PRACTICAL PHYSICS

SIGNIFICANT FIGURES

The *significant figures* (SF) in a measurement are the figures or digits that are known with certainty plus one that is uncertain. Significant figures in a measured value of a physical quantity tell the number of digits in which we have confidence. Larger the number of significant figures obtained in a measurement, greater is its accuracy and vice versa.

Rules to find out the number of significant figures :

- **I Rule** : All the non-zero digits are significant e.g. 1984 has 4 SF.
- **II Rule** : All the zeros between two non-zero digits are significant. e.g. 10806 has 5 SF.
- **III Rule** : All the zeros to the left of first non-zero digit are not significant. e.g.00108 has 3 SF.
- **IV Rule** : If the number is less than 1, zeros on the right of the decimal point but to the left of the first non-zero digit are not significant. e.g. 0.002308 has 4 SF.
- **V Rule** : The trailing zeros (zero to the right of the last non-zero digit) in a number with a decimal point are significant. e.g. 01.080 has 4 SF.
- **VI Rule** : When the number is expressed in exponential form, the exponential term does not affect the number of S.F. For example in x =12.3=1.23 10^1=0.123 10^2 =0.0123 10^3=123 10^{-1} each term has 3 SF only.
- **VII Rule** : In a number without decimal, zeros to the right of non-zero digit are not significant, but when same value is recorded on the basis of actual experiment, they becomes significant.

  Ex. 15600 has 3 SF but 15600 mA has 5 SF

GOLDEN KEY POINTS

- To avoid the confusion regarding the trailing zeros of the numbers without the decimal point the best way is to report every measurement in *scientific notation* (in the power of 10). In this notation every number is expressed in the form a 10^b, where a is the base number between 1 and 10 and b is any positive or negative exponent of 10. The base number (a) is written in decimal form with the decimal after the first digit. While counting the number of SF only base number is considered (Rule VI).
- The *change in the unit of measurement of a quantity does not affect the number of SF.*

  For example in 2.308 cm = 23.08 mm = 0.02308 m each term has 4 SF.

Example

Write down the number of significant figures in the following :

(a) 165 — 3SF (following rule I)

(b) 2.05 — 3 SF (following rules I & II)

(c) 34.000 m — 5 SF (following rules I & V)

(d) 0.005 — 1 SF (following rules I & IV)

(e) 0.02340 N m^{-1} — 4 SF (following rules I, IV & V)

ROUNDING OFF

To represent the result of any computation containing more than one uncertain digit, it is *rounded off* to appropriate number of significant figures.

Rules for rounding off the numbers :

- **I Rule** : If the digit to be rounded off is more than 5, then the preceding digit is increased by one. e.g. 6.87≈ 6.9
- **II Rule** : If the digit to be rounded off is less than 5, than the preceding digit is unaffected and is left unchanged. e.g. 3.94 ≈ 3.9
- **III Rule** : If the digit to be rounded off is 5 then the preceding digit is increased by one if it is odd and is left unchanged if it is even. e.g. 14.35 ≈ 14.4 and 14.45 ≈ 14.4

Example

The following values can be rounded off to four significant figures as follows :

(a) 36.879 ≈ 36.88 (∵ 9 > 5 ∴7 is increased by one *i.e. I Rule*)

(b) 1.0084 ≈ 1.008 (∵ 4 < 5 ∴8 is left unchanged *i.e. II Rule*)

(c) 11.115 ≈ 11.12 (∵ last 1 is odd it is increased by one *i.e. III Rule*)

(d) 11.1250 ≈ 11.12 (∵ 2 is even it is left unchanged *i.e. III Rule*)

(e) 11.1251 ≈ 11.13 (∵ 51 > 50 ∴ 2 is increased by one *i.e. I Rule*)

- If one digit is rounded off then compare with 5.
- If two digits rounded off then compare with 50.

  Ex. 2.360 → 2.4 , 2.350 → 2.4 & 2.250 →2.2
- If three digits rounded off then compare with 500.

Rules for arithmetical operations with significant figures

- **Rule I** : In addition or subtraction the number of decimal places in the result should be equal to the number of decimal places of that term in the operation which contain lesser number of decimal places. e.g. 12.587 – 12.5 = 0.087 = 0.1 (∵ second term contain lesser i.e. one decimal place)
- **Rule II** : In multiplication or division, the number of SF in the product or quotient is same as the smallest number of SF in any of the factors. e.g. 5.0 0.125 = 0.625 = 0.62

  Note : First carry out actual addition or subtraction then round off.

ORDER OF MAGNITUDE

Order of magnitude of a quantity is the power of 10 required to represent that quantity. This power is determined after rounding off the value of the quantity properly. For rounding off, the last digit is simply ignored if it is less than 5 and, is increased by one if it is 5 or more than 5.

GOLDEN KEY POINTS

- When a number is divided by 10^x (where x is the order of the number) the result will always lie between 0.5 and 5, i.e. $0.5 \le N/10^x < 5$

Example

Order of magnitude of the following values can be determined as follows :

(a) 49 = 4.9 $10^1 \approx 10^1$ ∴ Order of magnitude = 1

(b) 51 = 5.1 $10^1 \approx 10^2$ ∴ Order of magnitude = 2

(c) 0.049 = 4.9 $10^{-2} \approx 10^{-2}$ ∴ Order of magnitude = –2

(d) 0.050 = 5.0 $10^{-2} \approx 10^{-1}$ ∴ Order of magnitude = –1

(e) 0.051 = 5.1 $10^{-2} \approx 10^{-1}$ ∴ Order of magnitude = –1

Example

The length, breadth and thickness of a metal sheet are 4.234 m, 1.005 m and 2.01 cm respectively. Give the area and volume of the sheet to correct number of significant figures.

Solution

• Length (ℓ) = 4.234 m • Breadth (b) = 1.005 m • Thickness (t) = 2.01 cm = 2.01 10^{-2} m

Therefore area of the sheet = 2 (ℓ b + b t + t ℓ)

= 2 (4.25517 + 0.0202005 + 0.0851034)

= 2 (4.255 + 0.0202 + 0.0851)

= 2 (4.360) = 8.7206 = 8.721

Since area can contain a maximum of 3 SF (Rule II of article 2) therefore, rounding off, we get :Area = 8.72 m^2

Like wise volume = ℓ b t = 4.234 1.005 0.0201 m^3 = 0.0855289 m^3

Since volume can contain 3 SF, therefore, rounding off, we get : Volume = 0.0855 m^3

ERROR IN MEASUREMENTS

The difference between the true value and the measured value of a quantity is known as the error of measurement.

CLASSIFICATION OF ERRORS

Errors may arise from different sources and are usually classified as follows :-

Systematic or Controllable Errors :

Systematic errors are the errors whose causes are known. They can be either positive or negative. Due to the known causes these errors can be minimised. Systematic errors can further be classified into three categories :

(i) **Instrumental errors** : These errors are due to imperfect design or erroneous manufacture or misuse of the measuring instrument. These can be reduced by using more accurate instruments.

(ii) **Environmental errors** : These errors are due to the changes in external environmental conditions such as temperature, pressure, humidity, dust, vibrations or magnetic and electrostatic fields.

(iii) **Observational errors** : These errors arise due to improper setting of the apparatus or carelessness in taking observations. **Ex.** parallax error.

- **Random Errors :** These errors are due to unknown causes. Therefore they occur irregularly and are variable in magnitude and sign. Since the causes of these errors are not known precisely they can not be eliminated completely. For example, when the same person repeats the same observation in the same conditions, he may get different readings at different times.

  Random errors can be reduced by repeating the observation a large number of times and taking the arithmetic mean of all the observations. This mean value would be very close to the most accurate reading.

  Note :- If the number of observations is made n times then the random error reduces to (1/n) times.

  Ex. : If the random error in the arithmetic mean of 100 observations is 'x' then the random error in the arithmetic mean of 500 observations will be x/5.

- **Gross Errors :** Gross errors arise due to human carelessness and mistakes in reading the instruments or calculating and recording the measurement results.

  For example : (i) Reading instrument without proper initial settings.

  (ii) Taking the observations wrongly without taking necessary precautions.

  (iii) Exhibiting mistakes in recording the observations.

  (iv) Putting improper values of the observations in calculations.

  These errors can be minimised by increasing the sincerity and alertness of the observer.

REPRESENTATION OF ERRORS : Errors can be expressed in the following ways :-

Absolute Error (Δa) : The difference between the true value and the individual measured value of the quantity is called the absolute error of the measurement. Suppose a physical quantity is measured n times and the measured values are a_1, a_2, a_3 ....a_n.

The arithmetic mean (a_m) of these values is $a_m = \dfrac{a_1 + a_2 + a_3 + \ldots\ldots\ldots\ldots a_n}{n} = \dfrac{1}{n}\sum_{i=1}^{n} a_i$

If the true value of the quantity is not given then mean value (a_m) *can be taken as the true value.*

Then the absolute errors in the individual measured values are –

$$\Delta a_1 = a_m - a_1$$
$$\Delta a_2 = a_m - a_2$$
....
....
$$\Delta a_n = a_m - a_n$$

The arithmetic mean of all the absolute errors is defined as the final or mean absolute error $(\Delta a)_m$ or $\overline{\Delta a}$ of the value of the physical quantity a, $(\Delta a)_m = \dfrac{|\Delta a_1| + |\Delta a_2| + \ldots\ldots\ldots\ldots + |\Delta a_n|}{n} = \dfrac{1}{n}\sum_{i=1}^{n}|\Delta a_i|$

So, if the measured value of a quantity be 'a' and the error in measurement be Δa, then the true value (a_t) can be written as $a_t = a \pm \Delta a$

- **Relative or Fractional Error** : It is defined as the ratio of the mean absolute error $((\Delta a)_m$ or $\overline{\Delta a})$ to the true value or the mean value (a_m or $\bar{a}$) of the quantity measured.

 Relative or fractional error = $\dfrac{\text{Mean absolute error}}{\text{Mean value}} = \dfrac{(\Delta a)_m}{a_m}$ or $\dfrac{\overline{\Delta a}}{\bar{a}}$

 When the relative error is expressed in percentage, it is known as percentage error,

 Percentage error = relative error 100 $\Rightarrow$ percentage error$=\dfrac{\text{mean absolute error}}{\text{true value}}\times 100\% = \dfrac{\overline{\Delta a}}{a}\times 100\%$

- **Propagation of errors in mathematical operations**

 (a) If x = a + b, then the maximum possible absolute error in measurements of x will be $\Delta x = \Delta a + \Delta b$

 (b) If x = a − b, then the maximum possible absolute error in measurement of x will be $\Delta x = \Delta a + \Delta b$

 (c) If $x = \dfrac{a}{b}$ then the maximum possible fractional error will be $\dfrac{\Delta x}{x} = \dfrac{\Delta a}{a} + \dfrac{\Delta b}{b}$

 (d) If $x = a^n$ then the maximum possible fractional error will be $\dfrac{\Delta x}{x} = n\dfrac{\Delta a}{a}$

 (e) If $x = \dfrac{a^n b^m}{c^p}$ then the maximum possible fractional error will be $\dfrac{\Delta x}{x} = n\dfrac{\Delta a}{a} + m\dfrac{\Delta b}{b} + p\dfrac{\Delta c}{c}$

 (f) If $x = \log_e a$ then the maximum possible fractional error will be $\dfrac{\Delta x}{x} = \dfrac{1}{x}\dfrac{\Delta a}{a}$

GOLDEN KEY POINTS

- Systematic errors are repeated consistently with the repetition of the experiment and are produced due to improper conditions or procedures that are consistent in action whereas random errors are accidental and their magnitude and sign cannot be predicted from the knowledge of the measuring system and conditions of measurement. Systematic errors can therefore be minimised by improving experimental techniques, selecting better instruments and improving personal skills whereas random errors can be minimised by repeating the observation several times.
- Mean absolute error has the units and dimensions of the quantity itself whereas fractional or relative error is unitless and dimensionless.
- Absolute errors may be positive in certain cases and negative in other cases.

Example

Following observations were taken with a vernier callipers while measuring the length of a cylinder :

3.29 cm, 3.28 cm, 3.29 cm, 3.31 cm, 3.28 cm, 3.27 cm, 3.29 cm, 3.30 cm. Then find :

(a) Most accurate length of the cylinder. (b) Absolute error in each observation.

(c) Mean absolute error (d) Relative error (e) Percentage error

Express the result in terms of absolute error and percentage error.

Solution

(a) Most accurate length of the cylinder will be the mean length $(\bar{\ell})$ = 3.28875 cm = 3.29 cm

(b) Absolute error in the first reading = 3.29 − 3.29 = 0.00 cm

Absolute error in the second reading = 3.29 − 3.28 = 0.01 cm

Absolute error in the third reading = 3.29 − 3.29 = 0.00 cm

Absolute error in the forth reading = 3.39 − 3.31 = −0.02 cm

Absolute error in the fifth reading = 3.29 – 3.28 = 0.01 cm

Absolute error in the sixth reading = 3.29 – 3.27 = 0.02 cm

Absolute error in the seventh reading = 3.29 – 3.29 = 0.00 cm

Absolute error in the last reading = 3.29 – 3.30 = –0.01 cm

(c) Mean absolute error $=\overline{\Delta \ell}=\dfrac{0.00+0.01+0.00+0.02+0.01+0.02+0.00+0.01}{8}$ = 0.01 cm

(d) Relative error in length $=\dfrac{\overline{\Delta \ell}}{\overline{\ell}}=\dfrac{0.01}{3.29}$ = 0.0030395 = 0.003

(e) Percentage error = $\dfrac{\overline{\Delta \ell}}{\overline{\ell}}$ 100 = 0.003 100 = 0.3%

So length ℓ = 3.29 cm ± 0.01 cm (in terms of absolute error)

$\Rightarrow$ ℓ = 3.29 cm ± 0.30% (in terms of percentage error)

Example

The initial and final temperatures of water as recorded by an observer are (40.6 ± 0.2) C and (78.3 ± 0.3) C. Calculate the rise in temperature.

Solution

Given θ_1 = (40.6 ± 0.2) C and θ_2 =(78.3 ± 0.3) C

Rise in temperature $\theta = \theta_2 - \theta_1$ = 78.3 – 40.6 = 37.7 C. $\Delta\theta = \pm(\Delta\theta_1 + \Delta\theta_2)$ = ± (0.2 + 0.3) = ± 0.5 C

$\therefore$ Rise in temperature = (37.7 ± 0.5) C

Example

The length and breadth of a rectangle are (5.7 ± 0.1) cm and (3.4 ± 0.2) cm.

Calculate area of the rectangle with error limits.

Solution

Given ℓ = (5.7 ± 0.1) cm and b = (3.4 ± 0.2) cm

Area A = ℓ b = 5.7 3.4 = 19.38 cm^2

$$\frac{\Delta A}{A}=\pm\left(\frac{\Delta \ell}{\ell}+\frac{\Delta b}{b}\right)=\pm\left(\frac{0.1}{5.7}+\frac{0.2}{3.4}\right)=\pm\left(\frac{0.34+1.14}{5.7\times 3.4}\right)=\pm\frac{1.48}{19.38}$$

$$\Rightarrow \Delta A=\pm\frac{1.48}{19.38}\times A=\pm\frac{1.48}{19.38}\times 19.38=\pm 1.48$$ $\therefore$ Area = (19.38 ± 1.48) sq/cm

Example

A body travels uniformly a distance (13.8 ± 0.2) m in a time (4.0 ± 0.3) s. Calculate its velocity with error limits. What is the percentage error in velocity ?

Solution

Given distance s = (13.8 ± 0.2) m and time t=(4.0 ± 0.3) s, velocity $v=\dfrac{s}{t}=\dfrac{13.8}{4.0}$ =3.45ms^{-1}=3.5 ms^{-1}

$$\frac{\Delta v}{v}=\pm\left(\frac{\Delta s}{s}+\frac{\Delta t}{t}\right)=\pm\left(\frac{0.2}{13.8}+\frac{0.3}{4.0}\right)=\pm\left(\frac{0.8+4.14}{13.8\times 4.0}\right)=\pm\frac{4.49}{13.8\times 4.0}=\pm 0.0895$$

$\Rightarrow$ Δv = ± 0.0895 v = ± 0.0895 3.45 = ± 0.3087 = ± 0.31 $\therefore$ v = (3.5 ± 0.31) ms^{-1}

Percentage error in velocity= $\dfrac{\Delta v}{v}$ 100 = ± 0.0895 100 = ± 8.95% = ± 9%

Example

A thin copper wire of length L increase in length by 2% when heated from T_1 to T_2. If a copper cube having side 10 L is heated from T_1 to T_2 what will be the percentage change in

(i)area of one face of the cube (ii) volume of the cube.

Sol. (i) Area A=10L $\quad$ 10 L = 100 L^2, % change in area $= \frac{\Delta A}{A} \quad 100 = 2 \quad \frac{\Delta L}{L} \quad 100 = 2 \quad 2\% = 4\%$

(ii) Volume V=10 L $\quad$ 10 L $\quad$ 10L=1000 L^3

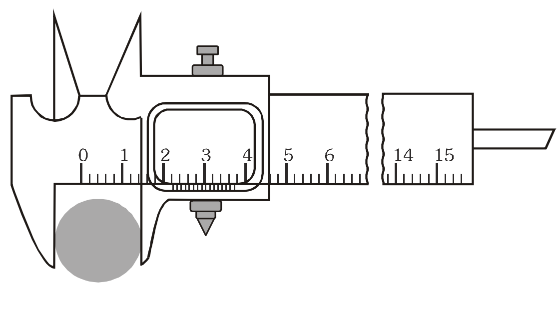
% change in volume $= \frac{\Delta V}{V} \quad 100 = 3 \quad \frac{\Delta L}{L} \quad 100 = 3 \quad 2\% = 6\%$

Conclusion : The maximum percentage change will be observed in volume, lesser in area and the least (minimum) change will be observed in length or radius.

LEAST COUNT

The smallest value of a physical quantity which can be measured accurately with an instrument is called the *Least Count* (LC) of the measuring instrument.

Least Count of vernier callipers :



Suppose the size of one Main Scale Division (MSD) is M units and that of one Vernier Scale Division (VSD) is V units. Also let the length of 'a' main scale divisions is equal to the length of 'b' vernier scale divisions.

$aM = bV \Rightarrow V = \frac{a}{b}M \quad \therefore M - V = M - \frac{a}{b}M = \left(\frac{b-a}{b}\right)M$

The quantity (M– V) is called *Vernier Constant* (VC) or *Least Count* (LC) of the vernier callipers.

$$\boxed{\text{L.C.} = M - V = \left(\frac{b-a}{b}\right)M}$$

Example

One cm on the main scale of vernier callipers is divided into ten equal parts. If 20 divisions of vernier scale coincide with 8 small divisions of the main scale. What will be the least count of callipers ?

Solution

20 division of vernier scale = 8 division of main scale $\Rightarrow$ 1 V. S .D. $= \left(\frac{8}{20}\right)$ M.S.D $= \left(\frac{2}{5}\right)$ M.S.D.

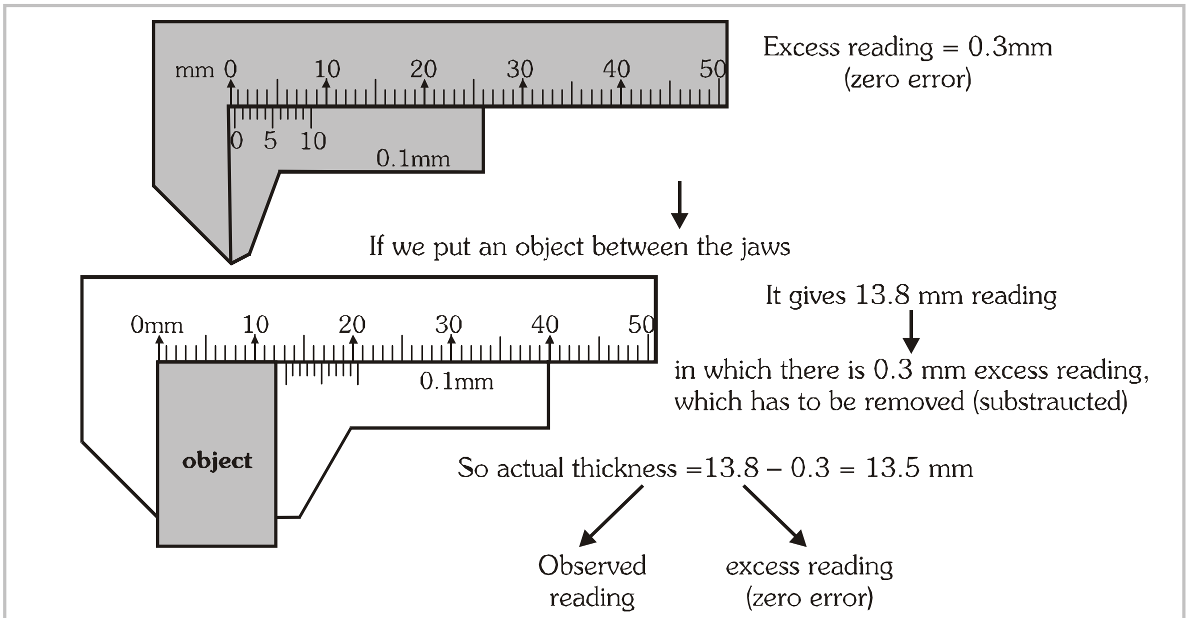
L.C. $= 1$ M.S.D.–1 V.S.D. = 1 M.S.D. $-\left(\frac{2}{5}\right)$ M.S.D. $= \left(1 - \frac{2}{5}\right)$ M.S.D.

$= \frac{3}{5}$ M.S.D. $= \frac{3}{5} \quad 0.1$ cm = 0.06 cm $\left(\because 1 \text{ M.S.D.} = \frac{1}{10} \text{ cm} = 0.1 \text{ cm}\right)$

Note : for objective questions L.C. $= M - V = \left(\frac{b-a}{b}\right)M = \left(\frac{20-8}{20}\right)\left(\frac{1}{10}\right)$ cm $= \frac{3}{50}$ cm = 0.06 cm

Zero Error

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



So we can formulate it as Actual reading = observed reading – excess reading (zero error)

ZERO CORRECTION

Zero correction is invert of zero error.

$$\boxed{\begin{aligned}\text{Actual reading} &= \text{observed reading} - \text{excess reading (zero error)}\\ &= \text{observed reading} + \text{zero correction}\end{aligned}}$$

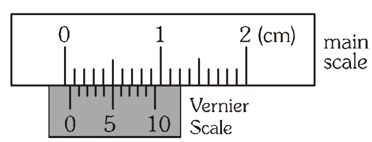
Zero correction = – (zero error)

Example

The figure shows a situation when the jaws of vernier are touching each other.

Each main scale division is of 1 mm

5^{th} division of vernier scale coincides with a main scale division.



L.C. $= \dfrac{1}{10} = 0.1$ mm. $\therefore$ Zero error = + 5 0.1 = 0.5 mm.

This error is to be subtracted from the reading taken for measurement.

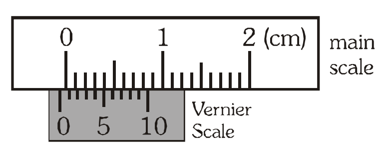
Also, zero correction = – 0.5 mm.

Example

The figure shows a situation when the jaws of vernier are touching each other.

Each main scale division is of 1 mm

4^{th} division of vernier scale coincides with a main scale division.

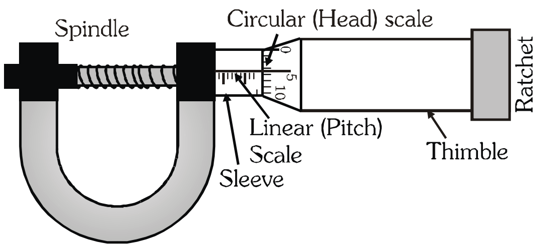


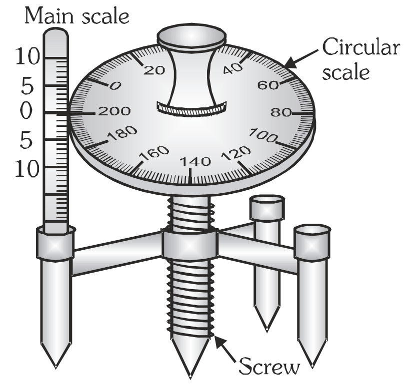
L.C. $= \dfrac{1}{10} = 0.1$ mm. $\therefore$ Zero error = – (10–4) 0.1 = – 0.6 mm .

This error is to be added in the reading taken for measurement.

Also, zero correction = + 0.6 mm.

- **Least Count of Screw Gauge & Spherometer :**





$$\text{L.C.} = \frac{\text{Pitch}}{\text{Total no. of divisions on the circular scale}}$$

where pitch is defined as the distance moved by the screw head when the circular scale is given one complete rotation. i.e.

$$\text{Pitch} = \frac{\text{Distance moved by the screw on the linear scale}}{\text{No.of full rotations given}}$$

$$\text{Radius of curvature} = \frac{\ell^2}{6h} + \frac{h}{2}$$

where $\ell = \dfrac{\ell_1 + \ell_2 + \ell_3}{3}$

h= difference of readings taken on curved surface & that on flat surface.

Note : With the decrease in the least count of the measuring instrument, the accuracy of the measurement increases and the error in the measurement decreases.

- **Precision of a measurement**

The precision of a measurement is determined by the least count of a measuring instrument. The smaller is the least count larger is the precision of the measurement.

- **Accuracy of a measurement**

Accuracy of an instrument represents the closeness of the measured value to actual value.

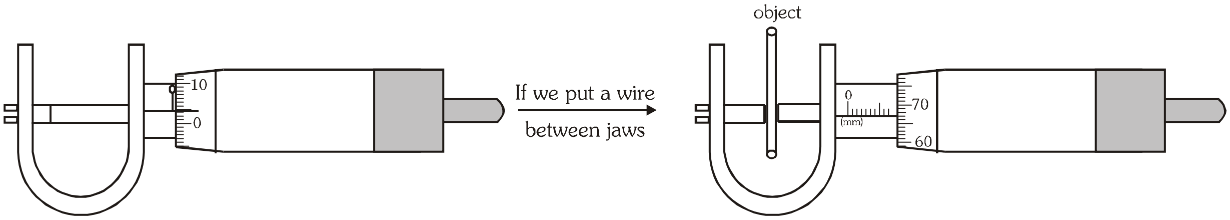
- **Zero Error**

If there is no object between the jaws (i.e. jaws are in contact), the screw gauge 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.

* All the instruments utilizing threads have back-lash error which belongs to random category.

Example

Find the thickness of the wire.



Solution

Excess reading (zero error) = 0.03 mm reading,

It is giving 7.67 mm in which there is 0.03 mm excess which has to be removed (substracted) so actual reading = 7.67 - 0.03 = 7.64 mm

- **Zero correction**

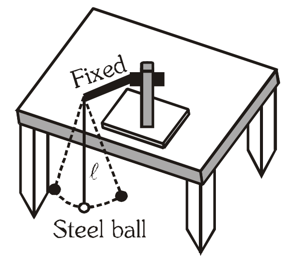
Zero correction is invert of zero error : Zero correction = – (zero error)

Actual reading = observed reading – zero error = observed reading + zero correction

SOME IMPORTANT EXPERIMENTS

1. **Determination of g using a simple pendulum :** A simple pendulum is an arrangement consisting of a small metal ball with a fine string suspended from a fixed point so that it can swing freely.

- **Arrangement**



The equation for the periodic motion of a simple pendulum as determined by Galileo is $T = 2\pi\sqrt{\frac{\ell}{g}}$. Here, ℓ is the length of the pendulum, g is acceleration due to gravity and T is time period of periodic motion. To determine g, rearrange the above equation to get, $g = 4\pi^2 \frac{\ell}{T^2}$

- **Procedure**

(a) Determine the time for 20 complete swings for six different lengths. (The length means the distance between point of suspension and centre of the ball).

(b) Repeat the time measurement five times for each length, making sure to get consistent readings.

(c) Determine the average time for 20 swings for each length. Then, calculate the time of one swing.

(d) Compute the acceleration due to gravity for each pendulum length.

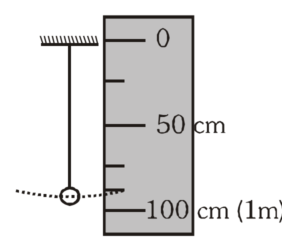
(e) Calculate the mean g and the percentage error in g for each length.

(f) Plot length versus time graph and length versus time squared, graph.

Example

In an experiment to determine acceleration due to gravity, the length of the pendulum is measured as 98 cm by a meter scale of least count of 1cm. The period of swing/oscillations is measured with the help of a stop watch having a least count of 1s. The time period of 50 oscillations is found to be 98 s. Express value of g with proper error limits.

Solution



As $T = 2\pi\sqrt{\frac{\ell}{g}}$ Now, time period of 50 oscillation is 98 s.

$\therefore$ Time period of one oscillation is $\frac{98}{50} = 1.96$ s.

As $T = 2\pi\sqrt{\frac{\ell}{g}}$ We have $g = \frac{4\pi^2\ell}{T^2} = 4 \quad (3.14)^2 \quad \frac{0.98}{1.96 \times 1.96} = 10.06$ m/s^2

Let us find the permissible error in the measurement.

As $g = \frac{4\pi^2\ell}{T^2}$ We have $\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T}{T}$, $\Delta g = 10 \left(\frac{1}{98} + \frac{2 \times 1}{98}\right)$ ($\because$ Least count of meter scale is 1 cm and least count of stop watch is 1s), $\Delta g = 0.3$ m/s^2 So, final result can be expressed as (10.1 ± 0.3) ms^{-2}.

- **Precautions**

(i) The oscillations amplitude should be kept small (10 or below) as the formula for time period is applicable for small angular displacements.

(ii) While measuring the length and time periods, an average of several readings should be taken.

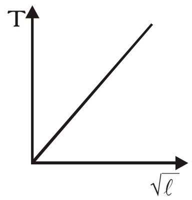
(iii) The instruments used should be checked for zero error.

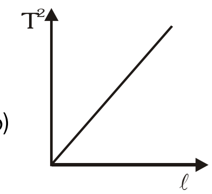
- **Factors Affecting the Time Period :**

The time period of a simple pendulum is affected by following factors.

(i) Time period is clearly a function of the length of pendulum. From the formula, it is clear that

$T \propto \sqrt{\ell}$ or $T^2 \propto \ell$.The graphical variation is shown here

(a)


(b)


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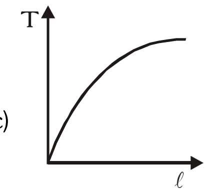
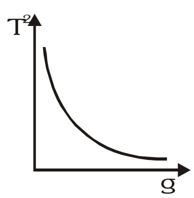
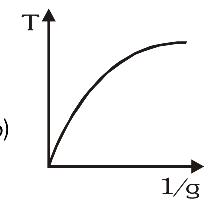
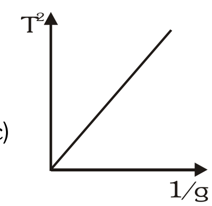


(ii) Time period is a function of acceleration due to gravity. $T \propto \dfrac{1}{\sqrt{g}}$ or $T^2 \propto \dfrac{1}{g}$

Following graphs represent the above variation

(a)


(b)


(c)


(iii) Time period is independent of mass of ball used in the pendulum. A wooden ball or a steel ball will have same time period if other factors are same.

(iv) The time period of a simple pendulum is independent of amplitude (provided amplitude is small). This type of motion is called isochrones motion.

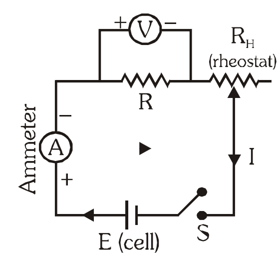
2. Verification of Ohm's law using voltmeter and ammeter :

According to ohm's law, the current flowing through a metallic conductor is directly proportional to the potential difference across the ends of the conductor provided the physical conditions like temperature and mechanical strain etc are kept constant.

$V = IR$, where R is a constant called resistance

- **Arrangement :**

The figure shows the arrangement used to verify ohm's law. It consists of a cell of emf E, connected to a fixed resistance R and a variable resistance R_H (rheostat). An ammeter is connected in the circuit to measure current I and a voltmeter is connected across the fixed resistance R to measure potential difference V,

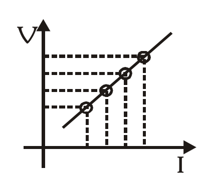


- **Procedure :** Following steps are to be followed.

(a) Close the switch S and note down the readings of voltmeter and ammeter.

(b) Repeat the above process for different values of variable resistance R_H.

(c) Plot a graph between V and I by taking V along y-axis and I along x-axis.

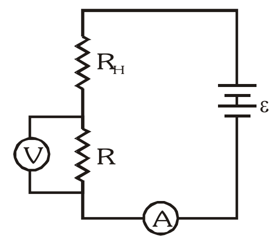


(d) Slope or gradient of this graph is $\dfrac{V}{I}$ = constant. This shows that $V \propto I$.

Example

In the circuit shown, voltmeter is ideal and its least count is 0.1 V. The least count of ammeter is 1 mA. Let reading of the voltmeter be 30.0 V and the reading of ammeter is 0.020 A. We shall calculate the value of resistance R within error limits.

Sol. V = 30.0; I = 0.020 A; $R = \dfrac{V}{I} = \dfrac{30.0}{0.020} = 1.50\ k\Omega$



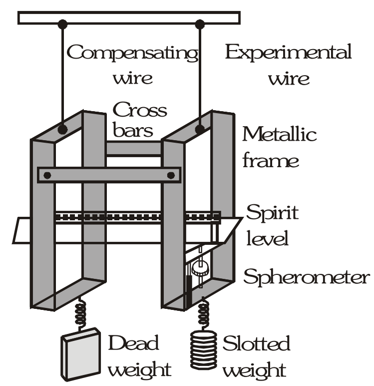
Error : As $R = \dfrac{V}{I}\ \therefore\ \dfrac{\Delta R}{R} = \dfrac{\Delta V}{V} + \dfrac{\Delta I}{I}$

$$\Rightarrow \Delta R = R\left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right) = 1.50 \quad 10^3 \left(\frac{0.1}{30.0} + \frac{0.001}{0.020}\right) = 0.080\ k\Omega.$$

3. Determination of Young's Modulus by Searle's Method :

When a deforming force is applied to deform a body, it shows some opposition. This opposition is called stiffness. Young's modulus is a physical quantity used to describe the stiffness of a body. It is the ratio of stress applied to strain produced, where stress applied is force applied per unit area and strain is the ratio of change in length to original length $Y = \left(\dfrac{F}{A}\right) \div \dfrac{x}{\ell} = \dfrac{F\ell}{Ax}$ Here, F is applied force, A is area of cross-section, ℓ is length and x is increase in length.

Arrangement : The arrangement consists of two wires. One of the wires is a reference wire loaded with a fixed weight. The other wire is the test wire, on which variable load is applied. The reference wire is used to compensate for the thermal expansion of the wire. The extension in the test wire is measured with the help of a spherometer and a spirit level arrangement.



• **Procedure :**

The following steps are required to measure the young's modulus.

(a) Using micrometer determine the radius of the wire.

Using the formula for area of circle = πr^2, calculate the area.

(b) Measure the length of the wire ℓ.

(c) Note down the load applied F and corresponding increase in length x.

(d) Convert load in kg to weight in newton by the formula 1 kgf = 9.81 N

(e) Plot a graph of extension x (along x-axis) against weight (along y-axis).

(f) The slope of this graph is the ratio $\dfrac{F}{x}$.

(g) Find Y using the formula $Y = \dfrac{F\ell}{Ax}$.

Example

In an experiment for measurement of young's modulus, following readings are taken. Load = 3.00 kg, length = 2.820 m, diameter = 0.041 cm and extension = 0.87. We shall determine the percentage error in measurement of Y.

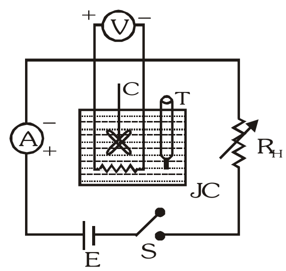
Solution

If Y = Young's modulus of wire, M = mass of wire, g = acceleration due to gravity, x = extension in the wire, A= Area of cross-section of the wire, ℓ = length of the wire.

$$Y = \frac{Mgx}{A\ell} \Rightarrow \frac{\Delta Y}{Y} = \frac{\Delta M}{M} + \frac{\Delta x}{x} + \frac{\Delta A}{A} + \frac{\Delta \ell}{\ell} \Rightarrow \frac{\Delta Y}{Y} = \frac{0.01}{3.00} + \frac{0.01}{0.87} + \frac{2\times 0.001}{0.041} + \frac{0.001}{2.820} = 0.064 \Rightarrow \frac{\Delta Y}{Y}\times 100 = \pm 6.4\%$$

4. **Measurement of specific heat of a liquid using a calorimeter :** Specific heat of a substance is the heat required to raise the temperature of unit mass of a substance by one degree Celsius. It is given by $S=\frac{Q}{m\Delta\theta}$' where Q is the heat supplied, m is the mass of substance and $\Delta\theta$ is the rise in temperature.

Arrangement : The arrangement consists of a joule calorimeter (JC) with a churner C, thermometer(T), variable resistor R_H, cell of emf E, an ammeter, a voltmeter and a switch.



Procedure : The following steps are required.

(a) Weigh the empty calorimeter with churner C. This is m_C.

(b) Weigh the calorimeter with the liquid in it. The difference in two masses gives the mass of liquid. This is m_ℓ.

(c) Make the set up shown. Keeping the switch open, note the reading of the thermometer θ_1.

(d) Close the switch S for a time t and continuously stir the liquid. At the time of opening the switch, note the reading of thermometer θ_2, voltmeter V and ammeter I.

(e) Calculate heat supplied to the colorimeter using H = VIt.

(f) Calculate rise in temperature using $\Delta\theta = \theta_2 - \theta_1 + d\theta$ .....Here $d\theta$ is the correction applied for radiation loss. $d\theta$ is the fall in temperature when the calorimeter and its contents are left to cool down for time $\frac{t}{2}$.

(g) Let S_C be the specific heat of calorimeter and S_ℓ be the specific heat of liquid, then the heat supplied is

$$Q = m_\ell S_\ell \Delta\theta + m_c S_c \Delta\theta \Rightarrow S_\ell = \frac{Q - m_c S_c \Delta\theta}{m_\ell \Delta\theta} = \frac{1}{m_\ell}\left(\frac{VIt}{\Delta\theta} - m_c S_c\right)$$

Precautions : Following precautions must be taken.

(i) Correction due to radiation loss $d\theta$ must be taken into account.

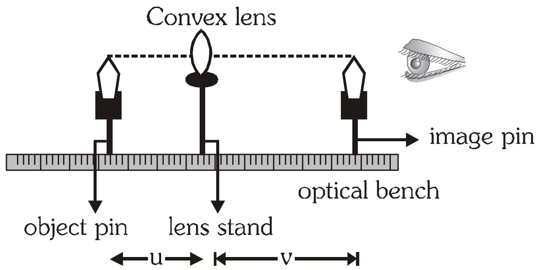
(ii) The stirring of liquid should be slow.

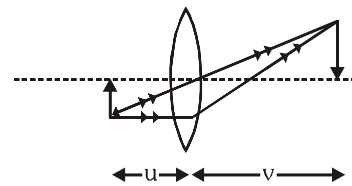
(iii) While reading voltmeter and ammeter, parallax should be removed.

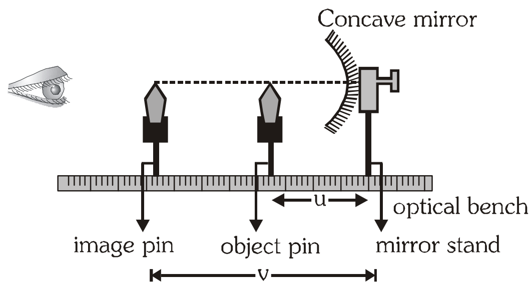
5. **Focal length of a convex lens/concave mirror using u-v method :**

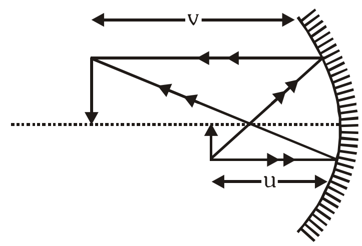
When an object is placed at a distance u in front of a convex lens/concave mirror, it forms an image at a distance v from the lens/mirror. The two values u and v are related to each other. For a convex lens, the relationship is $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$. For a concave mirror, the relationship is $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$.

Arrangement : The lens/mirror is fixed on an optical bench with a scale marked on it to measure the distance of object and image. The lens or mirror is fixed. There are two other stands in which two pin shaped objects are fixed. One of these is the object pin. This acts as an object. The other one is called image pin. It is used to locate the image position. When there is no parallax between the image pin and image seen in the lens/mirror, the image pin represents the position of the image.









Procedure : Following steps are to be followed.

(a) Fix the lens on the lens stand.

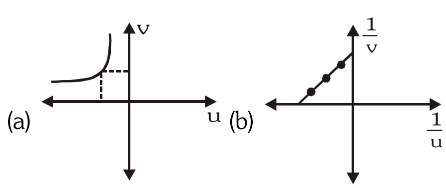
(b) Place object pin in front of the lens. Measure the distance between the two. The value of u will be negative of the above distance.

(c) Place the image pin on the other side of the lens at such a distance from the lens, so that there is no parallax between image pin and image seen in the lens. The value of v will be the distance between the lens and image pin.

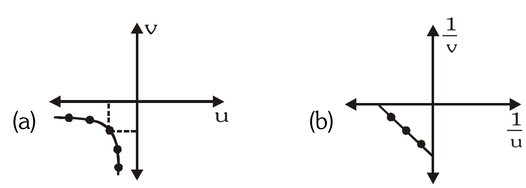
(d) Compute the focal length of the lens using lens formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$.

(e) Plot a graph between u and v and $\frac{1}{u}$ and $\frac{1}{v}$.

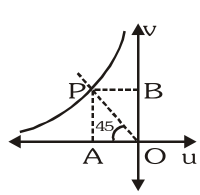
For a convex lens, the shape of graphs obtained are shown.



For a concave mirror, the shape of graphs obtained are shown.



(f) In the u-v curve, we draw a line at 45 as shown in figure.This line intersect the curve at point P. PB and PA are parallel to axes. Here OA = OB = 2f. So, focal length $f=\frac{OA}{2}$



Example

In an experiment to measure the focal length of a concave mirror, it was found that for an object distance of 0.30 m, the image distance come out to be 0.60 m. Let us determine the focal length.

Solution

By mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \begin{matrix} u=-0.30\text{m} \\ v=-0.60\text{m} \end{matrix} \Rightarrow \frac{1}{f}=\frac{-1}{0.30}-\frac{1}{0.60} \Rightarrow \frac{1}{f}=\frac{-3.0}{0.60} \Rightarrow f = 0.20$ m

As $\frac{1}{f}=\frac{1}{v}+\frac{1}{u} \Rightarrow \frac{-df}{f^2}=\frac{-dv}{v^2}-\frac{du}{u^2} \Rightarrow df=(0.20)^2\left[\frac{0.01}{(0.60)^2}+\frac{0.01}{(0.30)^2}\right] \Rightarrow df = 0.0055 \approx 0.01$ m

$\therefore$ Focal length $f = (0.20 \pm 0.01)$ m.

- **Precaution :** Following precautions must be taken.

(i) Both u and v should be measured carefully on the bench.

(ii) While locating the image, parallax should be removed.

6. Determination of speed of sound using resonance column :

It is a simple apparatus used to measure speed of sound in air with the help of a tuning fork of known frequency. The resonance column is an air column closed at one end. Its length is variable. It is based on the phenomenon of standing waves. A vibrating tuning fork is held near the open end of the tube which is partially empty. The air-column vibrates with the frequency of tuning fork. As the length of air column is increased from zero onwards, a stage is reached when very intense sound is observed. At this stage the natural frequency of the air-column matches with the frequency of tuning fork. This state is known as resonance. At resonances, the vibration of air column can be like any of the following figures.

- **Arrangement :** The arrangement is shown in the figure. It consists of a metallic tube and a connected glass tube. There is a reservoir containing water. This is connected to the metallic tube by a rubber pipe. Parallel to the glass tube is a scale to measure the length of air-column.

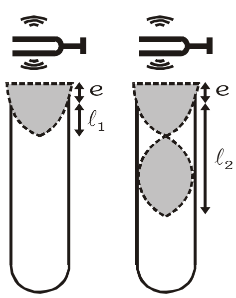


Fig. 1

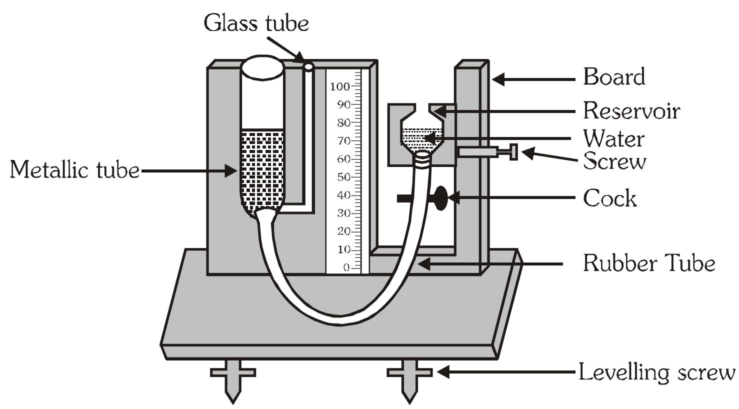


Fig. 2

- **Procedure :** Following steps are used in the experiment.

(a) Hold the vibrating tuning fork at the open end of the column and start increasing the length of the air column by adjusting the height of reservoir.

(b) Determine the first resonating length ℓ_1. This is the length at which an intense sound is observed.

(c) Determine the second resonating length ℓ_2. This is the length at which an intense sound is observed again.

(d) Compute the wavelength. It can be calculated as shown. From the figure-1 it is clear that

$\ell_1 + e = \frac{\lambda}{4}$ ...(i) $\qquad \ell_2 + e = \frac{3\lambda}{4}$ ...(ii)

Here λ is wavelength of sound and e is end correction (height of the antinode above the open end)

[Given by Lord Rayleigh] Subtracting $\ell_2 - \ell_1 = \dfrac{\lambda}{2}$ $\therefore \lambda = 2(\ell_2 - \ell_1)$

(e) Using the formula $v = f\lambda$, compute the speed of sound.

(f) Compute the end-correction from equation (i) and (ii) $\ell_1 + e = \dfrac{\lambda}{4}$, $\ell_2 + e = \dfrac{3\lambda}{4} \Rightarrow \ell_2 - 3\ell_1 - 2e = 0 \Rightarrow e = \left(\dfrac{\ell_2 - 3\ell_1}{2}\right)$

(g) Compute the error in end-correction by comparing it with Reyleigh's formula $e = 0.6\ R$. Where R is internal radius of resonance tube.

Example

The internal radius of a 1 m long resonance tube is measured as 3.0 cm. A tuning fork of frequency 2000 Hz is used. The first resonating length is measured as 4.6 cm and the second resonating length is measured as 14.0 cm. We shall calculate the following

Solution

(i) Maximum percentage error in measurement of e, as given by Reyleigh's formula.

(Given error in measurement of radius is 0.1 cm) $\Delta e = 0.6\ \Delta R = 0.6\quad 0.1 = 0.06$ cm

Percentage error is $\dfrac{\Delta e}{e} \times 100 = \dfrac{0.06}{0.6 \times 3} \times 100 = 3.33\%$

(ii) Speed of sound at the room temperature.

$\ell_1 = 4.6$ cm, $\ell_2 = 14.0$ cm, $\lambda = 2(\ell_2 - \ell_1) = 2(14.0 - 4.6) = 18.8$ cm, $v = f\lambda = 2000\quad \dfrac{18.8}{100} = 376$ m/s.

(iii) End correction obtained in the experiment. $e = \dfrac{\ell_2 - 3\ell_1}{2} = \dfrac{14.0 - 3 \times 4.6}{2} = 0.1\text{cm}.$

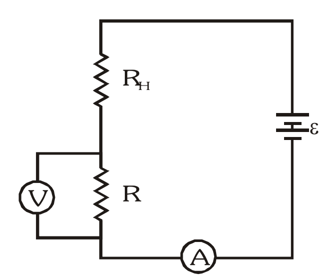
(iv) Percentage error in the calculation of e with respect to theoretical value.

Percentage error $= \dfrac{0.6 \times 3 - 0.1}{0.6 \times 3} \times 100 = 94.44\%$

Example

In the circuit shown, voltmeter is ideal and its least count is 0.1 V. The least count of ammeter 1 mA. Let reading of the voltmeter be 30.0 V and the reading of ammeter is 0.020 A. We shall calculate the value of resistance R within error limits.

Solution



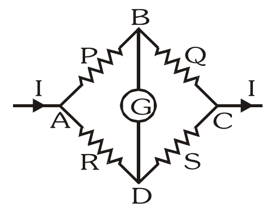
$V = 30.0, I = 0.020$ A, $R = \dfrac{V}{I} = \dfrac{30.0}{0.020} = 1.50\text{k}\Omega$

Error : As $R = \dfrac{V}{I}$ $\therefore \dfrac{\Delta R}{R} = \dfrac{\Delta V}{V} + \dfrac{\Delta I}{I} \Rightarrow \Delta R = R\left(\dfrac{\Delta V}{V} + \dfrac{\Delta I}{I}\right)$

$= 1.50\quad 10^3 \left(\dfrac{0.1}{30.0} + \dfrac{0.001}{0.020}\right) = 0.080\,\text{k}\Omega$ So, resistance is (1.5 ± 0.08) kΩ.

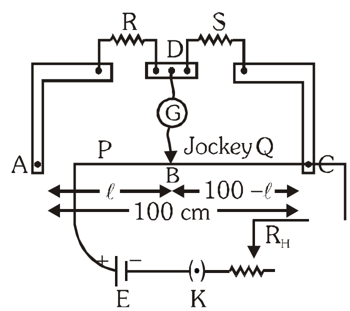
7. Determination of resistivity of a metal using : (i) Meter bridge (ii) Post office box

- **Meter bridge :** The resistance of a metal wire depends on its length, area of cross-section and resistivity of the metal. The formula is $R = \rho\frac{\ell}{A}$.Here, ρ is the resistivity. Its unit is Ω-m (ohm-meter). To measure its resistivity, we use a meter bridge. The working of a meter bridge is based on Wheatstone bridge principle. The circuit shown is called Wheatstone bridge.



When $\frac{P}{Q} = \frac{R}{S}$, there is no flow of current in the branch BD. At this state, galvanometer shows zero deflection.

- **Arrangement :** The arrangement consists of a 100 cm long wire connected between A and C. It is tapped at point B by a sliding contact called jockey. R is a known resistance. S is the resistance wire whose resistivity is to be determined. A cell and a variable resistance R_H are connected to supply current in the circuit.



- **Procedure :** Following steps are used in the experiment.

(a) Plug the key and slide the jockey on wire AC to locate point B where the galvanometer does not show deflection. Note down the length ℓ.

(b) Compute the resistance S using the formula $\frac{P}{Q} = \frac{R}{S}$. Here, $P=\rho_{wire}\frac{\ell}{A}$, $Q = \rho_{wire}\frac{100-\ell}{A}$ $\therefore S = R\left(\frac{100-\ell}{\ell}\right)$

(c) Compute the value of S by determining values of length ℓ. This can be done by using different values of R.

(d) Calculate the percentage error in measurement of S.

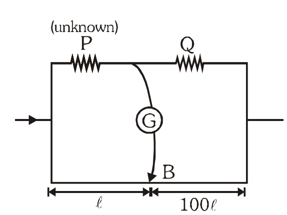
(e) Compute the resistivity by measuring length and area of cross-section of resistance wire S using the formula $S=\frac{\rho\ell}{A}$.

Example

In an experiment to determine an unknown resistance, a 100 cm long resistance wire is used. The unknown resistance is kept in the left gap and a known resistance is put into the right gap. The scale used to measure length has a least count 1 mm. The null point B is obtained at 40.0 cm from the left gap. We shall determine the percentage error in the computation of unknown resistance.

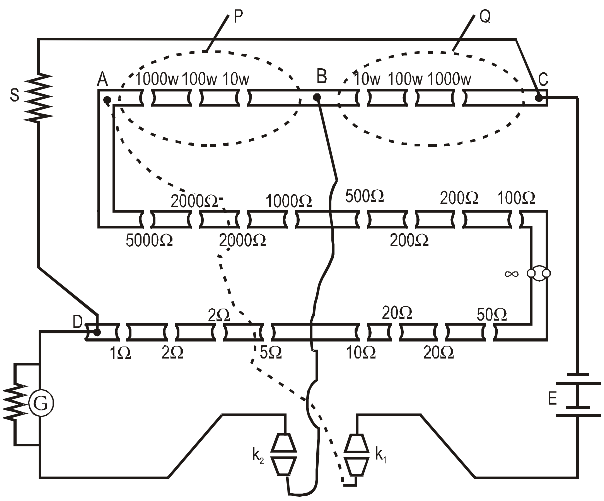
Solution

As shown in the figure. $\frac{P}{Q} = \frac{\ell}{100-\ell}$, $P \propto \frac{\ell}{100-\ell}$



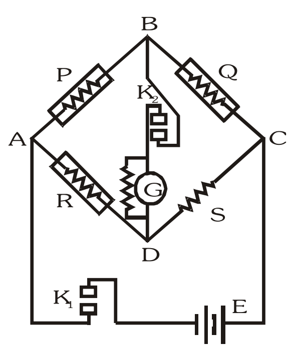
$$\Rightarrow \frac{\Delta P}{P} = \frac{\Delta\ell}{\ell} + \frac{\Delta(100-\ell)}{100-\ell} = \frac{\Delta\ell}{\ell} + \frac{\Delta\ell}{100-\ell} = \frac{0.1}{40.0} + \frac{0.1}{60.0} \Rightarrow \frac{\Delta P}{P}\ 100 = 0.42\%$$

(ii) **Post office box :** This apparatus was initially used in post-offices for measuring the resistance of the telephone or telegraph wires, or for finding the faults in these wires. In post office box, the two arms AB and BC are connected in series. Each of these arms contain resistances 10Ω, 100Ω and 1000 Ω. In the third arm AD there are resistances from 1Ω to 5000 Ω arranged in U shape. In order to insert keys in the arms AC and BD, the point A is connected to a tapping key k_1 and the point B is connected to another tapping key k_2. The wire whose resistance (S) is to be determined is connected in the arm CD. The galvanometer G is connected between B and D through the key k_2 and the cell is connected between A and C through the key k_1.



EQUIVALENT CIRCUIT

Working : First of all, from P a 1000 Ω resistor is selected and from Q also 1000 Ω resistor is selected Now by pulling plugs from R, a balance condition is obtained. As $\frac{P}{Q}=\frac{R}{S}$ [P = 1000 Ω, Q = 1000 Ω] . So S = R

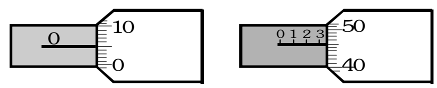


Now in order to increase the preciseness, P is selected to be 1000 Ω and Q = 10 Ω. In this case, S = $\frac{R}{100}$ As the least count decreases, hence preciseness increases.

SOME WORKED OUT EXAMPLES

Example#1

The circular scale of a micrometer has 200 divisions and pitch of 2mm. Find the measured value of thickness of a thin sheet.



(A) 3.41 mm (B) 6.41 mm (C) 3.46 mm (D) 3.51 mm

Solution **Ans. (B)**

Least count = $\dfrac{\text{pitch}}{\text{No. of divisions}} = \dfrac{2}{200} = 0.01\text{mm}$; Reading = 3 2 + (46–5) (0.01) = 6.41 mm

Example#2

The length of the string of a simple pendulum is measured with a meter scale to be 63.5 cm, the radius of the bob plus the hook is measured with the help of vernier caliper to be 1.55 cm. Select the incorrect statement :-

(A) Least count of meter scale is 0.1 cm (B) Least count of vernier caliper is 0.01 cm

(C) Effective length of pendulum is 65.1 cm (D) Effective length of pendulum is 65.2 cm

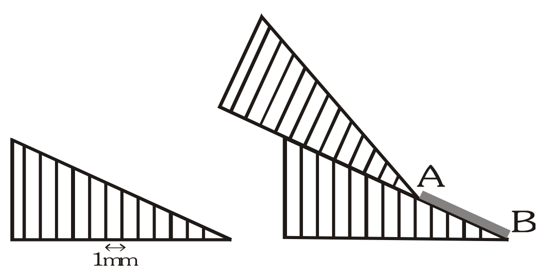
Solution **Ans. (C)**

From measurements least count of meter scale is 0.1 cm and least count of vernier calliper is 0.01 cm.

Effective length of simple pendulum = 63.5 + 1.55 = 65.15 = 65.2 cm

Example#3

A brilliant student of Class XII constructed a vernier calipers as shown. He used two identical inclines of inclination 37 and tried to measure the length of line AB. The length of line AB is



(A) $\dfrac{21}{4}$ mm (B) $\dfrac{25}{4}$ mm (C) $\dfrac{18}{4}$ mm (D) None of these

Solution **Ans. (B)**

Least count = $\dfrac{\ell}{\cos\theta} - \ell = 1\left(\dfrac{1}{4/5} - 1\right) = \left(\dfrac{5}{4} - 1\right) = \dfrac{1}{4}\text{mm}$

Length AB = (4) $\left(\dfrac{\ell}{\cos\theta}\right) + (5)\left(\dfrac{\ell}{\cos\theta} - \ell\right) = 4\left(\dfrac{5}{4}\right) + 5\left(\dfrac{1}{4}\right) = 5 + \dfrac{5}{4} = \dfrac{25}{4}\text{mm}$

Example#4

The side of a cube is (2.00 ± 0.01) cm. The volume and surface area of cube are respectively :–

(A) (8.00 ± 0.12) cm^3, (24.0 ± 0.24) cm^2 (B) (8.00 ± 0.01) cm^3, (24.0 ± 0.01) cm^2

(C) (8.00 ± 0.04) cm^3, (24.0 ± 0.06) cm^2 (D) (8.00 ± 0.03) cm^3, (24.0 ± 0.02) cm^2

Solution **Ans. (A)**

Volume $V=a^3=8\ cm^3$. Also $\frac{\Delta V}{V}=3\frac{\Delta a}{a} \Rightarrow \Delta V=3V\left(\frac{\Delta a}{a}\right)=(3)(8)\left(\frac{0.01}{2.00}\right)=0.12\ cm^3$

Therefore $V = (8.00 \pm 0.12)\ cm^3$; Surface Area $A = 6a^2 = 6\ (2.00)^2 = 24.0\ cm^2$.

Also $\frac{\Delta A}{A}=2\frac{\Delta a}{a} \Rightarrow \Delta A=2A\left(\frac{\Delta a}{a}\right)=2(24.0)\left(\frac{0.01}{2.00}\right)=0.24$. Therefore $A = (24.0 \pm 0.24)\ cm^2$

Example#5

Two clocks A and B are being tested against a standard clock located in the national laboratory At 10:00 AM by the standard clock, the readings of the two clocks are shown in following table

Day	Clock A	Clock B
I^{st}	10:00 : 06	8:15:00
II^{nd}	10:01:13	8:15:01
III^{rd}	9:59:08	8:15:04
IV^{th}	10:02:15	8:14:58
V^{th}	9:58:10	8:15:02

If you are doing an experiment that requires precision time interval measurements, which of the two clocks will you prefer?

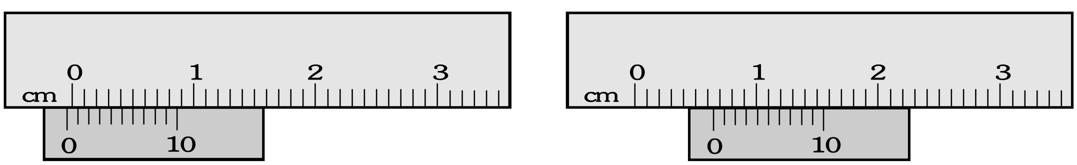
(A) clock A
(B) clock B
(C) either clock A or clock B
(D) Neither clock A nor clock B

Solution **Ans. (B)**

The average reading of clock A is, closure to the standard time and the variation in time is smaller for clock B. As clock's is zero error is not significant for precision work because a zero error can always be easily corrected. Hence clock B is to be preferred.

Example#6

The main scale of a vernier callipers reads in millimeter and its vernier is divided into 10 divisions which coincides with 9 divisions of the main scale. The reading for shown situation is found to be (x/10) mm. Find the value of x.



Solution **Ans. 69**

Least count = $\frac{1mm}{10}$ = 0.1 mm; Zero error = –(10–6) 0.1 = – 0.4 mm

Reading = 6 + 5 (0.1) – (–0.4) = 6.9 mm

Example#7

Write number of significant digits

(i) 62.3 cm
(ii) $6.23\quad 10^1$ cm
(iii) 20.000
(iv) $0.02\quad 10^{-19}$
(v) 500.000
(vi) 0.5210
(vii) 896.80
(viii) 201
(ix) 1200
(x) 1200 N

Solution **Ans.** (i) 3 (ii) 3 (iii) 5 (iv) 1 (v) 6 (vi) 4 (vii) 5 (viii) 3 (ix) 2 (x) 4

Example#8

Round off the following numbers to 3 significant digits-

(i) 899.68
(ii) 987.52
(iii) 2.0082
(iv) 336.5
(v) 335.5

Solution **Ans.** (i) 900 (ii) 988 (iii) 2.01 (iv) 336 (v) 336

Example#9

Solve with regards to significant figure

(i) 908 + 2.76 (ii) 999 – 989 (iii) 4.0 10^{-4} – 2.5 10^{-6}

(iv) 4.0 10^{-4} – 2.5 10^{-5} (v) 6.75 10^{3} + 4.52 10^{2} (vi) 625 125

Solution **Ans.** (i) 911 (ii) 10.0 (iii) 4.0 10^{-4} (iv) 3.8 10^{-4} (v) 7.20 10^{3} (vi) 5.00

Example#10

A scale is calibrated to centimeters and the following measurements are estimated by the scale. Find out the significant digits.

(i) 200 m (ii) 92.80 m (iii) 80.26 m (iv) 8.23 cm

(v) 8.921 mm (vi) 6.001 m

Solution **Ans.** (i) 3 (ii) 4 (iii) 4 (iv) 2 (v) 1 (vi) 4

Example#11

An object covers (16.0 ± 0.4) m distance in (4.0 ± 0.2) s. Find out its speed.

Solution **Ans.** (4.0 ± 0.3) ms^{-2}

$$\text{Speed } v = \frac{\text{distance}}{\text{time}} = \frac{16.0}{4.0} = 4.0 \text{ m/s; Error in speed } \Delta v = \pm\left(\frac{\Delta s}{s}+\frac{\Delta t}{t}\right)v = \left(\frac{0.4}{16.0}+\frac{0.2}{4.0}\right)(4.0) = \pm 0.3 \text{ m/s}$$

Example#12

Students I_1, J_1,J_3 and I_2 perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. they use different lengths of the pendulum and record time for different number of oscillations. The observations are shown in the table. Least count for length = 0.1 cm, Least count for time = 1s

Students	Length of the pendulum (cm)	No. of oscillations (n)	Time period of pendulum (s)
I_1	100.0	20	20
J_1	400.0	10	40
J_3	100.0	10	20
I_2	400.0	20	40

If P_1,P_2,P_3 and P_4 are the % error in g for students I_1,J_1,J_3 and I_2 respectively then-

(A) $P_1 = P_3$ (B) P_3 is maximum (C) P_4 is minimum (D) $P_2 = P_4$

Solution **Ans.** (B,C)

$$T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow g \propto \ell T^{-2} = \frac{\Delta g}{g} = \frac{\Delta\ell}{\ell}+\frac{2\Delta T}{T}.$$

$$\text{Therefore } P = \left(\frac{\Delta\ell}{\ell}+\frac{2\Delta T}{T}\right)100 \Rightarrow P_1 = \left(\frac{0.1}{100}+\frac{2(1)}{400}\right) \quad 100 = 0.6\%,\ P_2 = \left(\frac{0.1}{400}+\frac{2(1)}{400}\right) \quad 100 = 0.42\%$$

$$P_3 = \left(\frac{0.1}{100}+\frac{2(1)}{200}\right) \quad 100 = 1.1\%,\ P_4 = \left(\frac{0.1}{400}+\frac{2(1)}{800}\right) \quad 100 = 0.28\%$$

Example#13

The length of a cylinder is measured with a metre rod having least count 0.1 cm. Its diameter is measured with vernier callipers having least count 0.01 cm. Given the length is 5.0 cm and diameter is 2.00 cm. Find the percentage error in the calculated value of volume.

Solution **Ans.** 3

$$V = \pi r^2 h = \frac{\pi D^2 h}{4} \Rightarrow \frac{\Delta V}{V} = \frac{2\Delta D}{D}+\frac{\Delta h}{h} \quad \frac{\Delta V}{V}\times 100 = \left[2\times\left(\frac{0.01}{2.00}\right)+\left(\frac{0.1}{5.0}\right)\right]\times 100 = 3\%$$

EXERCISE–1 CHECK YOUR GRASP

MCQ's (only one correct answer)

1. Significant figures in 3400 are-
(A) 2 (B) 5 (C) 6 (D) 7

2. The percentage errors in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum error in the estimate of kinetic energy obtained by measuring mass and speed ?
(A) 11% (B) 8% (C) 5% (D) 1%

3. The density of a cube is measured by measuring its mass and the length of its side. If the maximum errors in the measurement of mass and length are 4% and 3% respectively, the maximum error in the measurement of the density is -
(A) 9% (B) 13% (C) 12% (D) 7%

4. An experiment measures quantities a, b and c, and X is calculated from $X = \frac{ab^2}{c^3}$. If the percentage error in a, b and c are ±1%, ±3% and ±2% respectively, the percentage error in X will be –
(A) ±13% (B) ±7% (C) ±4% (D) ±1%

5. If error in measuring diameter of a circle is 4%, the error in the radius of the circle would be
(A) 2% (B) 8% (C) 4% (D) 1%

6. If a, b, c are the percentage errors in the measurement of A, B and C, then percentage error in ABC would be approximately -
(A) abc (B) a + b + c (C) ab + bc + ac (D) $\frac{a}{b}+\frac{b}{c}+\frac{c}{a}$

7. The diameter of a wire is measured with a screw gauze having least count 0.01 mm. Which of the following correctly expresses the diameter –
(A) 0.20 cm (B) 0.002 m (C) 2.00 mm (D) 0.2 cm

8. While measuring acceleration due to gravity by a simple pendulum a student makes a positive error of 1% in the length of the pendulum and a negative error of 3% in the value of the time period. His percentage error in the measurement of the value of g will be -
(A) 2% (B) 4% (C) 7% (D) 10%

9. A student measured the diameter of a wire using a screw gauge with least count 0.001 cm and listed the measurements. The correct measurement is –
(A) 5.3 cm (B) 5.32 cm (C) 5.320 cm (D) 5.3200 cm

10. The pressure on a square plate is measured by measuring the force on the plate and the length of the sides of the plate. If the maximum error in the measurement of force and length are respectively 4% and 2%, the maximum error in the measurement of pressure is –
(A) 1% (B) 2% (C) 6% (D) 8%

11. When a copper sphere is heated, maximum percentage change will be observed in–
(A) radius (B) area (C) volume (D) none of these

12. The period of oscillation of a simple pendulum in the experiment is recorded as 2.63s, 2.56s, 2.42s, 2.71s and 2.80s respectively. The average absolute error is
(A) 0.1s (B) 0.11s (C) 0.01s (D) 1.0s

13. The significant digits in 200.40 are
(A) 4 (B) 5 (C) 2 (D) 3

14. A scientist performs an experiment in order to measure a certain physical quantity and takes 100 observations. He repeats the same experiment and takes 400 observations, by doing so
(A) The possible error remains same (B) The possible error is doubled
(C) The possible error is halved (D) The possible error is reduced to one fourth

15. A quantity is represented by $X = M^a L^b T^c$. The percentage error in measurement of M, L and T are α%, β % and γ % respectively. The percentage error in X would be
(A) $(\alpha a + \beta b + \gamma c)$ % (B) $(\alpha a - \beta b + \gamma c)$ % (C) $(\alpha a - \beta b - \gamma c)$ % (D) None of these

16. If error in measuring diameter of a circle is 4 %, the error in circumference of the circle would be :-
(A) 2% (B) 8% (C) 4% (D) 1%

17. A wire has a mass (0.3±0.003) g, radius (0.5±0.005) mm and length (6 ± 0.06) cm. The maximum percentage error in the measurement of its density is –
(A) 1 (B) 2 (C) 3 (D) 4

18. The length of a cylinder is measured with a metre rod having least count 0.1 cm. Its diameter is measured with vernier callipers having least count 0.01 cm. Given the length is 5.0 cm and diameter is 2.00 cm. The percentage error in the calculated value of volume will be –
(A) 2% (B) 1% (C) 3% (D) 4%

19. The volume of a sphere is 1.76 cm^3. The volume of 25 such spheres taking into account the significant figure is-
(A) 0.44 10^2 cm^3 (B) 44.0 cm^3 (C) 44 cm^3 (D) 44.00 cm^3

20. What is the fractional error in g calculated from $T = 2\pi\sqrt{\frac{\ell}{g}}$? Given that fractional errors in T and ℓ are ± x and ± y respectively.
(A) x + y (B) x – y (C) 2x + y (D) 2x – y)

21. The resistance is $R = \frac{V}{I}$ where V = 100 ± 5 Volts and I = 10 ± 0.2 amperes. What is the total error in R ?
(A) 5% (B) 7% (C) 5.2% (D) $\left(\frac{5}{2}\right)$%

22. The length, breadth and thickness of a strip are (10.0 ± 0.1)cm, (1.00 ± 0.01) cm and (0.100 ± 0.001) cm respectively. The most probable error in its volume will be
(A) ± 0.03 cm^3 (B) ± 0.111 cm^3 (C) ± 0.012 cm^3 (D) none of these

23. The external and internal radius of a hollow cylinder are measured to be (4.23 ± 0.01) cm and (3.89 ± 0.01) cm. The thickness of the wall of the cylinder is :-
(A) (0.34 ± 0.02)cm (B) (0.17 ± 0.02)cm (C) (0.17 ± 0.01)cm (D) (0.34 ± 0.01)cm

24. The radius of a disc is 1.2 cm. Its area according to idea of significant figures, will be given by:-
(A) 4.5216 cm^2 (B) 4.521 cm^2 (C) 4.52 cm^2 (D) 4.5 cm^2

25. The length ℓ, breadth b and thickness t of a block of wood were measured with the help of a measuring scale. The results with permissible errors are ℓ = 15.12 ± 0.01 cm, b = 10.15 ± 0.01 cm, t = 5.28 ± 0.01 cm. The percentage error in volume upto proper significant figures is –
(A) 0.28% (B) 0.36% (C) 0.48 % (D) 0.64%

26. The following observations were taken for determining surface tension of water by capillary tube method: Diameter of capillary D = 1.25 10^{-2} m Rise of water in capillary, h = 1.45 10^{-2} m. Taking g = 9.80 m/s^2 and using the relation T = (rhg/2) 10^3 N/m, what is the possible error in surface tension. T–
(A) 0.16% (B) 1.6% (C) 16% (D) 2.4%

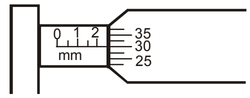
27. The least count of a stop watch is 1/5 sec. The time of 20 oscillations of a pendulum is measured to be 25 s. What is the maximum percentage error in this measurement
(A) 8% (B) 1% (C) 0.8% (D) 16%

28. The area of a rectangle of size 1.23 2.345 cm is
(A) 2.88 cm^2 (B) 2.884 cm^2 (C) 2.9 cm^2 (C) 2.88435 cm^2

29. What is vernier constant
(A) It is the value of the one main scale division by the total number of divisions on the main scale.
(B) It is the value of one vernier scale division divided by the total number of division on the vernier scale.
(C) It is the difference between value of one main scale division and one vernier scale division
(D) It is not the least count of vernier scale.

30. The vernier of a circular scale is divided into 30 divisions which coincide against 29 divisions of main scale. Each main scale division is 0.5 . The least count of the instrument is –
(A) 10' (B) 0.1' (C) 1' (D) 30'

31. What is the reading of micrometer screw gauge shown in figure



(A) 2.30 mm (B) 2.29 mm (C) 2.36 mm (D) 2.41 mm

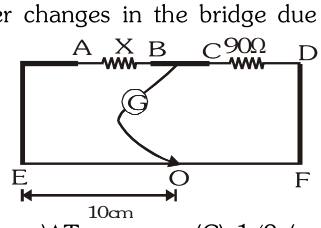
32. In a vernier calliper, N divisions of vernier scale coincide with (N – 1) divisions of main scale (in which 1 division represents 1mm). The least count of the instrument in cm. should be
(A) N (B) N – 1 (C) $\frac{1}{10N}$ (D) $\frac{1}{N-1}$

33. A vernier callipers having 1 main scale division = 0.1 cm is designed to have a least count of 0.02 cm. If n be the number of divisions on vernier scale and m be the length of vernier scale, then
(A) n= 10, m = 0.5 cm (B) n=9, m= 0.4 cm (C) n=10, m = 0.8 cm (D) n=10, m= 0.2 cm

34. In a vernier callipers, N divisions of the main scale coincide with N+m divisions of the vernier scale. What is the value of m for which the instrument has minimum least count?
(A) 1 (B) N (C) infinity (D) N/2

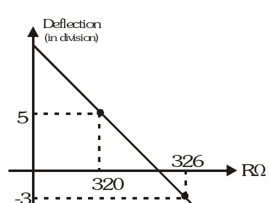
35. In a vernier callipers the main scale and the vernier scale are made up different materials. When the room temperature increases by ΔT C, it is found the reading of the instrument remains the same. Earlier it was observed that the front edge of the wooden rod placed for measurement crossed the N^{th} main scale division and N+2 MSD coincided with the 2nd VSD. Initially, 10 VSD coincided with 9 MSD. If coefficient of linear expansion of the main scale is α_1 and that of the vernier scale is α_2 then what is the value of α_1 / α_2? (Ignore the expansion of the rod on heating)
(A) 1.8 /N (B) 1.8/ (N+3.8) (C) 1.8/ (N–2) (D) 1.8/N+2

36. Consider the MB shown in the diagram, let the resistance X have temperature coefficient α_1 and the resistance from the RB have the temperature coefficient α_2. Let the reading of the meter scale be 10 cm from the LHS. If the temperature of the two resistance increase by small temperature ΔT then what is the shift in the position of the null point? Neglect all the other changes in the bridge due to temperature rise



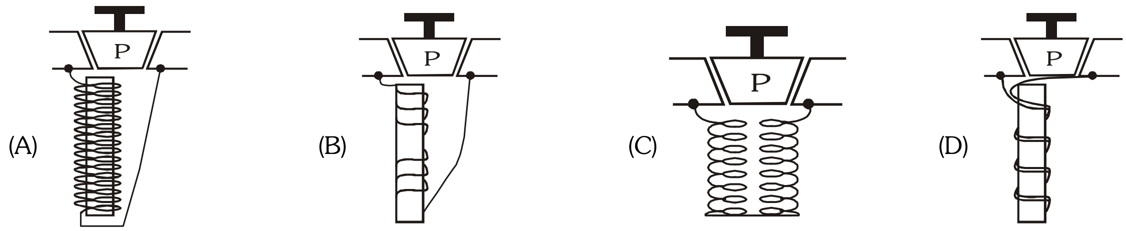
(A) $9(\alpha_1 - \alpha_2)\Delta T$ (B) $9(\alpha_1 + \alpha_2)\Delta T$ (C) $1/9(\alpha_1 + \alpha_2)\Delta T$ (D) $1/9(\alpha_1 - \alpha_2)\Delta T$

37. For a post office box, the graph of galvanometer deflection versus R (resistance pulled out of RB) for the ratio 100 : 1 is given as shown. A careless student pulls out two non consecutive values R marked in the graph. Find the value of unknown resistance



(A) 3.2 ohm (B) 3.24 ohm (C) 3.206 ohm (D) None

38. Identify which of the following diagrams represent the internal construction of the coils wound in a resistance box or PO box ?



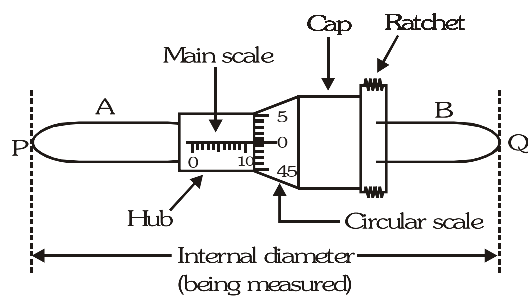
39. In a meter bridge set up, which of the following should be the properties of the one meter long wire?
(A) High resistivity and low temperature coefficient
(B) Low resistivity and low temperature coefficient
(C) low resistivity and high temperature coefficient
(D) High resistivity and high temperature coefficient

MCQ's (Multiple correct answer)

40. In the Searle's experiment, after every step of loading, why should we wait for two minutes before taking the readings? (More than one correct
(A) So that the wire can have its desired change in length
(B) So that the wire an attain room temperature
(C) So that vertical oscillations can get subsided
(D) So that the wire has no change in its radius

Comprehension

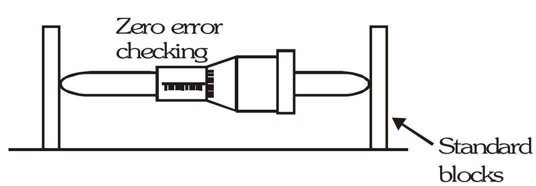
Internal micrometer is a measuring instrument used to measure internal diameter (ID) of a large cylinder bore with high accuracy. Construction is shown in figure. There is one fixed rod B (to the right in figure) and one moving rod A (to the left in figure). It is based on the principle of advancement of a screw when it is rotated in a nut with internal threads. Main scale reading can be directly seen on the hub which is fixed with respect to rod B. When the cap is rotated, rod A moves in or out depending on direction of rotation. The circular scale reading is seen by checking which division of circular scale coincides with the reference line.



This is to be multiplied by LC to get circular scale reading.

Least count = value of 1 circular scale division $= \dfrac{\text{pitch}}{\text{number of division on circular scale}}$

Length of rod A is chosen to match the ID (PQ) to be measured. Zero error is checked by taking reading between standard blocks fixed at nominal value of ID to be measured. Zero error is positive if cap end is on the right side of the main scale and negative it is on the left side.



1. In an internal micrometer, main scale division is of 0.5 mm and there are 50 divisions in circular scale. The least count of the instrument is -
(A) 0.005 mm (B) 0.001 mm (C) 0.05 mm (D) 0.01 mm

2. In the above instrument, while measuring an internal diameter. ID is set of 321 mm with no zero error. If cap end is after 7th division and 17th division of main scale coincides with the reference line, the ID is-

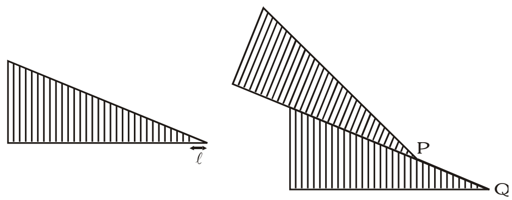
(A) 321. 717 mm (B) 321.87 mm (C) 328.17 mm (D) 324.67 mm

3. During zero setting of the above instrument, the end of the cap is on left side of the zero of main scale (i.e. zero of main scale is not visible) and 41[st] division of circular scale coincides with the reference line, the zero error is-
(A) –0.09 mm (B) +0.41 mm (C) –0.41 mm (D) +0.09 mm

Subjective Questions

1. In a given slide callipers 10 division of its vernier coincides with its 9 main scale divisions. If one main scale division is equal to 0.5 mm then find its least count.

2. Consider a home made vernier scale as shown in the figure. In this diagram, we are interested in measuring the length of the line PQ. If both the inclines are identical and their angles are equal to θ then what is the least count of the instrument.



3. The pitch of a screw gauge is l mm and there are 50 divisions on its cap. When nothing is put in between the studs, 44th division of the circular scale coincides with the reference line zero of the main scale is not visible. When a glass plate is placed between the studs, the main scale reads three divisions and the circular scale reads 26 divisions. Calculate the thickness of the plate.

4. A short circuit occurs in a telephone cable having a resistance of 0.45 Ωm^{-1} . The circuit is tested with a Wheatstone bridge. The two resistors in the ratio arms of the Wheatstone bridge network have values of 100Ω and 1110 Ω respectively. A balance condition is found when the variable resistor has a value of 400Ω. Calculate the distance down the cable, where the short has occurred.

5. A glass prism of angle A = 60 gives minimum angle of deviation θ = 30 with the maximum error of 1 when a beam of parallel light passed through the prism during an experiment. Find the permissible error in the measurement of refractive index μ of the material of the prism.

6. In a given optical bench, a needle of length 10 cm is used to estimate bench error. The object needle, image needle & lens holder have their reading as shown. x_0 = 1.1 cm; x_1 = 0.8 cm; x_L = 10.9 cm

Estimate the bench errors which are present in image needle holder and object needle holder. Also find the focal length of the convex lens when x_0 = 0.6 cm ; x_I = 22.5 cm; x_L = 11.4 cm

7. Consider S = x cos (θ) for x = (2.0 ± 0.2) cm, θ = 53 ± 2 . Find S.

ANSWER KEY

Single Choice Questions :

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	B	B	A	C	B	C	C	C	D	C	B	B	D	A	C
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
D	C	D	C	B	A	A	D	B	B	C	A	C	C	A	C
33	34	35	36	37	38	39	40								
C	A	B	A	B	D	A	ABC								

Comprehension : 1. D 2. D 3. A

Subjective Questions : 1. 0.05 mm 2. $LC = \ell\left[\frac{1-\cos\theta}{\cos\theta}\right]$ 3. R_t = 3.64 mm 4. 40m 5. $\frac{5\pi}{18}$%
6. 5.5 ± 0.05 cm 7. S = (1.2 ± 0.18) cm

EXERCISE–2(A) PREVIOUS YEARS QUESTIONS

1. The 'rad' is the correct unit used to report the measurement of : [AIEEE - 2006]
(1) the ability of a beam of gamma ray photons to produce ions in a target
(2) the energy delivered by radiation to a target
(3) the biological effect of radiation
(4) the rate of decay of a radioactive source

2. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are meausred by [AIEEE - 2008]
(1) a vernier scale provided on the microscope (2) a stanard laboratory scale
(3) a meter scale provided on the microscope (4) a screw gauge provided on the microscope

3. Two full turns of the circular scale of gauge cover a diastance of 1 mm on scale. The total number of divisions on circular scale is 50. Further, it is found that screw gauge has a zero error of -0.03 mm. While measuring the diameter of a thin wire a student notes the main scale reading of 3 mm and the number of circular scale division in line, with the main scale as 35. The diameter of the wire is [AIEEE - 2008]
(1) 3.32 mm (2) 3.73 mm (3) 3.67 mm (4) 3.38 mm

4. In an experiment the angles are required to be measured using an instrument 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree (=0.5), then the least count of the instrument is :- [AIEEE - 2009]
(1) One degree (2) Half degree (3) One minute (4) Half minute

5. In an optics experiment, with the position of the object fixed, a student varies the position of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45 with the x-axis meets the experimental curve at P. The coordinates of P will be :- [AIEEE - 2009]
(1) (f, f) (2) $(4f, 4f)$ (3) $(2f, 2f)$ (4) $\left(\frac{f}{2}, \frac{f}{2}\right)$

6. The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1 10^{-3} are:- [AIEEE - 2010]
(1) 4, 4, 2 (2) 5, 1, 2 (3) 5, 1, 5 (4) 5, 5, 2

7 . A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading : 0 mm. [AIEEE - 2011]
Circular scale reading : 52 divisions
Given that 1 mm on main scale corresponds to 100 divisions of the circular scale.
The diameter of wire from the above data is :-
(1) 0.026 cm (2) 0.005 cm (3) 0.52 cm (4) 0.052 cm

8. A spectrometer gives the following reading when used to measure the angle of a prism.
Main scale reading : 58.5 degree [AIEEE - 2012]
Vernier scale reading : 09 divisions
Given that 1 division on main scale corresponds to 0.5 degree. Total divisions on the vernier scale is 30 and match with 29 divisions of the main scale. The angle of the prism from the above data :]
(1) 59 degree (2) 58.59 degree (3) 58.77 degree (4) 58.65 degree

9. Resistance of a given wire is obtained by measuring the current flowing in it and the voltage difference applied across it. If the percentage errors in the measurement of the current and the voltage difference are 3% each, then error in the value of resistance of the wire is :- [AIEEE - 2012]
(1) 3% (2) 6% (3) zero (4) 1%

Que.	1	2	3	4	5	6	7	8	9
Ans.	3	1	4	3	3	2	4	4	2

EXERCISE–2(B) PREVIOUS YEARS QUESTIONS

MCQ With One Correct Answer

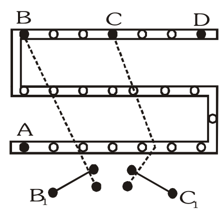
1. The edge of a cube is a = 1.2 10^{-2} m. Then its volume will be recorded as **[IIT-JEE 2003]**

(A) 1.7 10^{-6} m^3 (B) 1.70 10^{-6} m^3 (C) 1.70 10^{-7} m^3 (D) 1.78 10^{-6} m^3

2. A wire has a mass (0.3 ± 0.003)g, radius (0.5 ± 0.005) mm and length (6 ± 0.06) cm. The maximum percentage error in the measurement of its density is – **[IIT-JEE 2004]**

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

3. For the post office box arrangement to determine the value of unknown resistance, the unknown resistance should be connected between **[IIT-JEE 2004]**

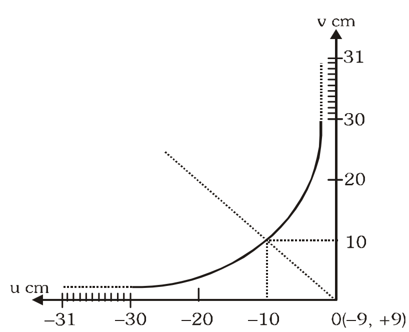


(A) B and C (B) C and D (C) A and D (D) B_1 and C_1

4. In a resonance column method, resonance occurs at two successive level of ℓ_1 = 30.7 cm and ℓ_2= 63.2 cm using a tuning fork of f = 512 Hz. What is the maximum error in measuring speed of sound using relations v = fλ & λ = 2 (ℓ_2–ℓ_1). **[IIT-JEE 2005]**

(A) 256 cm/sec (B) 92 cm/sec (C) 102.4 cm/sec (D) 204.8 cm/sec

5. Graph of position of image vs position of point object from a convex lens is shown. **[IIT-JEE 2006]**
Then, focal length of the lens is

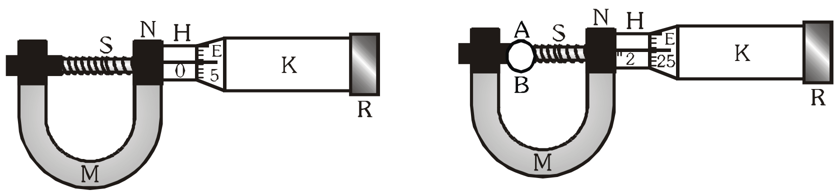


(A) 0.50 ± 0.05 cm (B) 0.50 ± 0.10 cm (C) 5.00 ± 0.05 cm (D) 5.00 ± 0.10 cm

6. A student performs an experiment for determination of $\left(g = \frac{4\pi^2\ell}{T^2}\right)$, ℓ ≈ 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 and he commits a human error of 0.1 s. For which of the following data, the measurement of g will be most accurate? **[IIT-JEE 2006]**

(A) ΔL = 0.5, ΔT = 0.1, n = 20 (B) ΔL = 0.5, ΔT = 0.1, n = 50
(C) ΔL = 0.5, ΔT = 0.01, n = 20 (D) ΔL = 0.1, ΔT = 0.05, n = 50

7. The circular scale of a screw gauge has 50 divisions and pitch of 0.5 mm. Find the diameter of sphere. Main scale reading is 2 – **[IIT-JEE 2006]**



(A) 1.2 (B) 1.25 (C) 2.207 (D) 2.25

8. A student performs an experiment to determine the Young's modulus of a wire, exactly 2m long, by Searle's method. In a particular reading, the student measures the extension in the length of the wire to be 0.8 mm with an uncertainty of ± 0.05 mm at a load of exactly 1.0 kg. The student also measures the diameter of the wire to be 0.4 mm with an uncertainty of ± 0.01 mm. Take g = 9.8 m/s^2 (exact). The Young's modulus obtained from the reading is – **[IIT-JEE 2007]**

(A) (2.0 ± 0.3) 10^{11} N/m^2 (B) (2.0 ± 0.2) 10^{11} N/m^2

(C) (2.0 ± 0.1) 10^{11} N/m^2 (D) (2.0 ± 0.05) 10^{11} N/m^2

9. In the experiment to determine the speed of sound using a resonance column – **[IIT-JEE 2007]**

(A) prongs of the tuning fork are kept in a vertical plane.

(B) prongs of the tuning fork are kept in a horizontal plane.

(C) in one of the two resonance observed, the length of the resonating air column is close to the wavelength of sound in air

(D) in one of the two resonance observed, the length of the resonating air column is close to half of the wavelength of sound in air

10. In an experiment to determine the focal length (f) of a concave mirror by the u-v method, a student placed the object pin A on the principal axis at a distance x from the pole P. The student looks at the pin and its inverted image from a distance keeping his/her eye in line with PA. When the student shift his/her eye towards left, the image appears to the right of the object pin. Then- **[IIT-JEE 2007]**

(A) $x < f$ (B) $f < x < 2f$ (C) $x = 2f$ (D) $x > 2f$

11. The diameter of a cylinder is measured using a Vernier callipers with no zero error. It is found that the zero of the Vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The Vernier scale has 50 divisions equivalent to 2.45 cm. The 24^{th} division of the Vernier scale excatly coincides with one of the main scale divisions. The diameter of the cylinder is :- **[JEE Advanced 2013]**

(A) 5.112 cm (B) 5.124 cm (C) 5.136 cm (D) 5.148 cm

12. Using the expression $2d \sin \theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90 . The wavelength λ is exactly known and the error in θ is constant for all values of θ. As θ increases from 0 :- **[JEE Advanced 2013]**

(A) the absolute error in d remains constant (B) the absolute error in d increases

(C) the fractional error in d remains constant (D) the fractional error in d decreases

<u>Multiple Choice Questions</u>

1. A student performed the experiment of determination of focal length of a concave mirror by u-v method using an optical bench of length 1.5 meter. The focal length of the mirror used is 24 m. The maximum error in the location of the image can 0.2 m. The 5 sets of (u, v) values recorded by the student (in cm) are : (42, 56), (48, 48),(60, 40), (66, 33), (78, 39). The data set(s) that connot come from experiment and is (are) incorrectly recorded is (are) **[IIT-JEE 2009]**

(A) (42, 56) (B) (48, 48) (C) (66, 33) (D) (78, 39)

2. A student performed the experiment to measure the speed of sound in air using resonance air-column method. Two resonances in the air-column were obtained by resonance and that with the longer air-column is the second resonance. Then, **[IIT-JEE 2009]**
   (A) The intensity of the sound heard at the first resonance was more than that at the second resonance
   (B) the prongs of the tuning fork were kept in a horizontal plane above the resonance tube
   (C) the amplitude of vibration of the ends of the prongs is typically around 1 cm
   (D) the length of the air-column at the first resonance was somewaht shorter than 1/4th of the wavelength of the sound in air

Subjective Questions

1. In a vernier callipers, n divisions of its main scale match with (n + 1) divisions on its vernier scale. Each division of the main scale is a units. Using the vernier principle, calculate its least count. **[IIT-JEE 2003]**

2. In a Searle's experiment, the diameter of the wire as measured by a screw gauge of least count 0.001 cm is 0.050 cm. The length, measured by a scale of least count 0.1 cm, is 110.0 cm. When a weight of 50N is suspended from the wire, the extension is measured to be 0.125 cm by a micrometer of least count 0.001 cm. Find the maximum error in the measurement of Young's modulus of the material of the wire from these data. **[IIT-JEE 2004]**

3. Draw the circuit for experimental verification of Ohm's law using a source of variable D.C. voltage, a main resistance of 100 Ω, two galvanometers and two resistance of values 10^6 Ω and 10^{-3} Ω respectively. Clearly show the positions of the voltmeter and the ammeter. **[IIT-JEE 2004]**

4. The pitch of a screw gauge is 1 mm and there are 100 divisions on the circular scale. While measuring the diameter of a wire, the linear scale reads 1 mm and 47^{th} division on the circular scale coincides with the reference line. The length of the wire is 5.6 cm. Find the curved surface area (in cm^2) of the wire in appropriate number of significant figures. **[IIT-JEE 2004]**

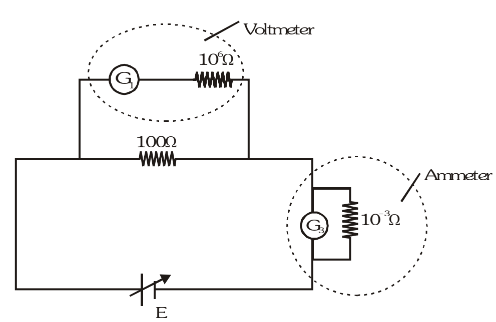
5. The edge of a cube is measured using a vernier calliper. (9 divisions of the main scale is equal to 10 divisions of vernier scale and 1 main scale division is 1 mm). The main scale division reading is 10 and 1 division of vernier scale was found to be coinciding with the main scale. The mass of the cube is 2.736 g. Calculate the density in g/cm^3 upto correct significant figures. **[IIT-JEE 2005]**

ANSWER KEY

Single Choice Questions : 1. A 2. D 3. C 4. D 5. C 6. D 7. A 8. B 9. A 10. B 11. B 12. D

Multiple Choice Questions : 1. C, D 2. A, D

Subjective Questions : 1. $\frac{a}{n+1}$ 2. 4.89% 3.



4. 2.6 cm^2 5. 2.66 g/cm^3