductor diode, a graph has to be plotted between forward bias voltage (V) and forward bias current (I). This graph is called the characteristic curve of semiconductor diode.

PROCEDURE :



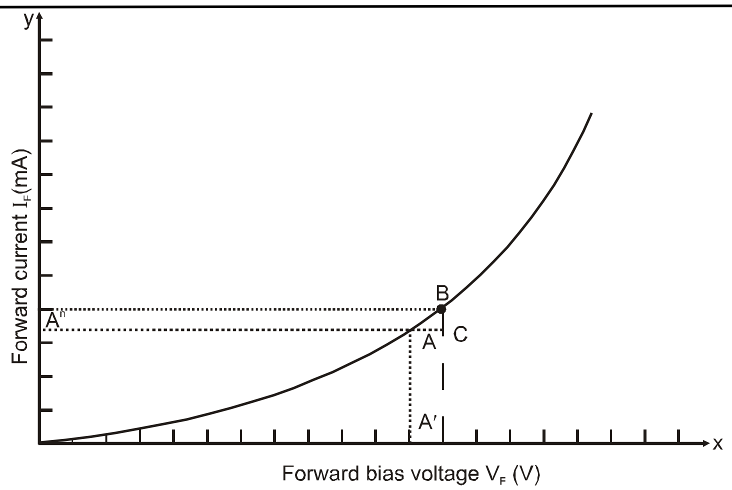
(a) Make the connections as shown in figure.
(b) Keep the moving contact of the rheostat to the minimum and insert the key K.
Voltmeter and milliammeter will show a zero reading.
(c) Move the contact towards the positive to apply the forward bias voltage V = 0.1 V.
The current remain zero
(d) Increase the forward bias voltage to 0.3 V in steps. The current will still be zero. (This is due to the junction potential barrier of 0.3 V).
(e) Increase V to 0.4 V. Record the current.
(f) Increase V in step of 0.2 and note the corresponding current.
(g) At V = 2.4 V. The current increases suddenly. This represents the forward breakdown stage.
(h) Draw a graph of I on y-axis and V on x-axis. The graph will be as shown in figure

Record of Readings

(i) Least count of voltmeter = ...V   Zero error of mA = ...mV
(ii) Least count of milliammeter = ...mA   Zero error of voltmeter = ...V

S.No.	Forward bias voltage V_F(V)	Forward bias current I_F(mA)
1	0	0
2	:	0
3	:	0
4	:	:
:	:	:
:	:	:
:	:	:
:	:	:

Graph :



Calculations

(i) For static resistance (R)

$$R = \frac{V_F}{I_F}$$

From the graph $R = \frac{OA'}{OA''}$ = ..., ohm

Diode is ...... (specify the code)

(ii) For dynamic resistance (r)

$$r = \frac{\Delta V_F}{\Delta I_F}$$

$\therefore$ From the graph $r = \frac{AC}{BC}$ ohms

Result

(i) The static resistance of the given semiconductor diode = ... ohm

(ii) The dynamic resistance of the given semiconductor diode = ... ohm

Precautions

(i) Make all connections neat, clean and tight

(ii) Key should be used in circuit and opened when the circuit is not in use

(iii) Avoid applying forward bias voltage beyond breakdown

Possible sources of errors

(i) The connection may not be tight (ii) The junction diode may be faulty

EXPERIMENT # 24

AIM

To draw the characteristic curves of a zener diode and to determine its reverse breakdown voltage.

APPARATUS

A zener diode (with reverse breakdown voltage of 6 V), a ten volt battery, a rheostat, two voltmeters (range 0, 10 V), one milliammeter, one 20Ω resistance, one way key, connecting wires.

THEORY :

Zener diode is a semiconductor diode in which the n-type sections are heavily doped, This heavy doping results in a low value of reverse breakdown voltage.

The reverse breakdown voltage of Zener diode is called Zener voltage (V_z). The reverse current that results after the breakdown is called zener current (I_z).

V_i = Input voltage

V_0 = Output voltage

R_i = Input resistance

I_i = Input current

I_z = Zener diode current

I_L = Load current

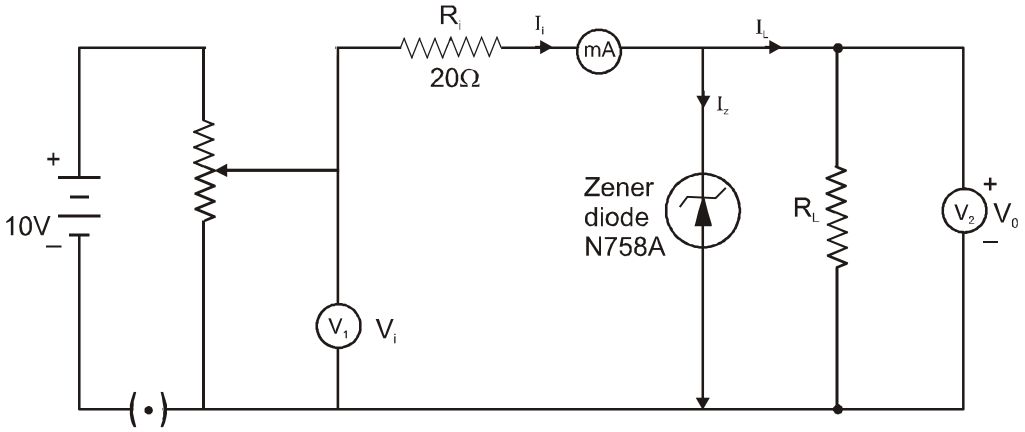
$I_L = I_i - I_z$

$V_0 = V_i - R_i I_i$

$V_0 = R_L I_L$

Initially as V_i increases, I_i increases hence V_0 increases linearly. At break-down, increase of V_i increases I_i by large amount, so that $V_0 = V_i - R_iI_i$ becomes constant.

This constant value of V_0 Which is the reverse breakdown voltage, is called zener voltage.



PROCEDURE :

(a) Make the connections as shown in figure above making sense that zener diode is reverse biased

(b) Bring the moving contact to rheostat to the minimum and insert the key K. Voltmeter and ammeter will read zero

(c) Move the contact a little towards positive end to apply some reverse bias voltage (V_i). Milliammeter reading remains zero.

(d) As V_i is further increased, I_i starts increasing and V_0 becomes less than V_i. Note the values of V_i V_0 and I_i.

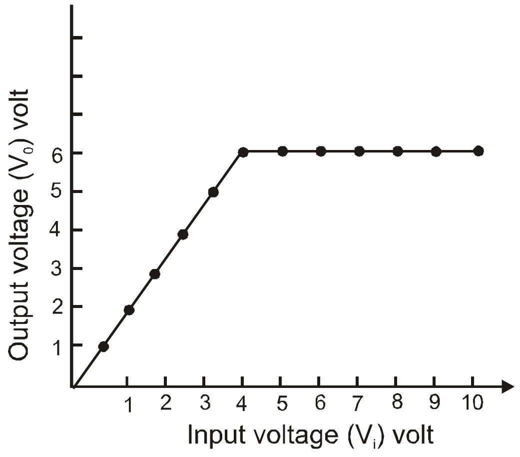
(e) Keep increasing V_i in small steps of 0.5 V. Note the corresponding values of I_i and V_0

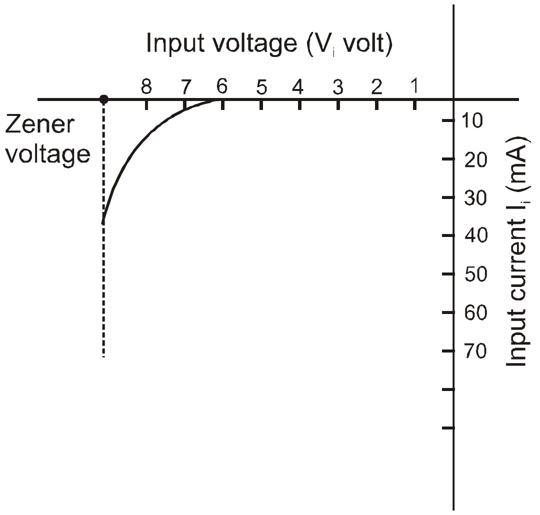
(f) At one stage as V_i is increased, I_i increases by large amount and V_0 does not increase. This is reverse break down situation.

(g) As V_i is increased further, I_i will increase keeping V_0 constant. Record your observation in tabular column

(h) Draw graph of output voltage V_0 along y-axis and input voltage along x-axis. The graph will be as shown in figure.

(i) Draw graph of input current along y-axis and input voltage along x-axis. The graph will be as shown in figure





RECORD OF READINGS

Least count of voltmeter V_1 = ...V

Least count of voltmeter V_2 = ...V

Least count of milli-ammeter = ...mA

Serial No.	Input voltage V_i (V)	Input current I_i (mA)	Output voltage V_0 (V)
1	0	0	0
2	0.5	:	:
3	1	:	:
4	1.5	:	:
5	:	:	:
6	:	:	:

RESULT :

The Breakdown voltage of given Zener diode is 6 volts.

PERCAUTIONS :

(i) Use voltmeter and milliammeter of suitable range.

(ii) Connect the zener diode p-n junction in reverse bias.

(iii) The key should be kept open when the circuit is not in use.

EXPERIMENT # 25

AIM

To study the characteristics of a common emitter n-p-n or p-n-p transistor and to find out the values of current and voltage gains.

REQUIREMENTS

An n-p-n transistor, a 3 V battery, a 30 V battery, two rehostats, one 0–3 V voltmeter, one 0–30 V voltmeter, one 0–500 μA microammeter, one 0–50 mA milliammeter, two one way keys, connecting wires.

THEORY :

A transistor can be considered as a thin wafer of one type of semiconductor between two layers of another type. A npn transistor has one p-type wafer in between two n-type. Similarly p-n-p the transistor has one n-type wafer between two p-type.

In a common emitter circuit, the emitter base makes the input section and the collector base the output section, with emitter base junction, forward bise and the collector base junction, reverse biased. The resistance offered by the emitter base junction is called input resistance R_i and has a low value. The resistance offered by the collector base junction is called output resistance R_0 and has high value. Due to the high output resistance, a high resistance can be used as a load resistance.

The ratio $\frac{R_L}{R_i}$ or $\frac{R_0}{R_i}$ measures the resistance gain of the common emitter transistor.

The ratio of change in collector current to the corresponding change in base current, measures the current gain in common emitter transistor and is represented by β.

$$\beta = \frac{\Delta I_c}{\Delta I_b}$$

The product of current gain and the resistance gain measures the voltage gain of the common emitter transistor.

FORMULA USED

Input resistance, $R_i = \frac{\Delta I_b}{\Delta I_b}$

Output resistance, $R_0 = \frac{\Delta V_c}{\Delta I_c}$

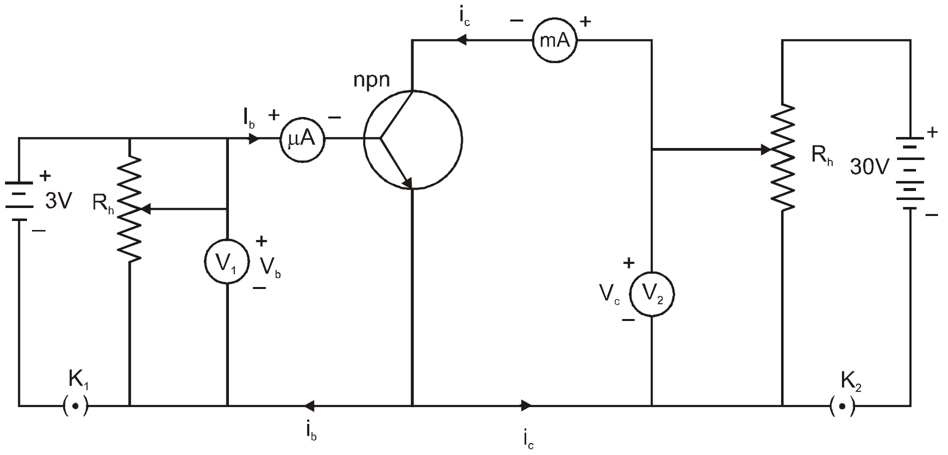
Resistance gain, $= \frac{R_0}{R_i}$

Current gain, $\beta = \frac{\Delta I_c}{\Delta I_b}$

Voltage gain = Current gain × Resistance gain

i.e., $A_V = \beta \frac{R_0}{R_i}$

CIRCUIT DIAGRAM



PROCEDURE

(a) Make circuit diagram as shown in given figure (A)

(b) Drag the moveable contact of rheostat to the minimum so that voltmeters, V_1 and V_2 read zero volt

FOR INPUT CHARACTERISTICS

(c) Apply the forward bias voltage at the emitter base junction note the base voltage (V_b) and the base current (I_b)

(d) Keep increasing V_b till I_b rises suddenly

(e) Make collector voltage 10 V and repeat the above steps

(f) Now make collector voltage 20 V, 30 V and repeat the above steps. Note the value of V_b and I_b in each case

FOR OUTPUT CHARACTERISTICS

(g) Make all reading zero. Keep the collector voltage zero.

(h) Make base current I_b = 100 μA by adjusting the base voltage. You will be able to read some collector current even though the collector voltage is zero.

(i) Make the collector voltage 10V, 20V, 30V, etc. and note corresponding collector currents. Record your observations in the tabular form as given below.

(j) Make the current I_b equal to 200 μA, note the values of I_c corresponding to the different values of V_c

RECORD OF REOBSERVATIONS

Least count of voltmeter, V_1 = ...V

Least count of voltmeter, V_2 = ...V

Least count of milliammeter = ...mA

Least count of microammeter = ...μA

Table–1 For base voltage and base current

Sr.No.	Base voltage(V_b) (V)	Base current I_b (μA)			
		V = 0 V	V = 10 V	V = 20 V	V = 30 V
1					
2					
3					
4					
5					

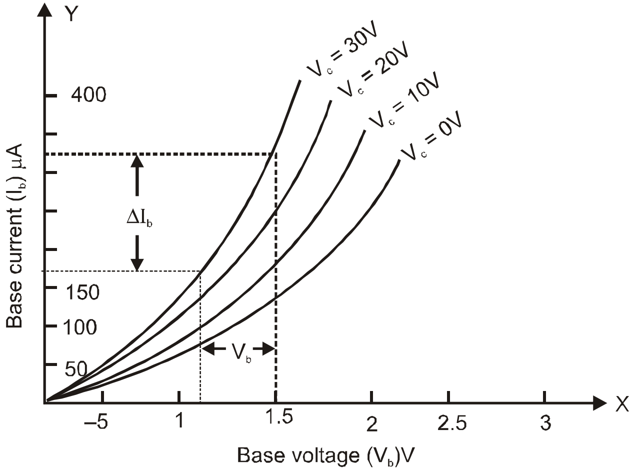
Table–2 For collector voltage and collector current

Sr.No.	Collector voltage V_c (V)	Collector current I_C (mA)			
		V = 0 V	V = 10 V	V = 20 V	V = 30 V
1					
2					
3					
4					
5					

GRAPHS

I (For Input Characteristics)

Draw a graph of base voltage (V_b) on the x-axis and base current (I_b) on the y-axis from table no. 1. The graph will be as shown in figure.

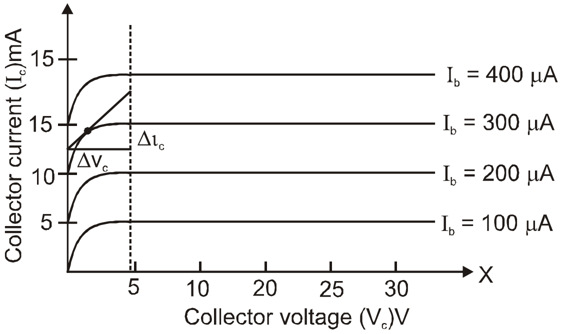


The slope of the graph gives the value of $\frac{\Delta I_c}{\Delta V_c}$ and its reciprocal gives the value of input resistance R_1.

$R_1 = \frac{\Delta V_b}{\Delta I_b}$ = ...ohms

II For Output Characteristics

Draw the graph between collector voltage V_c and colletor current I_c for 10 mA base current I_b taking V_c along x-axis and I_c along y-axis from table no.2. The graph will be as shown in figure.

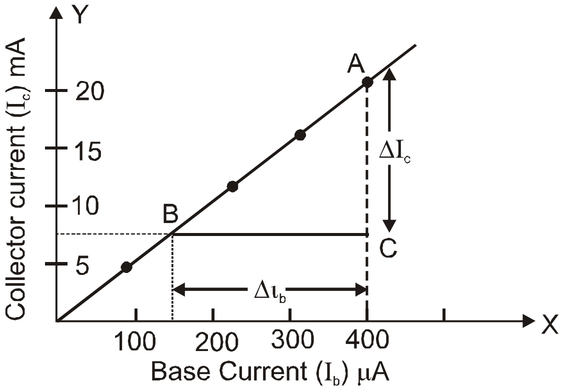


From the graph the slope gives the value of $\frac{\Delta I_c}{\Delta V_c}$ and its reciprocal gives the output resistance.

$R_0 = \frac{\Delta V_c}{\Delta I_c}$ = ...ohm

III For Calculation of Current Gain

Plot a graph of base current (I_b) on x-axis and collector current I_c on y-axis. The graph will be as shown in figure.



The slope of the graph will give the value of $\frac{\Delta I_c}{\Delta I_b}$ which is the value of current gain (β).

AC = ...mA
= ....A
BC = ...μA
= ....A

$\beta = \frac{AC}{BC}$ = ...

For calculation of voltage gain (A_v)

Voltage gain = Current gain × Resistance gain

$A_v = \beta \times \frac{R_o}{R_i}$

RESULT :

For the given common emitter transistor, Current gain β = ...
Votage gain A_v = ...

PERCAUTIONS :

(i) Use voltmeter and milliammeter of suitable range
(ii) The key should be kept open when the circuit is not in use

POSSIBLE SOURCES OF ERROR :

(i) Voltmeter and ammeter may have a zero error
(ii) All the connections may not be tight

EXPERIMENT # 26

AIM

To identify a diode, a L.E.D., a transitor, a resistor and a capacitor from a mixed collection of such item

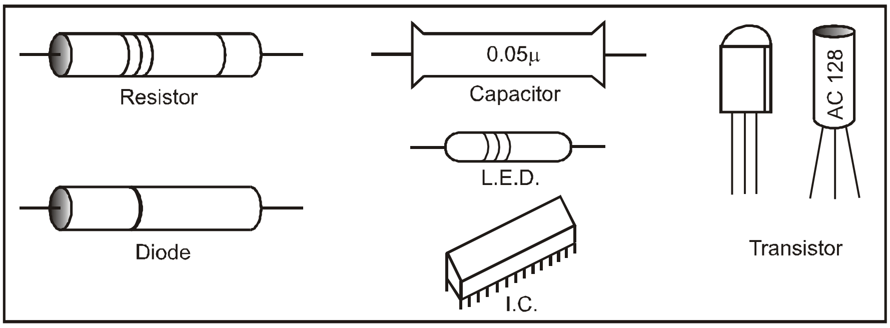
APPARATIUS

A multimeter and a collection of a junction diode, L.E.D., a transister, a resistor, a capacitor and integrated circuit.

THEORY :

For identification of different items, we have to consider both, their physical appearance and working

1. An IC (integrated circuit) is in the form of a chip (with flat back) and has multiples terminals, say 8 or more. Therefore, it can easily be identified.
2. A transistor it a three terminal device and can be sorted out just by apperance
3. A resistor, a capacitor, a diode and an LED are two terminal devices. For identifying these we use the following facts :
   - **(i)** A diode is a two terminal device that conducts only when it is forward biased
   - **(ii)** An LED is a light emitting diode. It is also a two terminal device which conducts and emits light only when it is forward biased.
   - **(iii)** A Resistor is a two terminal device. It conduct both with d.c. voltage and a.c. voltage. Further, a resistor conducts equally even when teminals of d.c. battery are reversed.
   - **(iv)** A capacitor is a two terminal device which does not conduct with d.c. voltage applies either way. But, conducts with a.c. Voltage



PROCEDURE :

1. Looks at the given mixture of various components of electrical circuit and pick up the one having more than three terminals. The number of terminals may be 8, 10, 14 or 16. This component will have a flat face. This component will be the integrated circuit i.e., IC.
2. Now find out the component having three legs or terminals. It will be a transistor
3. The component having two legs may either be a junction or capacitor or resistor or a light emitting diode. These items can be distinguished from each other by using a multimeter as an ohmmeter.
4. Touch the probes to the two ends of each item and observe the deflection on the resistance scale. After this, interchange the two probes and again observe the deflection
5. **(i)** If the same constant deflection is observed in the two cases (before and after interchanging the probes), the item under observation is a resistor.
   - **(ii)** If unequal deflections are observed, it is a junction diode.
   - **(iii)** If unequal deflections are observed in the two cases along with emission of light in the case when deflection is large, the item under observation is an LED
   - **(iv)** On touching the probes, if a large deflection is observed, which then gradually decrease to zero the item under observation is a capacitor.

   In case the capacity of the capacitor is of the order of picofarad, then the deflection will become zero within no time.

RESULT :

When the item is observed physically

S.No.	Number of legs (or pins) of the item	Inference
1	More than three	The item is an IC
2	Three	The item is a transistor
3	Two	Junction diode, L.E.D., resistor or capacitor

With multimeter as an ohmmeter :

S.No.	Possible deflection before and after interchanging the probes	Inference
1	Same constant deflection	The item is a resistor
2	Small deflection in one case and large deflection in the other	The item is a junction diode
3	Small deflection in one case and large deflection in the other along with emission of light	The item is an L.E.D
4	Large deflection, which gradually falls to zero	The item is a capacitor of small capacity

PERCAUTIONS :

Observe all those precautions which were related to multimeter and explained at the end of multimeter.

EXPERIMENT # 27

AIM

Use of multimeter to :

(a) Identify base of transistor.
(b) Distinguish between N-P-N and P-N-P type transistor.
(c) Identify terminals of an IC
(d) See the unidirectional flow of current in case of a diode and LED.
(e) Check whether the given electronic component (e.g., diode, transistor or IC) is in working order.

APPARATUS

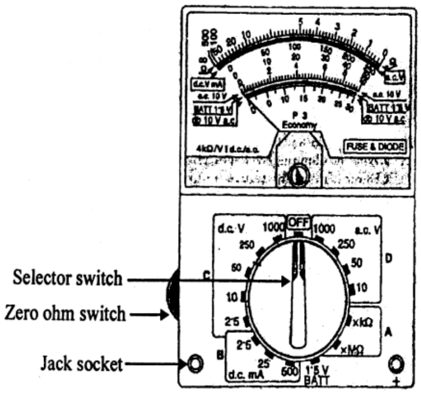
A multimeter, P-N-P transistor, N-P-N transistor, an IC, junction diode, L.E.D., etc

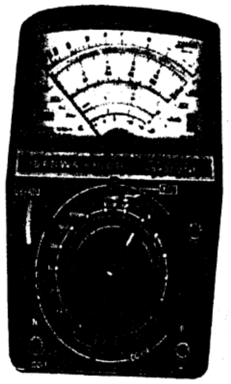
THEORY :

Multimeter : It is an electrical instrument which can be used to measure all the three electrical quantities i.e., electrical resistance, current (a.c. and d.c.) and voltage (direct and alternating). Since it can measure Ampere (A) (unit of current), Volt (V) (Unit of e.m.f) and Ohm (unit of resistance), that is why also called as AVO meter. In this single instrument will replace the voltmeter and Ammeter.

CONSTRUCTION

The most commonly used form of multimeter is shown in figure, which is basically a pointer type moving coil galvanometer. The pointer of the multimeter can move over its dial, which is marked in resistance, current and voltage scales of different ranges. The zeros of all the scales are on the extreme left, except that of resistance scale, whose zero is on the extreme right. A dry cell of 1.5 V is provided inside it. When the multimeter is used as an ohmmeter, the dry cell comes in closed circuit.





1. **Circuit jacks :** In the multimeter shown in fig. there are two circuit jacks, one each at the extreme corners of the bottom of the multimeter. The jack at right corner is marked positive (+), while the other at left corner is marked negative (–). In certain multimeters, the positive circuit jack is not

provided but circuit jacks are provided in front of all the markings in regions A, B, C and D. When the range switch is turned in any region, then all the circuit jacks in that region act as the positive circuit jacks.

Two testing leads (generally one black and the other red in colour) are provided with a multimeter. Each lead carries two probes (One smaller than the other) as its two ends. The smaller probe of red lead is inserted in jack marked positive, while the smaller probe of black lead is inserted in jack marked negative.

It may be pointed out that the battery cell remains connected to the meter only, when the range switch is in region A. Further, actually the positive of the battery cell is connected to the negative circuit jack and the negative of the battery cell is connected to the positive circuit jack.

2. **Zero ohm switch :** This is provided at the left side of the multimeter. However, in some multimeters, the zero ohm switch is also provided on its front panel. This switch is set, while measuring a resistance. In order to set this switch, the smaller probes are inserted in the two jacks and the bigger probes are short circuited. This switch is worked, till the pointer comes to zero mark, which lies at the right end resistance scale. The section of multimeter as different types of meters is explained below

(i) **Ammeter :** The galvanometer gets converted into d.c. ammeter when range switch lies in the region B of the multimeter panel. When range switch is in region B, it can be used as d.c. ammeter of range 0 to 0.25 mA, 0 to 25 mA and 0 to 500 mA by bringing the knob in front of the desired mark when the range switch is in the region B, a very small resistance called shunt resistance whose value is different range, gets connected in parallel to the galvanometer. In this position, the battery cell is cut off from the meter.

(ii) **Voltmeter :** Multimeter can be used to measure both direct and alternating voltage

(a) **d.c. Voltmeter :** The galvanometer gets converted into d.c. voltmeter when the range switch lies in the region C of the multimeter panel. With different position of range switch in this region, it can be used as d.c. voltmeter of ranges 0-0.25 V, 0-2.5 V 0-50 V and 0 to 1000 volts. When the ranges switch is in region C, a high resistance, whose value depends upon the range selected, gets connected in series to the galvanometer. In this case the battery cell is not in circuit with the meter.

(b) **a.c. Voltmeter :** The galvanometer gets converted into a.c. voltmeter when the range switch is turned and it lies in the region D of the multimeter panel. With the different positions of the range switch in this region, multimeter can be used as a.c. voltmeter of range 0 to 10 V, 50 V, 250 V and 1000 V. A solid state crystal diode rectifier is incorporated in the circuit so as to use it for a.c. measuement.

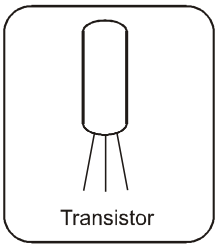
(iii) **ohm-meter :** When the knob in the lower part of the multimeter i.e., the range switch is turned so as to be in the region A of the multimeter panel, the galvanometer gets converted into a resistance meter. When range switch is in front of a small black mark against ×KΩ mark, it works as resistance meter of range 0 to 50 KΩ and when knob is in front of × MΩ mark, it works as a resistance meter of range 0 to 50 × 10^6 ohm. When the range switch is in region A, a battery cell of 0.5 V and suitable resistor whose value is different for × KΩ and × MΩ marks, gets connected in series to the galvanometer.

PROCEDURE

(1) Take a multimeter and plug in the smaller probse of the testing leads into jack sockets marked as positive (+) and negative (–).

(2) Turn the selector switch in the region A, so that it points towards the small black mark against ×MΩ or ×KΩ. Adjust the zero ohm switch till the pointer of he multimeter comes to zero mark of the resistance scale (on exterme right), when the two probes are short ciruited.

(a) To identify the base of transistor :



(3) In most of the cases the central lead of a transistor is base lead but in some cases it may not be so. In order to identify the base lead, the two probes to the extreme two legs of the transistor. Note the resistance of transistor between these two legs. Now, interchange the probes touching the two extreme legs of the transistor again and note the resistance of transistor between these legs.

If in both cases the resistance of transistor is high, then the central leg is base of transistor and the two exterme legs are emitter and collector, because emitter collector junction offers high resistance in both direction.

But if the resistance is high in one direction and low in the other direction, then one of the extreme legs is base of transistor.

(4) To find, which of the extreme legs is base, touch one probe to the other to the central leg. Note the resistance between these two legs. Now interchange the two probes and again note the resistance. In case the resistance is low in one direction and high in other direction, then the left leg is base otherwise the right leg is base of the transistor.

(b) To find whether the given transistor is N-P-N or P-N-P :

(5) First find the base of transistor as explained above

(6) Now touch the probe of black wire to the base and the probe of the red wire to any one of the remaining two legs and note the resistance from the multimeter.

(7) In case the resistance of the transistor is low, it is an N-P-N transistor, otherwise P-N-P

(c) Flow of current in junction diode :

(8) Touch the two probes of the multimeter with the two legs of the diode and note the value of resistance. Now interchange the two probes and note the resistance. If in one case resistance is low and in other case resistance is high, then it shows the unidirection flow of current through a junction diode.

Flow of current in a L.E.D.

(9) Touch the two probes of the multimeter with the two legs of the L.E.D. and note the value of resistance. Now interchange the two probes and note the resistance. If in one case resistance is low and in other case resistance is high, also the L.E.D. will glow by emitting light when its resistance is low, then it shows the unidirectional flow of current through a L.E.D.

(d) Check whether the given diode or transistor is in working order :

(10) Set the multimeter as resistance meter as explained in steps 1 and 2. Now touch the probes with the two legs of the junction diode and note the value of resistance. Now interchange the probes and again note the resistance. If in one case resistance is low and in the second case resistance is high, then the junction diode is in working order. If in both cases the resistance is then the junction diode is spoilt.

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(11) Confirm the base, emitter and collector of the given transistor. Find the resistance of E-B junction and B-C junction using the multimeter, keeping in mind either the given transistor is P-N-P or N-P-N. again find the resistance of E-B junction and B-C junction by interchanging the probes. If in both directions the resistances of both the junctions come to be low, then the given transistor is spoiled if in one direction resistance is low while in other direction the resistance is high, show that the transistor is in working order.

PERCAUTIONS :

The following precautions should be observed while using a multimeter.

(1) The electrical quantity to be measured should be confirmed each time before starting the measurement otherwise the multimeter may get damaged if one starts measuring voltage and the selector switch is in the region of current or resistance etc.

(2) The instrument should not be exposed to high temperature and moisture for long time, otherwise it will get damaged.

(3) When order of the magnitude of voltage or current is not known, measurement is always started on the highest range and then adequate lower range is selected in gradual steps.

(4) while handling high voltages, probes should be held from their insulating covers.

(5) Due to high sensitivity of the instruments, it should not be given big shocks/vibrations.

(6) Batteries out of life should be immediately replaced by new ones. Otherwise components inside will get corroded by leakage of the electrolyte.