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Physics

Volume - I

SIERRA INNOVATIONS

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PHYSICS

VOLUME - I

CHAPTER 1

Physics and Measurement

CHAPTER OUTLINE

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INTRODUCTION

Physics is an experimental science, and experiments require the measuring of physical quantities. Measuring a physical quantity includes comparing it to a reference standard known as the quantity's unit. Some physical quantities are defined as base quantities, and other values are called derived quantities since they are stated in terms of the base quantities. This results in a system of base quantities and their units.

UNIT

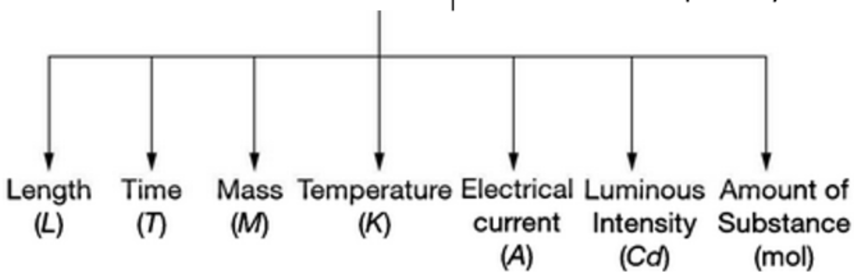
All physical quantity is measured by comparing it to a basic, arbitrarily selected, internationally accepted reference standard known as a unit.

Although the number of physical quantities appears to be quite vast, we only use a small number of units to express all of them because they are inter-related. Fundamental or base units are the units for fundamental or base quantities. All additional physical values have units that are combinations of the fundamental units. The units obtained for the derived quantities are referred to as derived units. The system of units is a complete set of these units, including both basic and derived units.

FUNDAMENTAL AND DERIVED QUANTITIES

The fundamental quantities are the basic physical quantities that are independent of other quantities. Mass, length, and time, for example, are considered fundamental quantities. In the same way, derived units are units that can be derived from basic units. Almost all quantities in mechanics can be described in terms of mass, length, and time.

fundamental quantity



The main systems of units are given as follows:

(a) CGS or Centimetre, Gram, Second System

(b) FPS or Foot, Pound, Second System

(c) MKS or Metre, Kilogram, Second System

(d) SI system: Totally, there are seven basic or fundamental quantities in the international system of units called the SI system which can express all physical quantities including heat, optics and electricity and magnetism.

SI Units			
Base quantity	**Name**	**Symbol**	**Definition**
Length	Metre	m	The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299792458 when expressed in the unit ms^{-1}, where the second is defined in terms of the caesium frequency ∆VCS.
Mass	Kilogram	kg	The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be 6.62607015 10^{-34} when expressed in the unit J s, which is equal to kg m^2s^{-1}, where the metre and the second are defined in terms of c and ∆VCS.
Time	Second	s	The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency ∆VCS, the unperturbed ground-state hyperfine transition frequency of the caesium-133 atom, to be 9192631770 when expressed in the unit Hz, which is equal to s^{-1}.
Electric	Ampere	A	The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be 1.602176634 10^{-19} when expressed in the unit C, which is equal to A s, where the second is defined in terms of ∆VCS.
Thermo dynamic Temperature	Kelvin	K	The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380649 10^{-23} when expressed in the unit $JK^{-1,}$ which is equal to kg $m^2s^{-2}k^{-1}$, where the kilogram, metre and second are defined in terms of h, c and ∆VCS.
Amount of substance	Mole	mol	The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly 6.02214076 10^{23} elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number. The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

Luminous intensity	Candela	cd	The candela, symbol cd, is the SI unit of luminous intensity in given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540 10^{12} Hz, K_{cd}, to be 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr kg^{-1} $m^{-2}s^{3}$, where the kilogram, metre and second are defined in terms of h, c and ΔVCS.

These are some basics of physical quantity
There are also two supplementary units used as radian (rad) for plane angle and steradian (sr) for solid angle. The unit for plane angle is radian with the symbol **rad** and the unit for the solid angle is steradian with the symbol **sr**. Both these are dimensionless quantities

DIMENSIONS OF PHYSICAL QUANTITIES

The dimensions of a physical quantity describe its nature. All derived unit physical quantities can be expressed in the form of some combination of seven fundamental or basic quantities. These fundamental values will be symbolized by square brackets [] as the seven dimensions of the physical world.
Thus, length has the dimension [L], mass [M], time [T], electric current [A], thermodynamic temperature [K], luminous intensity [cd], and amount of substance [mol]
The dimensions of a physical quantity are the powers (or exponents) to which the base quantities are raised to represent that quantity.
For example, the volume occupied by an object is expressed as the product of length, breadth and height, or three lengths. Hence the dimensions of volume are $[L] \times [L] \times [L] = [L]^3 = [L^3]$.
As the volume is independent of mass and time, it is said to possess zero dimension in mass [M°], zero dimension in time [T°] and three dimensions in length

DIMENSIONAL FORMULAE AND DIMENSIONAL EQUATIONS

The dimensional equation of a physical quantity is an equation formed by equating a physical quantity with its dimensional formula. For instance, consider the dimensional equations of volume [V], speed [v], force [F] and mass density [ρ] may be expressed as

$[V] = [M^{\circ} L^{3} T^{\circ}]$

$[v] = [M^{\circ} L T^{-1}]$

$[F] = [M L T^{-2}]$

$[\rho] = [M L^{-3} T^{\circ}]$

The dimensional equation can be derived from the equation expressing the physical quantity correlations. The dimensional equation can be derived from the equation expressing the physical quantity correlations. Dimensional formulas for a large number and range of physical quantities,

Table: Some units retained for general use (Though outside SI)

Name	Symbol	Value in SI Unit
Minute	min	60 s
Hour	h	60 min = 3600 s
Day	d	24 h = 86400 s
Year	y	365.25 d = 3.156×10^{7} s
Degree	°	1° = (π/180) rad

Litre	L	1 $dm^3 = 10^{-3}$ m^3
Tonne	t	10^3 kg
Carat	c	200 mg
Bar	bar	0.1 MPa = 10^5 Pa
Curie	Ci	3.7×10^{10} s^{-1}
Roentgen	R	2.58×10^{-4} C/kg
Quintal	q	100 kg
Barn	b	100 $fm^2 = 10^{-28}$ m^2
Are	a	1 $dam^2 = 10^2$ m^2
Hectare	ha	1 $hm^2 = 10^4$ m^2
Standard atmospheric pressure	atm	101325 Pa = 1.013×10^5 Pa

Various Physical Quantities, there Relation with Fundamental Quantities and Dimensional Formulae

S.No.	Physical Quantity	Relation with other quantities	Dimensional formulae	Unit in S.I. system
1.	Length, Width, Height, Displacement (l)	-	$[M^0 L^1 T^0]$	m
2.	Area (A)	length × length	$[M^0 L^2 T^0]$	m^2
3.	Volume (V)	length × length × length	$[M^0 L^3 T^0]$	m^3
4.	Velocity (v)	Displacement/time	$[M^0 L^1 T^{-1}]$	m/s
5.	Acceleration, Gravitation Acceleration (g)	Change in velocity/time	$[M^0 L^1 T^{-2}]$	m/s^2
6.	Density (d)	Mass/volume	$[M^1 L^{-3} T^0]$	kg/m^3
7.	Linear Momentum (P)	Mass × velocity	$[M^1 L^1 T^1]$	kg m/s
8.	Force (F)	Mass × acceleration	$[M^1 L^1 T^2]$	kg m/s^2 – N
9.	Impulse (J or I)	Force × time	$[M^1 L^1 T^{-1}]$	N s
10.	Pressure (P)	Force / area	$[M^1 L^{-1} T^2]$	N/m^2
11.	Universal Gravitational Constant (G)	$G = (F \times r^2)/(m_1m_2)$	$[M^{-1} L^3 T^2]$	N m^2/kg^2
12.	Work (W), Energy (E)	Force × displacement	$[M^1 L^2 T^{-2}]$	J
13.	Power (P)	Work / time	$[M^1 L^2 T^3]$	W
14.	Surface Tension (T)	Force / length	$[M^1 L^0 T^2]$	N/m
15.	Force Constant (K)	Force / displacement	$[M^1 L^0 T^2]$	N/m
16.	Radius of Gyration (k)	Distance	$[M^0 L^1 T^0]$	M
17.	Moment of Inertia (I)	Mass × distance^2	$[M^1 L^2 T^0]$	kg m^2
18.	Frequency (v)	Vibration / time	$[M^0 L^0 T^1]$	Hz
19.	Angle (θ)	Arc / radius	$[M^0 L^0 T^1]$	rad
20.	Angular Velocity (ω)	Angle / time interval	$[M^0 L^0 T^1]$	rad/s
21.	Angular Acceleration (α)	Angular Velocity / time interval	$[M^0 L^0 T^{-2}]$	rad/s^2
22.	Angular Momentum (J or L)	Momentum × perpendicular distance	$[M^1 L^2 T^{-1}]$	kg m^2/s
23.	Torque or couple (τ)	Force × perpendicular distance	$[M^1 L^2 T^{-2}]$	kg m^2/s^2 or Nm

24.	Stress	Reaction force / area	$[M^1 L^{-1} T^{-2}]$	N/m^2
25.	Strain	Change in configuration / initial configuration	$[M^0 L^0 T^0]$	No any (unit less)
26.	Planck Constant (h)	Energy / frequency	$[M^1 L^2 T^{-1}]$	J s
27.	Velocity Gradient	Velocity / distance	$[M^0 L^0 T^{-1}]$	s^{-1}
28.	Elasticity Constant	Stress / strain	$[M^1 L^{-1} T^{-2}]$	N/m^2
29.	Wavelength	Distance	$[M^0 L^1 T^0]$	m
30.	Pressure Gradient	Pressure / distance	$[M^1 L^{-2} T^2]$	N/m^2
31.	Viscosity Coefficient (η)	Force / area × velocity gradient	$[M^1 L^{-1} T^1]$	$N\ s/m^2$
32.	Surface Energy Density	Energy / area	$[M^1 L^0 T^{-2}]$	J/m^2
33.	Pressure Energy	Pressure × volume	$[M^1 L^2 T^{-2}]$	J
34.	Specific Heat	Energy / mass × rise in temperature	$[M^0 L^2 T^{-2} K^{-1}]$	J/kg K
35.	Heat Capacity, Entropy	Mass × Specific heat	$[M^1 L^2 T^2 K^{-1}]$	J/K
36.	Stefan Constant (σ)	Energy / area × time × temperature	$[M^1 L^0 T^2 K^{-4}]$	$J\ m^{-7}s^{-1}K^4$
37.	Boltzmann Constant (K)	Kinetic energy / temperature	$[M^1 L^2 T^2 K^{-1}]$	J/K
38.	Latent Heat	Heat energy / mass	$[M^0 L^2 T^0]$	J/ kg
39.	Activity (A)	Disintegration / time	$[M^0 L^0 T^{-1}]$	Disintegration n/s or s^{-1}
40.	Wein's Constant (b)	Wavelength × temperature difference	$[M^0 L^1 T^0 K^1]$	m K
41.	Charge (Q)	Current × time	$[M^0 L^0 T^1 A^1]$	C
42.	Potential Difference (V)	Work / charge	$[M^1 L^2 T^0 A^{-1}]$	V
43.	Resistance (R)	Potential Difference / current	$[M^1 L^2 T^{-3} A^{-2}]$	Ω
44.	Capacitance (C)	Charge / Potential Difference	$[M^{-1} L^{-2} T^4 A^2]$	F
45.	Current Density (J)	Electric Current / area	$[M^0 L^{-2} T^0 A^3]$	A/m^2
46.	Conductance (G)	1/Resistance	$[M^1 L^2 T^3 A^2]$	Ω^{-1}
47.	Electric Field (B)	Electric Force/charge	$[M^1 L^1 T^3 A^{-1}]$	N/C
48.	Electric Flux (ϕ_E)	Electric Field × area	$[M^1 L^3 T^{-1} A^{-1}]$	V m
49.	Magnetic Field	Force / current × length	$[M^1 L^0 T^2 A^{-1}]$	T
50.	Magnetic Flux (ϕ_θ)	Magnetic Field × area	$[M^1 L^2 T^2 A^{-1}]$	Wb
51.	Magnetic Dipole Moment	Torque / Magnetic Field	$[M^0 L^2 T^0 A^1]$	$A\ m^2$

DIMENSIONAL ANALYSIS AND ITS APPLICATIONS

Dimensional analysis contributes in the derivation, precision, and dimensional consistency or homogeneity of diverse mathematical expressions. When multiplying the magnitudes of two or more physical quantities, their units must be treated as standard algebraic symbols. Units in the numerator and denominator that are identical can be cancelled. The same is true for the dimensions of physical quantities. Physical values represented by symbols on both sides of a mathematical equation must have the same dimensions, as well.

USES OF DIMENSIONS EQUATION

The dimension equation can be applied in the following ways.:

(a) Conversion from one unit system to another.

(b) To validate and test the accuracy of a physical equation or formula.

(c) To establish a link between various physical quantities in any physical phenomenon.

(c) Conversion from one unit system to another:

(e) To verify and validate the accuracy of a physical equation or formula.

PRINCIPLE OF HOMOGENEITY

Only physical values with the same dimensions can have their magnitudes added or removed from one another.

In other words, we can add and subtract physical quantities that are equivalent. As a result, velocity cannot be added to force, nor can an electric current be removed from thermodynamic temperature. This fundamental principle is known as the principle of dimension homogeneity.

To derive a link between different physical quantities in any physical phenomenon: for example, if a physical quantity is dependent on a number of parameters whose dimensions are unknown, the principle of dimension homogeneity can be utilized.

LIMITATIONS OF DIMENSIONS

(a) The nature of physical quantities, i.e. whether a given quantity is scalar or vector, cannot be determined from a dimensionless equation.

(b) The value of the proportionality constant is also unknown.

(c) No relationship can be formed between physical values with exponential, logarithmic, and trigonometric functions.

Some Prefix

Table: SI prefixes

Power of 10	Prefix	Symbol
18	exa	E
15	peta	P
12	tera	T
9	giga	G
6	mega	M
3	kilo	k
2	hecto	h
1	deka	da
– 1	deci	d
– 2	centi	c
– 3	milli	m
– 6	micro	μ
– 9	nano	n
– 12	pico	p
– 15	femto	f
– 18	atto	a

Some question related to unit and dimension

1. $\frac{\alpha}{t^2} = Fv + \frac{\beta}{x^2}$

Find dimension formula for $[\alpha]$ and $[\beta]$

(here t = time, F = force, v = velocity, x = distance)

Solution:

Since $[Fv] = M^1 L^2 T^{-3}$,

So $\left[\frac{\beta}{x^2}\right]$ should also be $M^1 L^2 T^{-3}$

$$\frac{[\beta]}{[x^2]} = M^1 L^2 T^{-3}$$

$[\beta] = M^1 L^4 L^{-3}$

and $\left[Fv + \frac{\beta}{x^2}\right]$ will also have dimension $M^1L^2T^{-3}$

So $$\frac{[\alpha]}{[t^2]} = M^1 L^2 T^{-3}$$

$[\alpha] = M^1 L^2 T^{-1}$

2. For n moles of gas, Van der Waal's equation i

$$\left(P-\frac{a}{V^2}\right)(V-b)=nRT$$

Find the dimensions of a and b, where P is gas

v = volume of gas T = temperature of gas

Solution:

$\left(P-\frac{a}{V^2}\right)$ (V – b) = nRT

↑ Should be a kind of pressure ↑ should be a kind of volume

So $\frac{[a]}{[V^2]}=M^1L^{-1}T^{-2}$

So $[\beta] = L^3$

$\frac{[a]}{[L^3]^2}=M^{-1}L^{-1}T^{-2}$

$\Rightarrow$ $[a] = M^1 L^5 T^{-2}$

3. $\alpha=\frac{F}{V^2}\sin(\beta t)$

(here v = velocity, F = force, t = time)

Find the dimension of α and β

Solution:

So $[\alpha]=\frac{[F]}{[v^2]}$

$=\frac{[M^1L^1T^{-2}]}{[L^1T^{-1}]^2}=M^1L^{-1}T^0$

SIGNIFICANT FIGURES

Generally, the reported measurement result is a number that contains all of the number's digits that are known accurately plus the first digit that is unknown. Significant digits or significant figures are the dependable digits plus the first uncertain digit. Alternatively, we might say that all properly known digits in a measurement plus the first uncertain digit create important numbers.

The length of an object stated after measurement to be 287.5 cm has four significant figures: digits 2, 8, 7, and 5 are confirmed, but digit 5 is doubtful. A change in units has no impact on the number of significant digits or figures in a measurement.

(1) For example, the length 2.308 cm has four significant figures. But in different units, the same value can be written as 0.02308 m or 23.08 mm or 23080 μm

All these numbers have the same number of significant figures (digits 2, 3, 0, 8), namely four. This shows that the location of decimal point is of no consequence in determining the number of significant figures

The example gives the following rules :

RULES FOR COUNTING SIGNIFICANT FIGURES

- All the non-zero digits are significant.
- All the zeros between two non-zero digits are significant, no matter where the decimal point is, if at all.
- If the number is less than 1, the zero(s) on the right of decimal point but to the left of the first non-zero digit are not significant. [In 0.00 2308, the underlined zeroes are not significant].
- The terminal or trailing zero in a number without a decimal point are not significant.
- [Thus 123 m = 12300 cm = 123000 mm has three significant figures, the trailing zero being not significant.]
- The trailing zero(s) in a number with a decimal point are significant. [The numbers 3.500 or 0.06900 have four significant figures each.]
- The power of 10 is irrelevant to the determination of significant figures. However, all zeroes appearing in the base number in the scientific notation are significant

Now suppose we change units, then 4.700 m = 470.0 cm = 4700 mm = 0.004700 km Since the last number has trailing zero(s) in a number with no decimal, we would conclude erroneously from observation (1) above that the number has two significant figures

RULES FOR ARITHMETIC OPERATIONS WITH SIGNIFICANT FIGURES

(1) In multiplication or division, the final result should retain as many significant figures as are there in the original number with the least significant figures

Example 1: Each side of a cube is measured to be 7.203 m. What are the total surface area and the volume of the cube to appropriate significant figures?

Answer: The number of significant figures in the measured length is 4. The calculated area and the volume should therefore be rounded off to 4 significant figures.

Surface area of the cube $= 6(7.203)^2\ m^2$
$= 311.299254\ m^2$
$= 311.3\ m^2$

Volume of the cube $= (7.203)^3\ m^3$
$= 373.714754\ m^3$
$= 373.7\ m^3$

Example 2: 5.74 g of a substance occupies 1.2 cm^3. Express its density by keeping the significant figures in view.

Answer: There are 3 significant figures in the measured mass whereas there are only 2 significant figures in the measured volume. Hence the density should be expressed to only 2 significant figures.

Density $= \frac{5.74}{1.2}\, g\, cm^{-3}$

$= 4.8\ g\ cm^{-3}$

(2) In addition, or subtraction, the final result should retain as many decimal places as are there in the number with the least decimal places. ex. of addition

Suppose we have to find out the sum of the numbers 436.32 gm, 227.2 g and 0.301 gm by arithmetic addition.

Solution:

$$\begin{array}{r} 436.32 \\ 227.2 \\ 0.301 \\ \hline 663.821 \end{array}$$

But the least precise measurement (227.2) gm is correct to only one decimal place. So final should be rounded off to one decimal place.

So, sum will be 663.8 gm

Rounding Off a Digit

(a) If the number to the right of the cut off digit is less than 5, the cut off digit is kept.
If it is greater than 5, the cut off digit increases by one.
For example, is rounded to 6.2 (two significant digits) and is rounded to 5.33 (three significant digits).

(b) If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is increased by 1. For example, is rounded off to three significant digits.

(c) If the digit to be dropped is simply 5 or 5 followed by zeroes, then the preceding digit is left unchanged if it is an even number. For example, or becomes after rounding off to two significant digits.

(d) If the digit to be dropped is 5 or 5 followed by zeroes, then the preceding digit is raised by one if it is an odd number.

ERROR ANALYSIS

The uncertainty in a measurement is referred to as error. The disparity between the measured and real values of a physical quantity under inquiry is referred to as this.

There are three methods for determining an error.

(i) Absolute error
(ii) Relative error
(iii) Percentage error

COMBINATION OF ERROR

Addition and Subtraction:- for both addition and subtraction, the absolute errors are to be added up.

$\Delta X = \pm (\Delta A + \Delta B)$

Example:

The original length of a wire is (153.7 $\pm$ 0.6) cm. It is stretched to (155.3 $\pm$ 0.2) cm. Calculate the elongation in the wire with error limits.

Solution:

Elongation (l) = 155.3 – 153.7 = 1.6 cm

$\Delta l = \pm (\Delta l_1 + \Delta l_2)$

$= \pm (0.6 + 0.2) = \pm 0.8$ cm

$\therefore$ Elongation = (1.6 $\pm$ 0.8) cm.

Multiplication and Division

In multiplication and division error formula will same

$$\frac{\Delta X}{X} = \pm\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$$

Example:

The measures of the lengths of a rectangle are l = (3.0 $\pm$ 0.01) cm and breadth b = (2.00 $\pm$ 0.02) cm. What the area of the rectangle?

Solution:

Area = lb = 3 × 2 = 6 cm^2

$$\text{Error} = \pm 6\left(\frac{0.01}{3} + \frac{0.02}{2}\right) = \pm 0.08\,\text{cm}^2$$

Area = (6.00 $\pm$ 0.08) cm^2.

Example:

The change in the velocity of a body is (12.5 $\pm$ 0.2) m/s in a time (5.0 $\pm$ 0.3) s. Find the average acceleration of the body within error limits.

Solution:

Here

v = (12.5 $\pm$ 0.2) m/s;   t = (5.0 $\pm$ 0.3) s

$$\therefore \quad a = \frac{12.5}{5.0} = 2.5\,\text{m/s}^{-2}$$

Also

$$\frac{\Delta a}{a} = \pm\left(\frac{\Delta v}{v} + \frac{\Delta t}{t}\right) = \pm\left(\frac{0.2}{12.5} + \frac{0.3}{5.0}\right) = \pm 0.08$$

$\Delta a = \pm (0.08 \times 2.5) = \pm 0.2$

a = (2.5 $\pm$ 0.2) m/s^2

Power Functions

Let $\quad X = \dfrac{A^n}{B^m}$

Then $\quad \ln(X) = n \ln(A) - m \ln(B)$

Differentiating both sides, we get

$$\frac{dX}{X} = n\cdot\frac{dA}{A} - m\frac{dB}{B}$$

Summery of Error Analysis in A Table View

Operation	Formula	Maximum Absolute Error	Maximum Relative Error	Maximum Percentage Error
Sum	A + B	$\Delta A + \Delta B$	$\frac{\Delta A + \Delta B}{A + B}$	$\left(\frac{\Delta A + \Delta B}{A + B}\right) \times 100$
Difference	A – B	$\Delta A + \Delta B$	$\frac{\Delta A + \Delta B}{A - B}$	$\left(\frac{\Delta A + \Delta B}{A - B}\right) \times 100$
Multiplication	A × B	$A\Delta B + B\Delta A$	$\frac{\Delta A}{A} + \frac{\Delta B}{B}$	$\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right) \times 100$
Division	$\frac{A}{B}$	$\frac{B\Delta A + A\Delta B}{B^2}$	$\frac{\Delta A}{A} + \frac{\Delta B}{B}$	$\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right) \times 100$
Power	A^n	$nA^{n-1}\,\Delta A$	$n\frac{\Delta A}{A}$	$n\frac{\Delta A}{A} \times 100$

LENGTH-MEASURING INSTRUMENTS

The fundamental physical quantity is length. A metre scale is the most used device for measuring length in everyday life.

to measure length accurately up to range in millimetre, we use the following instruments.

(1) Vernier calipers

(2) Micrometer

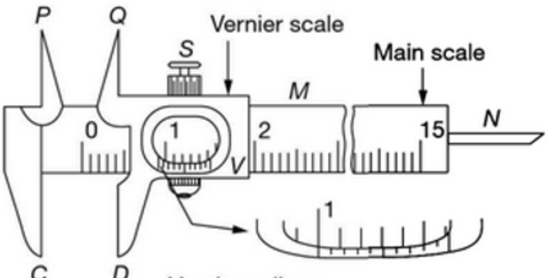
(3) Screw gauge

Vernier Calipers

This instrument has three parts.

1. Main scale
2. Vernier scale
3. Metallic strip

Vernier Calipers



Vernier calipers

(i) Main scale: It consists of a strip, graduated in and at one of its edge. Also, it carries two fixed jaws as shown in the above figure

(ii) Vernier scale: Vernier scale V slides on metallic strip. This scale can be fixed in any position by the screw

(iii) Metallic strip: There is a thin metallic strip attached to the back side of and connected with Vernier scale. When jaws and touch each other, the edge of touches the edge of. When the jaws and are separated, the moves outward. This strip is used for measuring the depth of a vessel.

There are two division in scale

1. Vernier Scale Divisions (VSD)
2. Main Scale Divisions (MSD).

Vernier constant (VC) or the least count (LC)

The difference between the values of one main scale division and one Vernier scale division is known as Vernier constant (VC) or the least count (LC). This is precisely the smallest distance that can be accurately measured with the Vernier scale.

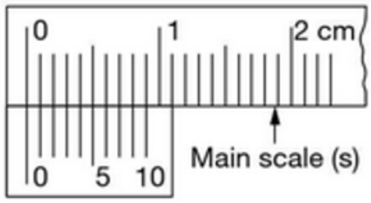
the least count of vernier calliper os 0.01cm

value of 10 division of vernier scale os 0.9mm

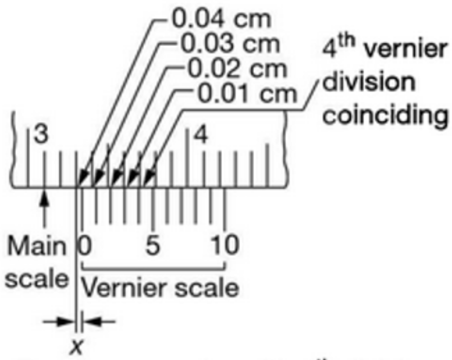
so the least count : 1mm -0.9mm = 0.01 cm

Reading a Vernier Caliper

If we need to measure a length, the end of the length coincides with the zero of the primary scale. Assume the end is somewhere between 1.0 and on the main scale.



Vernier scale (V)



Reading a vernier with 4th division coinciding

Zero Error and Zero Correction

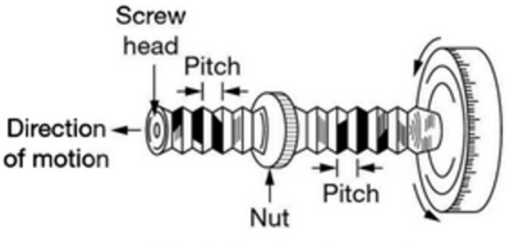
If the zero of the Vernier scale does not match with the zero of the main scale when jaw B contacts jaw and the straight edge of touches the straight edge of, the instrument has a zero mistake. This zero error is always algebraically removed from the measured length.

The magnitude of zero correction is equal to zero error, but its sign is opposite that of zero error. As a matter of generality, zero correction is always algebraically applied to the measured length. Subtraction of zero error algebraically Zero correction was added algebraically.

Positive and Negative Zero Error

When the zero of the Vernier scale is to the right of the main scale, the zero error is positive; when it is to the left of the main scale, the zero error is negative (when jaws and are in contact) When the Vernier zero precedes the main scale zero, the error is referred to as negative zero error. Negative zero error occurs when the fifth Vernier scale division coincides with the main scale division.

Principal of a Micrometer Screw

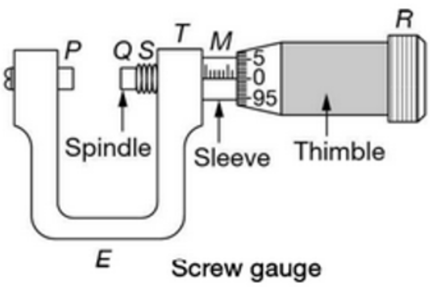


Principle of a micrometer

The standard count of Vernier calipers in the laboratory is, When measuring lengths with greater accuracy, say up to, screw gauge and spherometre are used When a precisely cut single threaded screw is turned in a tightly fitted nut, the screw head moves in a forward or backward direction along the screw's axis, in addition to the circular motion of the screw. The pitch (p) of the screw is the linear distance travelled by the screw after one complete spin. The pitch is defined as the distance between two successive threads measured along the screw's axis.

I If the circular scale (which we will explain later) is rotated through one circular division, the screw moves forward or backward by the pitch. This is the exact smallest distance that can be accurately determined, and it is referred to as the screw's least count (LC).

Screw Gauge



Screw gauge

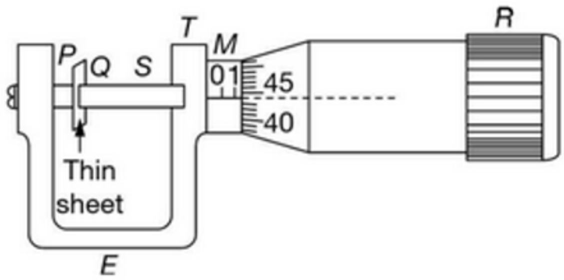
Screw gauges work on the same principle as micrometer screws. It is made up of a -shaped metal frame. A little metal piece is attached to one end of it. It has a planar face and is termed a clip. The other end of has a cylindrical hum.

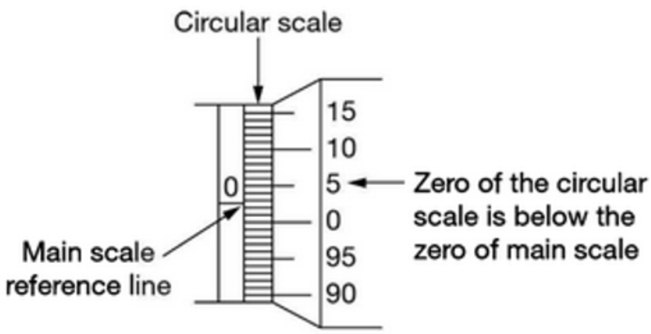
The screw pitch determines whether it is graduated in millimeters or half millimeters. This scale is known as a pitch scale or a linear scale.

A nut is inserted through the hub as well as the frame. A screw is moved through the nut. Yet, the screw's front face, which faces the plane face, is similarly plane in nature. When the screw is rotated, a hollow cylindrical cap is capable of spinning over the hub. The screw travels in or out as the cap is rotated. The cap's surface is divided into 50 or 100 equal pieces. The circular scale is also known as the head scale. When the faces and are just touching in an accurately set instrument, the zero of the circular scale should correspond with the zero of the linear scale.

To measure diameter of a given wire using a screw gauge

If, with the wire between plane faces and, the edge of the cap is ahead of the Nth division of the linear scale and the Nth division of the circular scale is over the reference line, then total reading should be taken by the instruments.





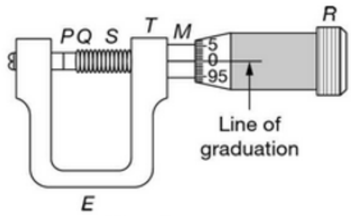
as shown in figure main scale and circular scale coincide the accurte reading can be taken.

Zero Error and Zero Correction

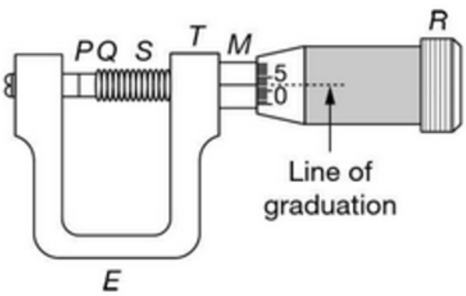
When the faces and are just touching each other and the zero mark of the circular scale does not correspond with the zero of the pitch scale, the instrument is said to have zero error.

Positive Zero Error Negative Zero Error

If the zero of the circular scale moves beyond the reference line, the zero error becomes negative and the zero correction becomes positive. Also, if it is placed behind the reference line, the zero error becomes positive and the zero correction becomes negative.



Negative zero error
(3 division error) i.e.,–0.003 cm



Negative zero error
(2 division error) i.e.,+0.002 cm

For example, if the zero of the circular scale moves beyond the reference line by 5 divisions, the zero correction L.C. is zero, and if the zero of the circular scale is 4 divisions behind the reference line, the zero correction L.C. is zero.

Backlash error

When the screw's rotational orientation is immediately changed, the screw head may revolve but the screw itself may not travel forward or backward. As a result, even if the screw is moved, the scale reading may not change. This is known as the Backlash error.

This error is caused by a loose screw. This is caused primarily by threading corrosion and deterioration from extensive screw use. To reduce this inaccuracy, we recommend that the screw be twisted in the same direction for each set of observations.