UNITS DIMENSIONS & MEASUREMENT

Abhilash Sharma

B.Tech - NIT Calicut

- Experience - 8+ years
- 700+ selections in JEE Advanced
- 6000+ selections in JEE Mains

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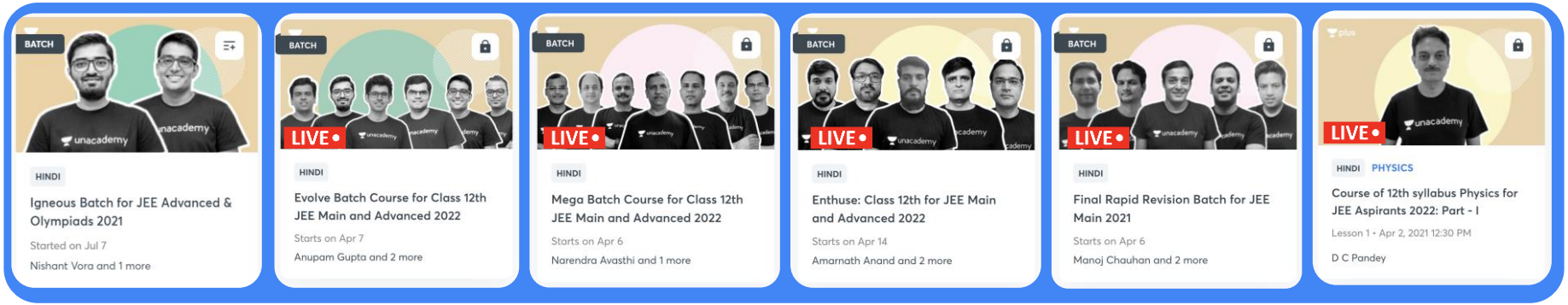

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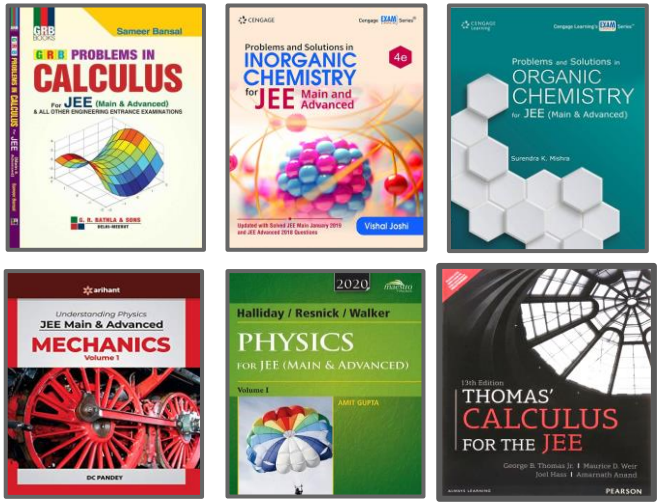

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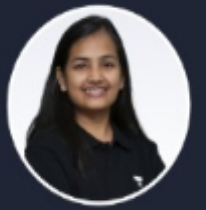

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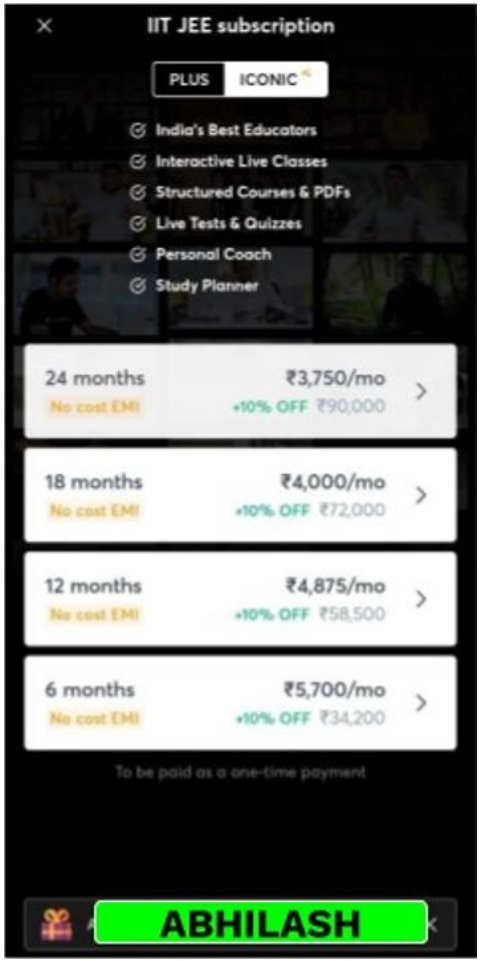
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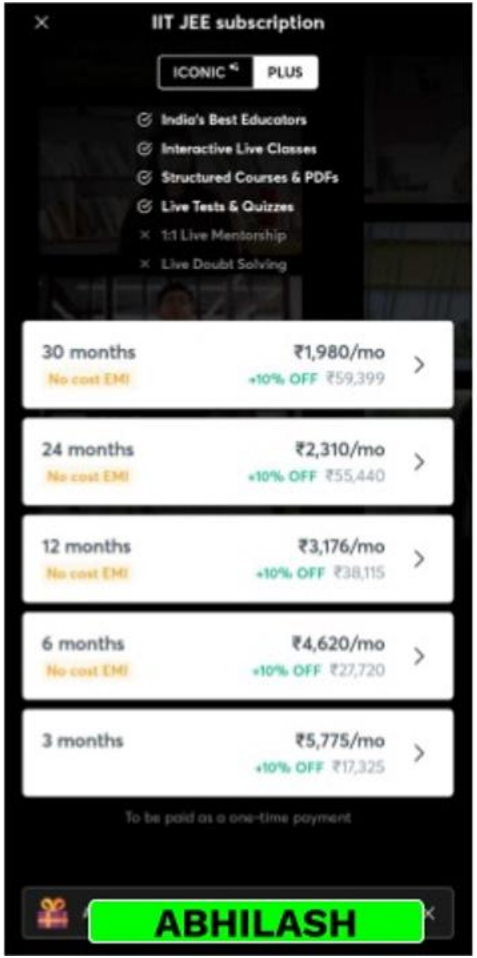
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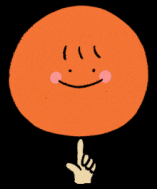
Guaranteed 1-2 Questions in JEE Main & JEE Advanced

Units Dimension & Measurement



Content of the lecture

Basic via Main to Advanced

1. Units & Dimension
2. Significant Figures & Rounding Off
3. Error Analysis
4. Vernier Caliper & Screw Gauge
5. Errors in Vernier Caliper & Screw Gauge
6. Special JEE Advanced Problems

Unacademy Atoms

हमारे छोटे-छोटे प्रयासों की वजह से ही बड़ी कामयाबी मिलती है। इसलिए हर एक प्रयास महत्वपूर्ण होता है।

Physical Quantities

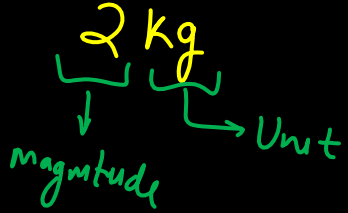
A quantity which can be measured (quantized)

Example : length, mass, time, force etc.

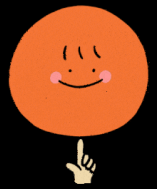
On the other hand, happiness, sorrow etc. are not physical quantities

Units

Physical quantity (Q) = Magnitude x Unit = n x u



4 Litre



Types of Quantities

Only 7

1. Fundamental Quantities
2. Derived Quantities

Fundamental & Derived Quantities

26 Alphabet

52 Alphabet

Types of Physical Quantities

Fundamental Quantities

These are only few (7) quantities which are independent of all other quantities and they act as basis for all other quantities.

Derived Quantities

All other physical quantities can be derived by suitable multiplication or division of different powers of fundamental quantities.

7 Fundamental Quantities

$$Acc = \frac{\Delta V}{\Delta t} = \frac{d/t}{t} = \frac{L}{T^2}$$

$$I = \frac{Q}{T}$$

$$\boxed{Q = IT}$$

Easy to Measure ← 4)

	Magnitude	Unit	Symbol
1)	length	metre	m / L
2)	mass	kilogram	kg / M
3)	time	second	s / T
4)	electric current ~~intensity~~	ampere	A / I
5)	thermodynamic temperature	kelvin	K / k or θ
6)	quantity of matter	mole	mol / n
7)	luminous intensity	candela	cd / S

System of Units

System of units: A complete set of units, both fundamental and derived for all kinds of physical quantities is called system of units.

$l \Rightarrow 2\ \text{metre} = 200\ \text{cm}$

$m \Rightarrow 4\ \text{kg} \Rightarrow 4000\ \text{gram}$

$\text{Speed} = 18\ \frac{\text{km}}{\text{hr}} = 5\ \text{m/s}$

System of Units

L, M, T

CGS/Gaussian system: In it length, mass and time have units centimeter (cm), gram (g) and second (s) respectively.

(SI Unit)

MKS/Giorgi system: In this system length, mass and time have units metre, kilogram and second.

FPS system: In this system foot, pound and second are used respectively for measurements of length, mass and time.

System of Units

System	Length	Mass	Time
F.P.S.	foot	pound	second
C.G.S.	centimetre	gram	second
M.K.S.	metre	kilogram	second

Unitless Quantities

Ratio (numerical value only): When a physical quantity is a ratio of two similar quantities, it has no unit. For example,

1)Relative density = Density of object/Density of water at 4°C

2)Refractive index = Velocity of light in air/Velocity of light in medium

3)Strain = Change in dimension/Original dimension

Mercury (Hg)

$\rho_R = \frac{\rho_{Hg}}{\rho_{water}} = \frac{13.6 \times 10^3}{10^3}$

$= 13.6$

Note

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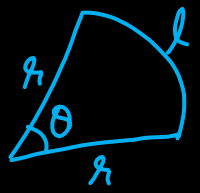
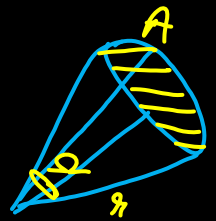
Angle is exceptional physical quantity, which though is a ratio of two similar physical quantities (angle = arc / radius) but still requires a unit (degrees or radians) to specify it along with its numerical value.



$\theta = \frac{l}{r} = \frac{\text{metre}}{\text{metre}}$

$\theta \Rightarrow$ degree OR Radian



$\Omega \Rightarrow$ Solid Angle

$\Omega = \frac{\text{Area}}{r^2}$

$\Rightarrow$ Steradian

Example

Find a suitable SI unit for Universal Gravitation Constant.

$$F = \frac{G m_1 m_2}{r^2}$$

$$N = \frac{[G]\ kg\ kg}{m^2}$$

$$[G] = \frac{Nm^2}{kg^2}$$

Unacademy Atoms

Express the SI unit of Energy(Joule) in terms of SI unit of Mass, Length and Time.

Energy $\Rightarrow$ 1 Joule

$$E = \frac{1}{2}mv^2 = kg\left(\frac{m}{s}\right)^2 = \frac{kgm^2}{sec^2}$$

Dimensions

When a derived quantity is expressed in terms of fundamental quantities, it is written as a product of different powers of the fundamental quantities. The powers are called its dimensions.

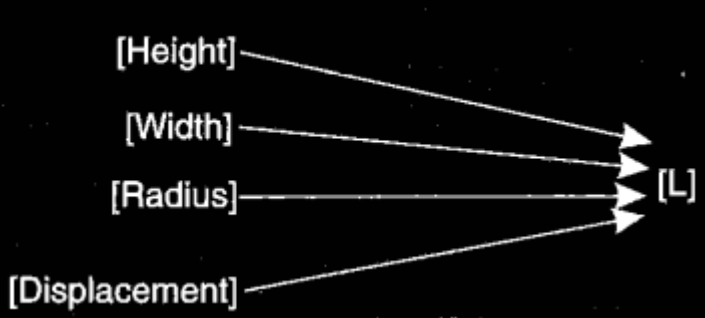
$$\text{Speed} = \frac{\text{distance}}{\text{time}} = \frac{L}{T} = L^1T^{-1}$$

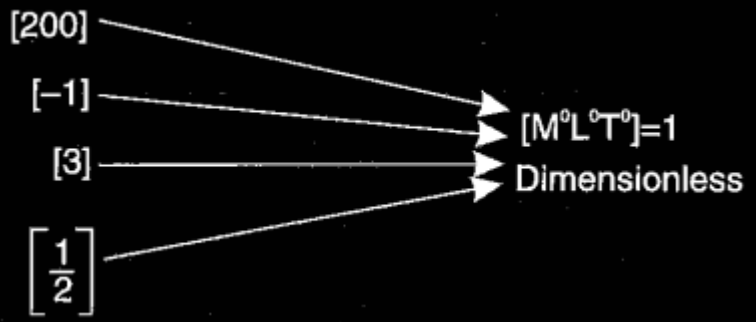
$\Rightarrow$ Dimension is (1) in Length, (−1) in time

Dimensions

Unit Name and Symbol	Dimension Symbol
Meter (m)	L
Kilogram (kg)	M
Second (s)	T
Ampere (A)	I
Kelvin (K)	Θ /k
Mole (mol)	N
Candela (cd)	J /s

Important points





$V = V_1 + V_2 \Rightarrow (V \Rightarrow L^3)$

$= L^3 + L^3$

$= 2L^3$

$2l \Rightarrow [L]$

Find Dimensions of Force

$$F = ma = m\frac{v}{t} = \frac{m\left(l/t\right)}{t} = \frac{ml}{t^2}$$

$$F \Rightarrow M^1L^1T^{-2}$$

Find the Dimensions of Energy

$$\text{Energy} = \text{Work} = F \cdot d$$

$$= (MLT^{-2}) \cdot (L)$$

$$E \Rightarrow ML^2T^{-2}$$

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The SI unit of a physical quantity is pascal - second. The dimensional formula of this quantity will be

[JEE Main 2022]

A. $[ML^{-1}T^{-1}]$

B. $[ML^{-1}T^{-2}]$

C. $[ML^{2}T^{-1}]$

D. $[M^{-1}L^{3}T^{0}]$

$X \Rightarrow Pa\ sec$

$X \Rightarrow (Pressure)(Time)$

$X = \left(\frac{F}{A}\right)(T)$

$= \left(\frac{MLT^{-2}}{L^2}\right)T$

$X = ML^{-1}T^{-1}$

Find the Dimensions of Voltage

Method (1)

$V = IR = I\frac{\rho l}{A}$

$V = \frac{W}{q} = \frac{\text{Energy}}{\text{Current} \times \text{time}}$

$V = \frac{ML^2T^{-2}}{IT}$

$V = ML^2I^{-1}T^{-3}$

Method (2)

$V = Ed$

$V = \left(\frac{F}{q}\right)d$

$V = \frac{\text{Energy}}{\text{Current} \times \text{time}}$

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Q

$V = IR$

$R = \frac{V}{I}$

In the following 'I' refers to current and the other symbols have their usual meaning. Choose the option that corresponds to the dimensions of electrical conductivity. (σ)

[JEE Mains 2019]

A. $M^{-1} L^{-3} T^{3} I$

B. $M^{-1} L^{-3} T^{3} I^{2}$

C. $M^{-1} L^{3} T^{3} I$

D. $ML^{-3} T^{-3} I^{2}$

$\sigma = \frac{1}{\rho}$ Conductivity $= \frac{1}{\text{Resistivity}}$

$R = \frac{\rho l}{A} \Rightarrow \frac{1}{\rho} = \frac{l}{AR} = \frac{l}{A\left(\frac{V}{I}\right)}$

$\frac{1}{\rho} = \frac{LI}{L^2\left(ML^2I^{-1}T^{-3}\right)} = M^{-1}L^{-3}I^{2}T^{3}$

A physical quantity $\vec{S}$ is defined as $\vec{S} = (\vec{E} \times \vec{B})/\mu_0$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity(ies) ?

[JEE Adv. 2021]

(A) $\frac{Energy}{Charge \times Current}$

(B) $\frac{Force}{Length \times Time}$

(C) $\frac{Energy}{Volume}$

(D) $\frac{Power}{Area}$

$E = BC$ ← 12th chapter
→ EM waves
→ Magnetic Energy

$\text{Energy Density} = \frac{B^2}{2\mu_0}$

$\text{Power} = \frac{W}{t}$

$S = \frac{EB}{\mu_0} = \frac{(BC)B}{\mu_0} = \left(\frac{B^2}{\mu_0}\right)C = \frac{\text{Energy}}{\text{Volume}} \times \text{Speed}$

$= \frac{\text{Energy}}{(L^3)}\left(\frac{L}{T}\right) = \frac{\text{Energy}/T}{L^2} = \frac{\text{Power}}{\text{Area}}$

$$S = \frac{\text{Energy}}{T\,(L^2)} = \frac{F\,d}{TL^2} = \frac{F\,L}{TL^2} = \frac{F}{TL}$$

Let us consider a system of units in which mass and angular momentum are dimensionless. If length has dimensions of L, which of the following statements(s) is/ are correct ?

[JEE Adv. 2019]

A. The dimension of force is L^{-2}

B. The dimension of linear momentum is L^{-1}

C. The dimension of energy is L^{-2}

D. The dimension of power is L^{-5}

B&C

$M = \text{Const}$

$L = \text{const.}$

$MVR = \text{const.}$

$(\text{Const})\left(\frac{L}{T}\right)(L) = \text{const}$

$\frac{L^2}{T} = \text{const}$

$L^2 = T$

A) $F = MLT^{-2} = (\text{const})(L)(L^2)^{-2} = L^{-3}$

B) $P = MV = (\text{const})(L/T) = \frac{L}{L^2} = L^{-1}$

c) $E = ML^2T^{-2} = (\text{const})(L^2)(L^2)^{-2}$

$= L^{2-4} = L^{-2}$

d) $\text{Power} = \frac{\text{Energy}}{\text{time}} = \frac{L^{-2}}{T} = \frac{L^{-2}}{L^2} = L^{-4}$

Dimensions

HW

Derive them

Velocity	$[L\ T^{-1}]$
Angular velocity	$[T^{-1}]$
Acceleration	$[L\ T^{-2}]$
Energy	$[M\ L^{2}\ T^{-2}]$
Energy density	$[M\ L^{-1}\ T^{-2}]$
Angular momentum	$[M\ L^{2}\ T^{-1}]$
Force	$[M\ L\ T^{-2}]$
Power	$[M\ L^{2}\ T^{-3}]$
Pressure	$[M\ L^{-1}\ T^{-2}]$
Density	$[M\ L^{-3}]$
Electric charge	$[I\ T]$
Electric potential	$[M\ L^{2}\ T^{-3}\ I^{-1}]$
Electric field	$[M\ L\ T^{-3}\ I^{-1}]$
Magnetic field	$[M\ T^{-2}\ I^{-1}]$

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Applications of Dimensional Analysis

1) To find Units of Physical constants

$$F = \frac{G_1 m_1 m_2}{r^2}$$

$$G_1 = \frac{Nm^2}{kg^2}$$

2) To find Dimensions of Physical constants

Plank's constant (h)

Photon Energy $= E = h\nu$ $\Rightarrow$ Energy $= [h][\text{frequency}]$

$$ML^2T^{-2} = [h]\left[\frac{1}{T}\right]$$

$$[h] = ML^2T^{-1}$$

Find the Dimensions of Viscosity (η)

$$F = \eta A \frac{dv}{dz}$$

$$MLT^{-2} = [\eta][L^2]\frac{[L/T]}{L}$$

$$\eta = ML^{-1}T^{-1}$$

3) Conversion of Units

$1\ cm = 0.01\ m$

$1\ m/s = \frac{18}{5}\ km/hr$

Dimensions remains same in all system of Unit

Step 1

$V = LT^{-1}$

Step 2

$1\ m/s = LT^{-1} = (1m)(1sec)^{-1}$

$1\ km/hr = LT^{-1} = (1km)(1hr)^{-1}$

Step 3

$$\frac{1\ m/s}{1\ km/hr} = \left(\frac{1\ m}{1\ km}\right)\left(\frac{1\ sec}{1\ hr}\right)^{-1} = \left(\frac{1m}{1km}\right)\left(\frac{1hr}{1sec}\right)^{+1}$$

$$\frac{1\ m/s}{1\ km/hr} = \left(\frac{1m}{1000m}\right)\left(\frac{3600\ sec}{1\ sec}\right) = \frac{18}{5}$$

$1\ m/s = \frac{18}{5}\ \frac{km}{hr}$ ⇐

[cm, g, sec] [m, kg, sec]

For Force, convert Dyne(CGS) to Newtons(MKS)

$1\ \text{Dyne} = MLT^{-2} = (1\ \text{gram})(1\ \text{cm})(1\ \text{sec})^{-2}$

$1\ \text{Newton} = MLT^{-2} = (1\ \text{kg})(1\ \text{m})(1\ \text{sec})^{-2}$

$$\Rightarrow \frac{1\ D}{1\ N} = \left(\frac{1\ \text{gram}}{1\ \text{kg}}\right)\left(\frac{1\ \text{cm}}{1\ \text{m}}\right)\left(\frac{1\ \text{sec}}{1\ \text{sec}}\right)^{-2} = \left(\frac{1\ \text{gram}}{1000\ \text{gram}}\right)\left(\frac{1\ \text{cm}}{100\ \text{cm}}\right)(1)^{-2}$$

$$\frac{1\ D}{1\ N} = (10^{-3})(10^{-2})(1)$$

$1\ D = 10^{-5}\ N \Rightarrow 1\ N = 10^{5}\ \text{Dyne}$

System 1	System 2
V_1	V_2
a_1	a_2
L_1	L_2
T_1	T_2

In two system of units the relation between velocity and acceleration given by $v_1 = (\alpha^2/\beta)\, v_2$ and $a_1 = (\alpha\beta)\, a_2$ where α and β are dimensionless constants. The relation between length and time in these two system of units will be

A. $L_1 = (\alpha^3/\beta^3)\, L_2$

B. $L_1 = (\alpha^2/\beta^3)\, L_2$

C. $T_1 = (\alpha^2/\beta^5)\, T_2$

D. $T_1 = (\alpha/\beta^2)\, T_2$

$$a_1 = (\alpha\beta)\, a_2$$

$$\frac{v_1}{t_1} = (\alpha\beta)\frac{v_2}{t_2}$$

$$\frac{(\alpha^2/\beta)v_2}{t_1} = \frac{(\alpha\beta)v_2}{t_2}$$ [Using Given data]

$$\frac{t_1}{\alpha^2/\beta} = \frac{t_2}{\alpha\beta} \Rightarrow t_1 = \frac{\alpha}{\beta^2} t_2$$

$$V_1 = \frac{\alpha^2}{\beta} V_2$$

$$\frac{L_1}{T_1} = \frac{\alpha^2}{\beta}\left(\frac{L_2}{T_2}\right)$$

$$\frac{L_1}{\left(\frac{\alpha}{\beta^2} t_2\right)} = \frac{\alpha^2}{\beta}\left(\frac{L_2}{t_2}\right)$$

$$L_1 = \frac{\alpha^3}{\beta^3} L_2$$

4) To check the correctness of an equation

Based on the principle of homogeneity

$F = m^2 a$ (wrong)

$M L T^{-2} \neq M^2 L T^{-2}$

Principle of Homogeneity

1. Only the quantities of same dimensions can be added or Subtracted

$2kg + 2sec$ ✗

$2cm - 4kg$ ✗

$2kg + 3kg$ ✓

$2cm + 3cm$ ✓

Principle of Homogeneity

2) Dimensions of LHS = Dimension of RHS

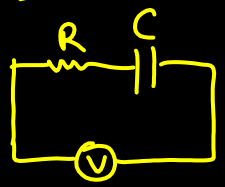
$2\,kg = 4\,litre$ ✗

$y = 2\,cm$

$y \Rightarrow$ Length

Principle of Homogeneity

12th Class



$q = C\varepsilon(1 - e^{-t/\tau})$

$\Rightarrow \frac{t}{\tau}$ = dimensionless

$\Rightarrow \tau = T'$

$\tau = RC$

3) Powers raised to a quantity is always dimensionless

$(x)^y$ $\Rightarrow$ x can have dimension but y cannot

e^{-a} $\Rightarrow$ a is dimensionless

Check the correctness of the following equation

$$F = mv^2/r^2$$ (wrong)

$$MLT^{-2} = \frac{M(LT^{-1})^2}{L^2} = MT^{-2}$$ ✗

Check the correctness of the following equation

$$H = \frac{2F}{L^3 g \rho}$$

H= Height
F= Force
L= Length
g= gravity
ρ= density

$$L = \frac{MLT^{-2}}{L^3 \times (LT^{-2})\left(\frac{M}{L^3}\right)}$$

L = no dimension ✗

Wrong Equation

In Van Der Waals equation $[P + a/V^2]\,[v - b] = RT$; P is pressure, V is volume, R is universal gas constant and T is temperature. The ratio of constants a/b is dimensionally equal to :

[JEE Main 2022]

A. P/V

B. V/P

C. PV

D. PV^3

$[V - b] \Rightarrow b \Rightarrow$ Volume

$b = V$

$\left[P + \frac{a}{V^2}\right] \Rightarrow \frac{a}{V^2} =$ Pressure

$a = PV^2$

$$\frac{a}{b} = \frac{PV^2}{V} = PV$$

The force of interaction between two atoms is given by $F = \alpha\beta \exp[-x^2/\alpha kT]$; where x is the distance, k is the Boltzmann constant and T is temperature and α and β are two constants. The dimensions of β is

A. $M^0L^2T^{-4}$

B. M^2LT^{-4}

C. MLT^{-2}

D. $M^2L^{2\ -2}$

[JEE Main 2022]

$F = \alpha\beta e^{\left[\frac{-x^2}{\alpha kT}\right]}$

$\Rightarrow \frac{x^2}{\alpha kT}$ = dimensionless

$x^2 = \alpha kT$

$L^2 = [\alpha](ML^2T^{-2})$

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

$kEnergy = \frac{1}{2}kT$

$\Rightarrow kT \Rightarrow$ Energy

L.H.S = R.H.S

$MLT^{-2} = (M^{-1}T^{2})\beta$ (const)

$M^{2}L^{1}T^{-4} = \beta$

5) To Derive New Formulas

$F = ma$

Suppose

Force ⇒ mass, acceleration

$F = \frac{m}{a}$ OR $F = \frac{a^2}{m}$?

$F = k m' a'$

k ⇒ Remains unknown

$F \propto m^x a^y \Rightarrow F = k m^x a^y$

$MLT^{-2} = (\text{const}) M^x (LT^{-2})^y$

$MLT^{-2} = M^x L^y T^{-2y}$

$\Rightarrow x = 1, \quad y = 1$

The time period of a simple pendulum is found to depend only upon the length of the string and acceleration due to gravity(g). Derive a formula for the same.

$T \propto l^x g^y$

$T = k l^x g^y$

$T = (\text{const})\, L^x (LT^{-2})^y$

$T' = L^{x+y} T^{-2y}$

$\Rightarrow 1 = -2y$ | $x + y = 0$

$y = -1/2$ | $x = 1/2$

$T = k l^{1/2} g^{-1/2}$

$T = k \sqrt{\frac{l}{g}}$

To find the distance d over which a signal can be seen clearly in foggy conditions, a railway - engineer uses dimensions and assumes that the distance depends on the mass density p of the fog, intensity (power / area) S of the light from the signal and its frequency f. The engineer finds d is proportional to $S^{1/n}$.
The value of n is

[JEE Adv. 2014]

$$d \propto \rho^x S^y f^z$$

$$d = k \rho^x S^y f^z$$

$$L = \left(\frac{M}{L^3}\right)^x \left(\frac{\text{Energy}}{\text{time} \times \text{Area}}\right)^y \left(T^{-1}\right)^z$$

$$L = M^x L^{-3x} \left(\frac{ML^2T^{-2}}{T\ L^2}\right)^y T^{-z}$$

$$L = M^x L^{-3x} (M^y T^{-3y}) T^{-z}$$

$$L' = M^{x+y} L^{-3x} T^{-3y-z}$$

$\Rightarrow -3x = 1$

$x = -1/3$

$x + y = 0$

$y = -x$

$y = +1/3$

$\Rightarrow y = \frac{1}{n}$

$\frac{1}{3} = \frac{1}{n}$

$n = 3$

Changing the Base Dimension

(favourite topic of Advanced)

↳ Question will change the fundamental Quantities

Unacademy Atoms

If speed V, area A and force F are chosen as fundamental units, then the dimension of Young's modulus will be

[JEE Main 2020]

A. FA^2V^{-1}

B. FA^2V^{-3}

C. FA^2V^{-2}

D. $FA^{-1}V^0$

V, A, F

Shortcut

$Y = \frac{F}{A} = F^1 A^{-1} V^0$

$Y \propto V^x A^y F^z$

$\frac{F}{A} = (LT^{-1})^x (L^2)^y (MLT^{-2})^z$

$ML^{-1}T^{-2} = M^z L^{x+2y+z} T^{-x-2z}$

$\Rightarrow z = 1$

$-2 = -x - 2z$

$x = 0$

Unacademy Atoms

Q

If momentum [P], area [A] and time [T] are taken as fundamental quantities, then the dimensional formula for coefficient of viscosity is:

[JEE Main 2022]

A. $[P\ A^{-1}\ T^{0}]$

B. $[P\ A\ T^{-1}]$

C. $[P\ A^{-1}\ T]$

D. $[P\ A^{-1}\ T^{-1}]$

$\eta \propto P^{x} A^{y} T^{z}$

$M L^{-1} T^{-1} = (MLT^{-1})^{x} (L^{2})^{y} (T)^{z}$

$M L^{-1} T^{-1} = M^{x} L^{x+2y} T^{-x+z}$

$\Rightarrow x = 1$ | $x + 2y = -1$ $\quad y = -1$ | $-1 = -x + z$ $\quad z = 0$

In a particular system of units, a physical quantity can be expressed in terms of the electric charge e, electron mass m_e, Planck's constant h, and Coulomb's constant $k = \frac{1}{4\pi\epsilon_0}$, where ϵ_0 is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B] = [e]^{\alpha}[m_e]^{\beta}[h]^{\gamma}[k]^{\delta}$. The value of $\alpha + \beta + \gamma + \delta$ is 4.

[JEE Advanced 2022]

~~$B = \frac{\mu_0 i}{2\pi r}$~~

$F = qvB$

$MLT^{-2} = (IT)(LT^{-1})[B]$

$B = MI^{-1}T^{-2}$

$F = BIl$

$MLT^{-2} = [B][I][L]$

$B = MI^{-1}T^{-2}$

$E = h\nu$

$ML^2T^{-2} = [h]T^{-1}$

$h = ML^2T^{-1}$

$F = \frac{kq_1q_2}{r^2}$

$MLT^{-2} = \frac{[k][IT]^2}{L^2}$

$\Rightarrow k = ML^3T^{-4}I^{-2}$

$$B = e^{\alpha} m^{\beta} h^{\gamma} K^{\delta}$$

$$M I^{-1} T^{-2} = (IT)^{\alpha} (M^{\beta}) (ML^2 T^{-1})^{\gamma} (M L^3 T^{-4} I^{-2})^{\delta}$$

$$M I^{-1} T^{-2} = M^{\beta+\gamma+\delta} \; L^{2\gamma+3\delta} \; T^{\alpha-\gamma-4\delta} \; I^{\alpha-2\delta}$$

$1 = \beta + \gamma + \delta$

$1 = \beta - 3 + 2$

$\beta = 2$

$2\gamma + 3\delta = 0$

$\gamma = -\frac{3\delta}{2}$

$\gamma = -3$

$-2 = \alpha - \gamma - 4\delta$

$-2 = (2\delta \cdot 1) - \gamma - 4\delta$

$-2 = -2\delta - \gamma - 1$

$-1 = -2\delta + \frac{3\delta}{2}$

$\delta = 2$

$-1 = \alpha - 2\delta$

$\alpha = -1 + 2(2)$

$\alpha = 3$

HW

Sometimes it is convenient to construct a system of units so that all quantities can be expressed in terms of only one physical quantity. In one such system, dimensions of different quantities are given in terms of a quantity X as follows: [position] = $[X^{\alpha}]$; [speed] = $[X^{\beta}]$; [acceleration] =$[X^{\rho}]$; [linear momentum] = $[X^{q}]$; [force] = $[X^{r}]$. Then

[JEE Advanced 2020]

A. $\alpha + \rho = 2\beta$

B. $\rho + q - r = \beta$

C. $\rho - q + r = \alpha$

D. $\rho + q + r = \beta$

Unacademy Atoms

Limitations of Dimensional Analysis

Limitations of Dimensional Analysis

1) Two different quantities can have same dimensions.
   Example: ~~Force~~ Energy and Torque

$$\tau = \vec{r} \times \vec{F} = Nm$$

$$E = \vec{F}\,\vec{d} = Nm$$

Limitations of Dimensional Analysis

2) Checking the correctness of the equation doesn't have 100% accuracy

$S = ut + 2at^2$ (wrong)

$L = (LT^{-1})(T) + (\text{const})(LT^{-2})(T^2)$

$L = L + L$

$L \simeq L$ ✓

Limitations of Dimensional Analysis

3) Proportionality constant cannot be determined

$$T = k\sqrt{\frac{l}{g}}$$

$k \Rightarrow ?$

Limitations of Dimensional Analysis

4) This method doesn't work if a quantity depends on more than 3 physical quantities

4 Variables & only 3 equation

Rounding Off

$28 \simeq 3$ (Round off)

$11 \simeq 1$ (Round off)

285 ?

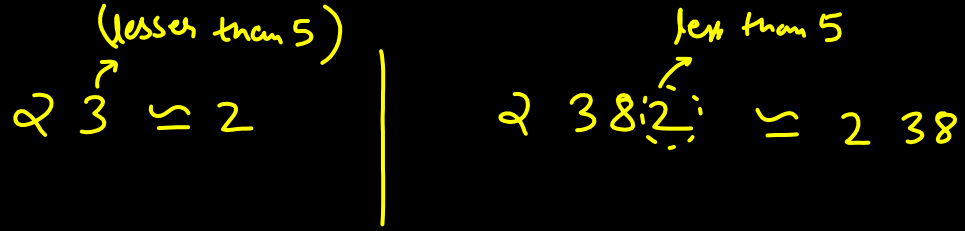
2805 ?

Rounding Off

Rule 1

If the digit to be dropped is less than 5, then the preceding digit is left unchanged.

Examples: x = 7.82 is rounded off to 7.8, again x = 3.94 is rounded off to 3.9

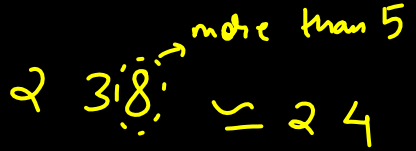


Rounding Off

Rule 2

If the digit to be dropped is more than 5, then the preceding digit is raised by one.

Examples: x = 6.87 is rounded off to 6.9, again x = 12.78 is rounded off to 12.8.



Rounding Off

Rule 3

If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is raised by one.

Examples: x= 16.351 is rounded off to 16.4, again x = 6.758 is rounded off to 6.8.

2852 ⇒ 2852 ≈ 29 (non zero)

Rounding Off

2 3 5 nothing ≃ 2.4

Rule 4

2 32.528

2.3328

If digit to be dropped is 5 or 5 followed by zeros, then preceding digit is left unchanged, if it is even.

Examples: x = 3.250 becomes 3.2 on rounding off, again x = 12.650 becomes 12.6 on rounding off.

2 25 nothing

≃ 2 2

3 50 ≃ 3

16.250 ≃ 16 2

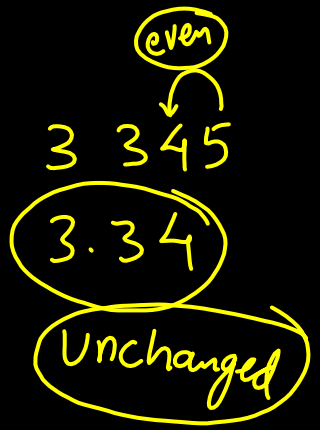
Rounding Off

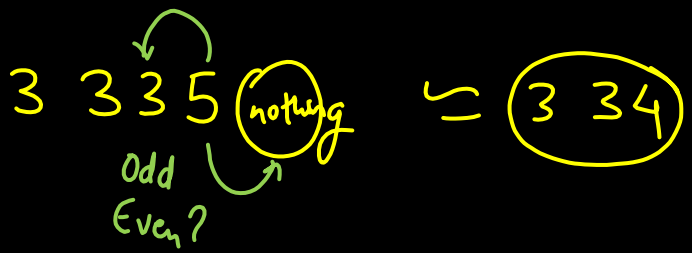
25? = 2.5 (nothing) ≈ 2

Rule 5

If digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one, if it is odd.

Examples: x = 3.750 is rounded off to 3.8, again x = 16.150 is rounded off to 16.2.





A student measuring the diameter of a pencil of circular cross - section with the help of a vernier scale records the following four readings 5.50 mm, 5.55 mm, 5.45 mm, 5.65 mm, The average of these four reading is 5.5375 mm and the standard deviation of the data is 0.07395 mm. The average diameter of the pencil should therefore be recorded as:

[JEE Main 2020]

A. (5.5375 ± 0.0739) mm

B. (5.5375 ± 0.0740)mm

C. (5.538 ± 0.074) mm

D. (5.54 ± 0.07) mm

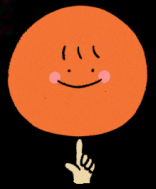
2.5 nothing ≃ 2

3 5 nothing ≃ 4

5 5375 ≃ 5 54

5.55 ⇒ 2 digits after decimal

0 07395 ≃ 0 07



Order of Magnitude

The order-of-magnitude of a given number is the nearest power often to which it is approximated.

For finding the order-of-magnitude (x) of a number (n) = $n \times 10^x$

n should lie between 0.5 & 5

2×10^5

Order = 5

6×10^7

$= 0.6 \times 10^8$

$\Rightarrow$ Order = 8

5×10^2 = 0.5×10^3

✓ X

Order of Magnitude

Number N	Expression in $N = a \times 10^b$	Order of magnitude b
0.2	2×10^{-1}	−1
1	1×10^0	0
5	5×10^0	0
6	0.6×10^1	1
31	3.1×10^1	1
32	3.2×10^1	1
999	0.999×10^3	3
1000	1×10^3	3

Q

The radius of Earth is 6400×10^3 m. Find its order of magnitude.

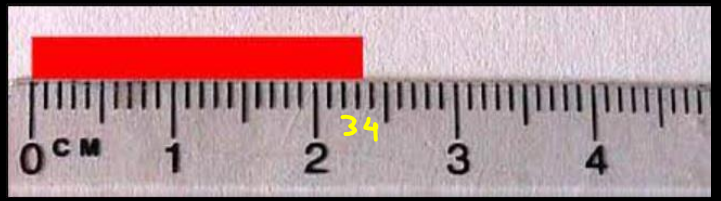
$= 64 \times 10^5$

$= 0.64 \times 10^7$

Ans ⇒ 7

Significant Figures

Significant Figures



Length ⇒ 2.3 ?

Not Sure

Sure

2 significant Digits

Significant Figures

=> Significant figures in the 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 the accuracy of the measurement. The converse is also true.

2.352863? cm

sure

7 SD

Rule 1

All non-zero digits are significant.

Examples: 42.3 has three significant figures.

243.4 has four significant figures.

24.123 has five significant figures.

Rule 2

A zero becomes significant figure if it appears between to non-zero digits. (Sandwich zero)

Examples: 5.03 has three significant figures.

5.604 has four significant figures.

4.004 has four significant figures.

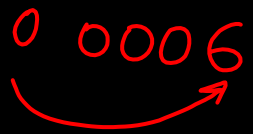
Rule 3

Leading zeros or the zeros placed to the left of the number are never significant.

Examples: 0.543 has three significant figures.

0.045 has two significant figures.

0.006 has one significant figures.



Rule 4

Trailing zeros or the zeros placed to the right of the number are significant.

Examples: 4.330 has four significant figures.

433.00 has five significant figures.

343.000 has six significant figures.

₹ 1006 = ₹ 100

₹ 10000

① ₹ 23 43

② ₹ 20.57

Total B.M = ₹ 4400

Rule 5

In exponential notation, the numerical portion gives the number of significant figures.

Examples: 1.32×10^{-2} has three significant figures.

1.32×10^{4} has three significant figures.

$C = 3 \times 10^{8}$

$C = 2998 \times 10^{8}$

Q

The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1×10^{-3} are :-

5 1 2

[AIEEE / JEE Main 2011]

A. 4,4,2

B. 5,1,2 ✓

C. 5,1,5

D. 5,5,2

Significant Figures

1) **Addition & Subtraction**

a) Count the number of significant figures in the decimal portion ONLY of each number in the problem

b) Add or subtract in the normal fashion

c) Number of digits in the decimal portion of the answer should be approximated to the least of the two numbers.

$$\begin{array}{r} 2\ 320 \rightarrow (3) \\ +\ 4\ 26 \rightarrow (2) \\ \hline 6\ 580 \end{array}$$

$\simeq \boxed{6\ 58} \Rightarrow$ 3 Significant Digits

Example

33.3 ① ← (has only one decimal place)

3.11 ②

+0.313 ③

36.723 ← (answer should be reported to one decimal place)

Answer = 36.7

36 7 (23

≈ 36 7

Exampl
e

$$
\begin{array}{rl}
62.831 & \leftarrow \text{(has 3 decimal places)} \\
-24.5492 & \\
\hline
38.2818 & \leftarrow \text{(answer should be reported to 3 decimal places after rounding off)}
\end{array}
$$

Answer = 38.282

$= 38\ 281\ 8$

$= 38\ 282$

more than 5

Two gold pieces, each of mass 0.035 g, are placed in a box of mass 2.3 g. The total mass of the box with gold pieces is

A. 2.3 g

B. 2.4 g

C. 2.37 g

D. 2.370 g

$$
\begin{array}{r}
2\,3 \rightarrow (1) \\
0\,0\,35 \rightarrow (2) \\
+\;0\,0\,35 \rightarrow (2) \\
\hline
2\,3\,7\,0
\end{array}
$$

$2370 \approx 2.4$ gram

The area of a square is 5.29 cm^2. The area of 7 such squares taking into account the significant figures is:

[Main 9 April 2019 (II)]

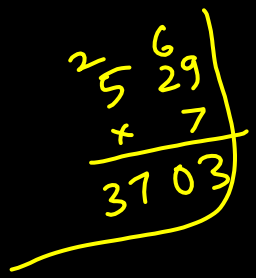
(a) 37cm^2 (b) 37.030 cm^2

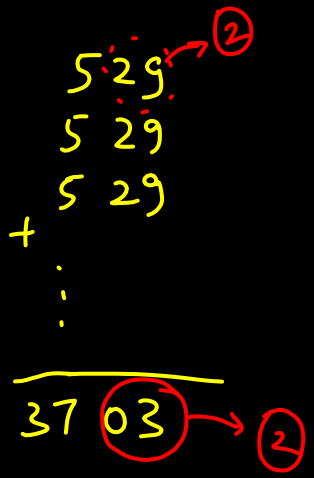
(c) 37.03 cm^2 (d) 37.0 cm^2

$A = 5\,29\ cm^2$

Total Area = $A + A + A \ldots\ldots + A$

$= 37\,03\ cm^2$





Significant Figures

2) **Multiplication and Division**

a) Multiply or divide in normal fashion

$x = 10.0 \Rightarrow (3)$

$y = 520\,06 \Rightarrow (5)$

b) The **LEAST** number of significant figures in any number of the problem determines the number of significant figures in the answer. (You are now looking at the **entire number**, not just the decimal portion)

$x\,y = 100 \times 520\,06$

$= 5200\,6$

$\simeq (520)$

Example

$$
\begin{array}{r}
142.06 \\
\times\ 0.23 \\
\hline
32.6738
\end{array}
\qquad
\begin{array}{l}
\\
\leftarrow \text{(two significant figures)} \\
\leftarrow \text{(answer should have two significant figures)}
\end{array}
$$

5

2

32 | 6738

= 33

Example

$$
\begin{array}{r}
51.028 \\
\times\ 1.31 \\
\hline
66.84668 \quad \leftarrow \text{(three significant figures)}
\end{array}
$$

Answer = 66.8

66 84668

≈ 66 8

Example

$$\frac{0.90}{4.26} = 0.2112676$$

Answer = 0.21

0 2 1 1 2 6 7 6

= 0 21

The length and breadth of a metal sheet are 3.124 m and 3.002 m respectively. The area of this sheet up to the correct number of significant figures is

A. 9.378 m^2

B. 9.37 m^2

C. 9.378248 m^2

D. 9.3782 m^2

[PYQ]
[2020]

Area = l × b
(4) (4)
= 3.124 × 3.002

= 9.378248

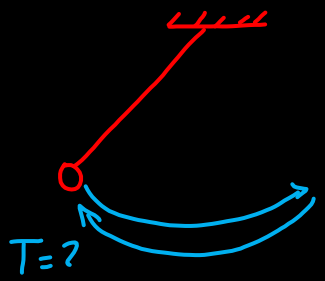
= 9.378

Unacademy Atoms

Error Analysis

Errors in Measurement

1) True/Mean Value



Let a physical quantity be measured n times. Let the measured values be a_1, a_2, a_3, ... a_n. The arithmetic mean of these values is

$$a_m = \frac{a_1 + a_2 + \cdots a_n}{n}.$$

$T_1 = 2$ sec

$T_2 = 1.9$ sec

$T_3 = 2.1$ sec.

$T_4 = 2$ sec

$$T_{avg} = \frac{2 + 1.9 + 2.1 + 2}{4} = 2 \text{ sec}$$

$T_m = 2$

$\Delta T_1 = T_m - T_1 = 2 - 2 = 0$

$\Delta T_2 = T_m - T_2 = 2 - 1.9 = +0.1$

$\Delta T_3 = T_m - T_3 = 2 - 2.1 = -0.1$

$\Delta T_4 = T_m - T_4 = 2 - 2 = 0$

2) Absolute Error

$\triangle a_1 = a_m - a_1$

$\triangle a_2 = a_m - a_2$

...

$\triangle a_n = a_m - a_n$

The absolute errors may be positive in certain cases and negative in certain other cases.

3) Mean Absolute Error

$$\overline{\Delta a} = \frac{|\Delta a_1| + |\Delta a_2| + \cdots |\Delta a_n|}{n}$$

$$\overline{\Delta T} = \frac{0 + 0.1 + 0.1 + 0}{4}$$

$$\overline{\Delta T} = \frac{0.20}{4} = 0.05 \text{ sec}$$

$$\text{Real Value} = T_m \pm \overline{\Delta T}$$

R Value $= 2 \pm 0.05$

T lies b/w $\Rightarrow$ [1.95 sec – 2.05 sec]

Hence the Final Result is

$$a = a_m \pm \overline{\Delta a}.$$

This implies that any measurement of the quantity is likely to lie between $(a_m + \overline{\Delta a})$ and $(a_m - \overline{\Delta a})$.

4) Relative error or Fractional error:

$$\text{Relative error or fractional error} = \frac{\text{mean absolute error}}{\text{mean value}} = \frac{\overline{\Delta a}}{a_m}$$

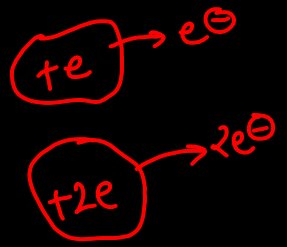
$$\text{fractional error} = \frac{\overline{\Delta T}}{T_m} = \frac{0.05}{2} = 0.025$$

5) Percentage Error

When the relative / fractional error is expressed in percentage, we call it percentage error. Thus percentage error $= \frac{\overline{\Delta a}}{a_m} \times 100\%$

/ error $= \frac{\overline{\Delta T}}{T_m} \times 100\% = 0.025 \times 100\%$.

$= 2.5\%$



A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90 s, 91 s, 95 s, and 92 s. If the minimum division in the measuring clock is 1 s, then the reported mean time should be: **[Main 2016]**

(a) $92 \pm \frac{2}{2}$ s (b) 92 ± 3s

(c) 92 ± 1.5 s (d) 92 ± 5.0 s

$T_1 = 90$ sec

$T_2 = 91$ sec

$T_3 = 95$ sec

$T_4 = 92$ sec

$$\Rightarrow T_m = \frac{90+91+95+92}{4} = \frac{368}{4} = 92 \text{ sec}$$

$\Delta T_1 = T_m - T_1 = 92 - 90 = 2$

$\Delta T_2 = 92 - 91 = 1$

$\Delta T_3 = 92 - 95 = -3$

$\Delta T_4 = 92 - 92 = 0$

$$\overline{\Delta T} = \frac{2+1+3+0}{4} = \frac{6}{4} = \frac{3}{2} = 1.5 \text{ sec}$$

$T_m \pm \overline{\Delta T} = 92 \pm 1.5 \simeq 92 \pm 2$

Propagation of Errors

1) Addition & Subtraction

(Error adds in both)

$x = a - b$

$\Rightarrow \boxed{\Delta x = \Delta a + \Delta b}$

$x = a + b$

$x \pm \Delta x = (a \pm \Delta a) + (b \pm \Delta b)$

$\cancel{x \pm \Delta x} = \cancel{(a+b)} \pm (\Delta a + \Delta b)$

$\boxed{\Delta x = \Delta a + \Delta b}$

$$x = (2 \pm 0.1) + (3 \pm 0.2)$$

$$\boxed{x = 5 \pm 0.3}$$

$$y = (2 \pm 0.1) - (3 \pm 0.2)$$

$$\boxed{y = -1 \pm 0.3}$$

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 with proper error limits.

$T_1 = 40\,6 \pm 0\,2 \ ^\circ C$

$T_2 = 78\,3 \pm 0\,3 \ ^\circ C$

$\Delta T = T_2 - T_1 = (78\,3 \pm 0\,3) - (40\,6 \pm 0\,2)$

$= 37.7 \pm 0\,5$

Propagation of Errors

2) Multiplication & Division

$x = ab$ OR $x = \frac{a}{b}$

$$\frac{\Delta x}{x} = \frac{\Delta a}{a} + \frac{\Delta b}{b}$$

$x = (2 \pm 0.1) \times (3 \pm 0.3)$

$x = 6 \pm \Delta x$

$$\frac{\Delta x}{x} = \frac{0.1}{2} + \frac{0.3}{3}$$

$$\Delta x = \frac{0.1}{2} x + \frac{0.3}{3} x$$

$\Delta x = 0.3 + 0.6 = 0.9$

$x = 6 \pm 0.9$

$$\frac{\Delta x}{x} \times 100\% = \frac{\Delta a}{a} \times 100\% + \frac{\Delta b}{b} \times 100\%$$

$$\% \Delta x = \% \Delta a + \% \Delta b$$

$$\% \Delta a = \frac{0.1}{2} \times 100 = 5\%$$

$$\% \Delta b = \frac{0.3}{3} \times 100 = 10\%$$

$$\% \Delta x = 15\%$$

$$x = 6$$

$$15\% \text{ of } 6 = 0.15 \times 6 = 0.9$$

The length and breadth of a rectangle are (4 ± 0.1) cm and (2 ± 0.2) cm. Calculate area of the rectangle with error limits.

$l = 4 \pm 0.1 \qquad b = 2 \pm 0.2$

$\text{Area} = l \times b = 4 \times 2 = 8 \text{ cm}^2$

$\frac{\Delta A}{A} = \frac{\Delta l}{l} + \frac{\Delta b}{b} = \frac{0.1}{4} + \frac{0.2}{2}$

$\Delta A = \frac{0.1}{4} A + \frac{0.2}{2} A = 0.2 + 0.8 = 1 \text{ cm}^2$

$A \pm \Delta A$

8 ± 1

The distance covered by a body in time (5.0 ± 0.6) s is (40.0 ± 0.4) m. Calculate the speed of the body. Also determine the percentage error in the speed.

$$v = \frac{d}{t} = \frac{40}{5} = 8 \text{ m/s}$$

$$\frac{\Delta v}{v} = \frac{\Delta d}{d} + \frac{\Delta t}{t} = \frac{0.4}{40} + \frac{0.6}{5}$$

$$\Delta v = \frac{0.4}{40} \times 8 + \frac{0.6}{5} \times 8 = 1.04$$

Propagation of Errors

3) Quantity raised to some Power

Examples ⇒ $x = a^2 b^3$ $\qquad y = \frac{a^5 d^7}{c^6}$

In General ⇒ $x = \frac{a^l b^m}{c^n}$

$$\frac{\Delta x}{x} = |l| \frac{\Delta a}{a} + |m| \frac{\Delta b}{b} + |n| \frac{\Delta c}{c}$$

$$\% \Delta x = |l| \% \Delta a + |m| \% \Delta b + |n| \% \Delta c$$

Q

$z = \frac{a^2 b^{2/3}}{c^{1/2} d^3}$

A phvsical quantity z depends on four observables a, b , c and d as $z = \frac{a^2 b^{\frac{2}{3}}}{\sqrt{c} d^3}$ The percentage error in the measurement of a, b, c and d are 2% , 1.5 %, 4% and 2.5% respectively. The percentage of error in z is. [JEE Main 2022]

A. 12.25%
B. 16.5%
C. 13.5%
D. 14.5% ✓

$\therefore \Delta x = 2(2\%) + \left(\frac{2}{3}\right)(1.5\%) + \frac{1}{2}(4\%) + 3(2.5\%)$

$= (4 + 1 + 2 + 7.5)\%$

$= 14.5\%$

The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1%, the maximum error in determining the density is [JEE Main 2018]

A. 2.5%

B. 3.5%

C. 4.5%

D. 6%

$\rho = \frac{m}{V} = \frac{M^1}{L^3}$

$\% \Delta m = 1.5\%$

$\% \Delta L = 1\%$

$\% \Delta \rho = 1(1.5\%) + 3(1\%)$

$= 4.5\%$

A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stopwatch with 1 s resolution measures the time taken for 40 oscillations to be 50 s. The accuracy in g is:

[JEE Main 2020]

A. 5.40 %

B. 3.40%

C. 4.40%

D. 2.40%

$T = 2\pi\sqrt{\frac{l}{g}}$

$g = \frac{4\pi^2 l}{T^2}$

$l = 25.0\ cm$

least value of length $= 0.1\ cm = \Delta l$

$T = 50\ sec \quad T = \frac{50}{40}$

least value of time $= \frac{1\ sec}{40} = \Delta T$

$\frac{\Delta T}{T} = \frac{1/40}{50/40} = \frac{1}{50}$

$\%\Delta g = 1(\%\Delta l) + 2(\%\Delta T)$

$= \frac{0.1}{25} \times 100\% + 2\left(\frac{1}{50} \times 100\%\right)$

$= 0.4\% + 4\%$

$= 4.4\%$

Summary of entire Topic

In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$.

The values of R and r are measured to be (60 ± 1) mm and (10 ± 1) , respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56 s, 0.57s, 0.54 s and 0.59 s. The least count of the watch used for the measurement of time period is 0.01 s. Which of the following statement(s) is (are) true ?

[JEE Advanced 2017]

A. The error in the measurement of r is 10 %

B. The error in the measurement of T is 3.57 %

C. The error in the measurement of T is 2 %

D. The error in the determined value of g is 11 %

$R = 60 \pm 1$

$r = 10 \pm 1$

$\% \frac{\Delta r}{r} = \frac{1}{10} \times 100\%$

$= 10\%$

Wrong method ?

$R - r = 50 \pm 2$

$T \propto (R-r)^{1/2}$

$\frac{\Delta T}{T} = \frac{1}{2} \times \left(\frac{2}{50} \times 100\%\right)$

$$T_m = \frac{0.52 + 0.56 + 0.57 + 0.54 + 0.59}{5} = 0.56$$

$\Delta T_1 = 0.04$

$\Delta T_2 = 0$

$\Delta T_3 = -0.01$

$\Delta T_4 = 0.02$

$\Delta T_5 = -0.03$

$$\overline{\Delta T} = \frac{0.04 + 0.01 + 0 + 0.02 + 0.03}{5}$$

$$\overline{\Delta T} = \frac{0.10}{5} = 0.02$$

$$\% \frac{\overline{\Delta T}}{T_m} = \frac{0.02}{0.56} \times 100\% \simeq 4\%$$

$$T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$$

$$T^2 = 4\pi^2\left(\frac{7(R-r)}{5g}\right)$$

$$\boxed{g = \frac{28\pi^2(R-r)}{5T^2}}$$

$$g \propto \frac{(R-r)^1}{T^2}$$

$$\therefore \Delta g = 1\,\% \Delta(R-r) + 2\,\% \Delta T$$

$$\simeq 4\,\% + 2(4\,\%)$$

$$\simeq 12\,\%$$

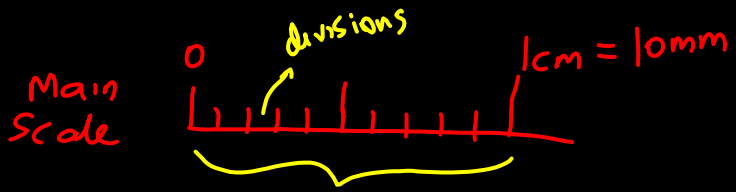
$$R - r = 50 \pm 2$$

$$\%(R-r) = \frac{2}{50} \times 100$$

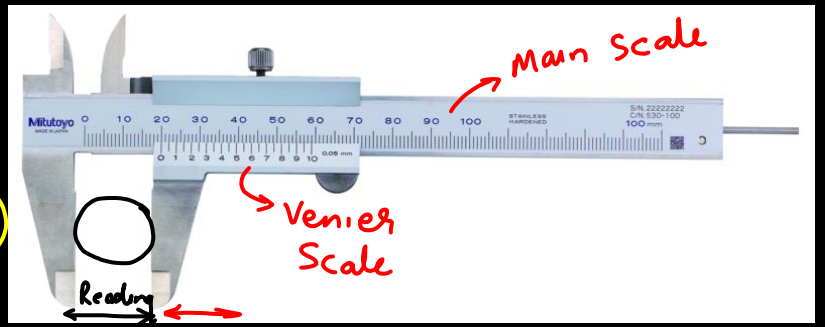
$$= 4\,\%$$

Vernier Caliper & Screw Gauge

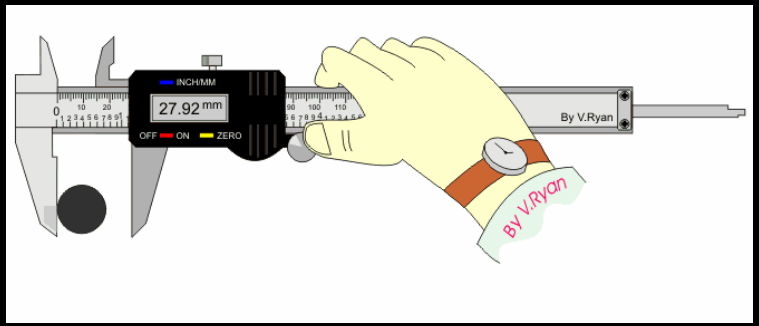
Vernier Caliper



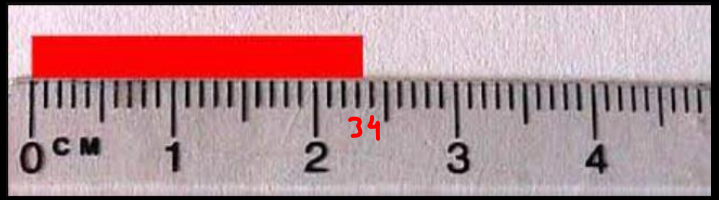
1 MSD = 1mm = 0.1 cm



Vernier Scale Division (VSD)



Vernier Caliper



2 3 ?

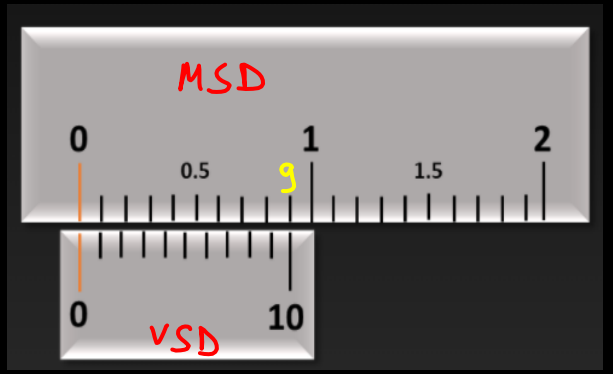
↳ Determined by Vernier Scale

Least Count

⇒ Least value that device can measure

(1 MSD)

In the ordinary vernier calipers, one main scale division is 1 mm and 10 vernier scale division coincide with 9 main scale divisions.



$$\text{Least Count} = 1\,\text{MSD} - 1\,\text{VSD}$$

$$10\,\text{VSD} = 9\,\text{MSD}$$

$$1\,\text{VSD} = \frac{9}{10}\,\text{MSD}$$

Least Count

$$1\ VSD = \frac{9}{10}(1mm) = 0.9\ mm$$

$$LC = 1\ MSD - 1\ VSD$$

$$= 1mm - 0.9mm$$

$$\boxed{LC = 0.1mm} = 0.01\ cm$$

A vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the vernier scale which match with 16 main scale divisions. For this vernier calipers, the least count is

[IIT JEE 2010]

A. 0.02 mm
B. 0.05 mm
C. 0.1 mm
D. 0.2 mm

1 MSD = 1 mm

20 VSD = 16 MSD

$1\ VSD = \frac{16}{20}\ MSD$

1 VSD = (0 8)(1mm)

1 VSD = 0 8mm

L.C = 1MSD - 1VSD

= (1 - 0 8) mm

= 0 2mm

Q

One main scale division of a vernier callipers is ‘a’ cm and n^{th} division of the vernier scale coincide with $(n-1)^{th}$ division of the main scale. The least count of the callipers in mm is

[JEE Main 2021]

A. 10na / (n -1)
B. 10a / (n - 1)
C. (n -1 / 10n) a
D. 10a / n

$1\ MSD = a\ cm$

$LC = 1\ MSD - 1\ VSD$

$= a - \left(\frac{n-1}{n}\right)a$

$LC = \frac{a}{n}\ cm = \frac{10a}{n}\ mm$

$n\ VSD = (n-1)\ MSD$

$1\ VSD = \left(\frac{n-1}{n}\right)MSD$

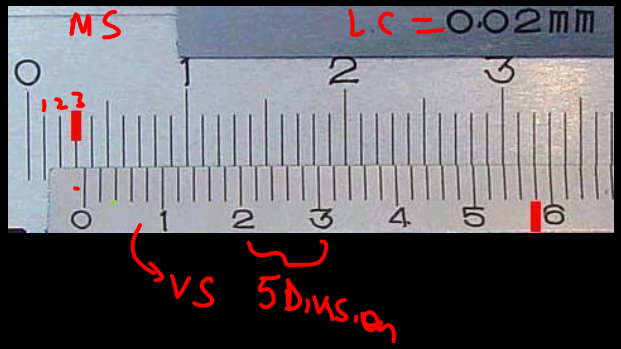
$1\ VSD = \left(\frac{n-1}{n}\right)a$

Vernier Caliper Reading

MSR = 3 MSD ⇐
= 3 mm

29th division of ⇐
VS

1. Check the zero of vernier scale to note down Main Scale Reading (MSR).
2. Now find the division on Vernier scale that is perfectly coinciding with main scale to get Vernier Scale Reading (VSR).
3. Apply the formula



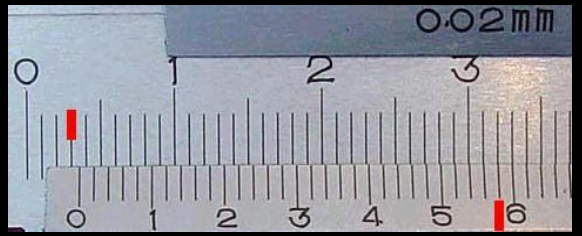
Vernier Caliper

Reading = MSR + (VSR x LC)

$= 3\,mm + 29 \times 0.02$

$= 3 + 0.58$

Reading = 3.58 mm



Example

LC = 0.02 mm

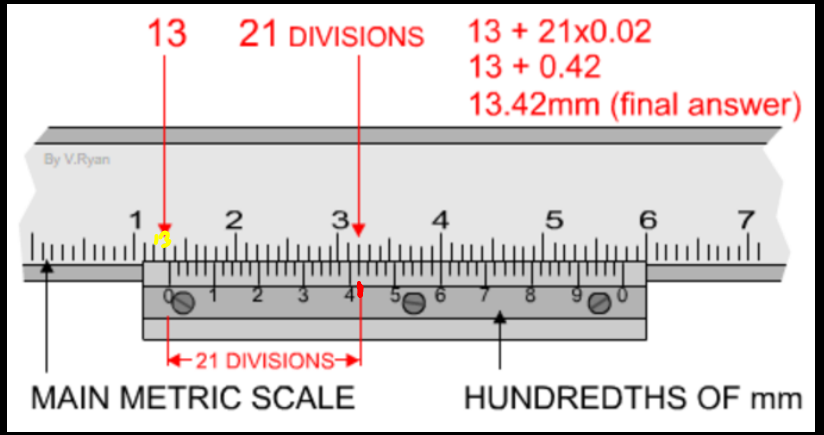
MSR = 13 mm

VSR = 21

Reading = 13mm + 21 x 0.02

= 13 + 0.42

= 13.42 mm



Q

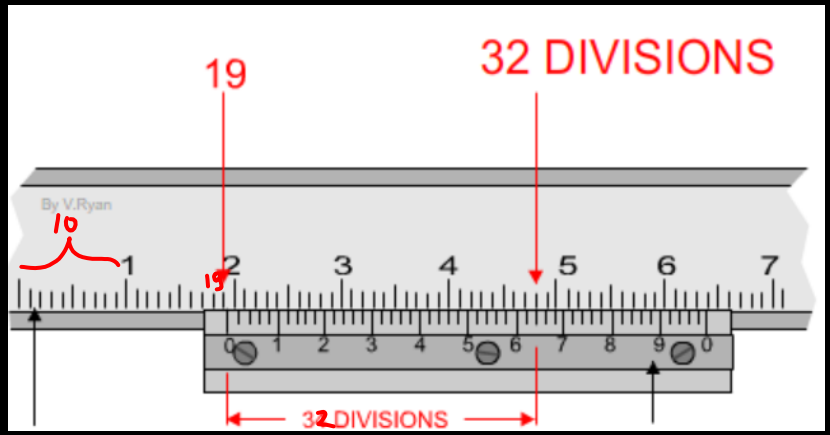
LC = 0.1 mm

MSR = 19mm

VSR = 32

Reading = 19 + 32 × 0.1

= 22.2 mm



Unacademy Atoms

Q

1MSD = 5.15 − 5.10
= 0.05 cm

MSR = 5.10 cm

VSR = 24

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 2.45cm. The 24th division of the vernier scale exactly 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

50 VSD = 2.45 cm

$1\,VSD = \frac{2.45}{50}\,cm = 0.049\,cm$

L.C. = 1MSD − 1VSD

= 0.050 − 0.049

L.C. = 0.001 cm

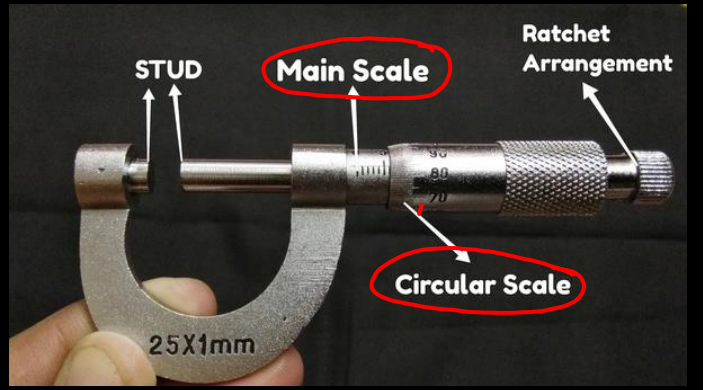
$$\text{Reading} = \text{MSR} + (\text{VSR} \times \text{LC})$$

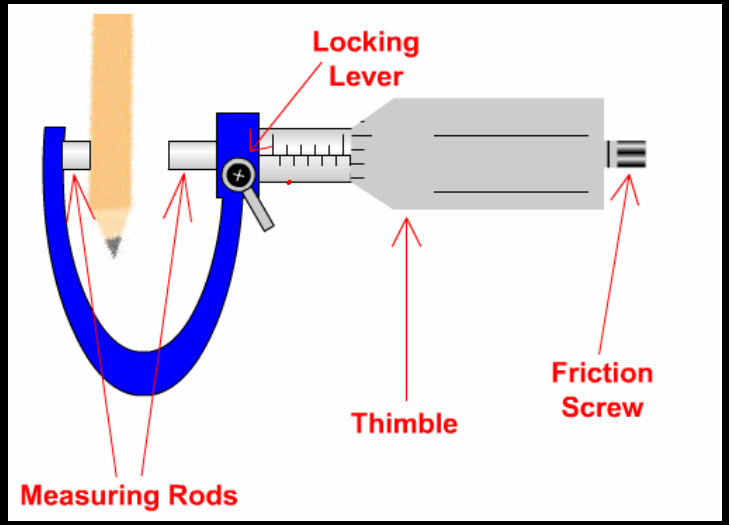
$$= 5.10 + (24 \times 0.001)$$

$$= 5.10 + 0.024$$

$$= \boxed{5.124 \text{ cm}}$$

Screw Gauge


STUD
Main Scale
Ratchet Arrangement
Circular Scale
25X1mm

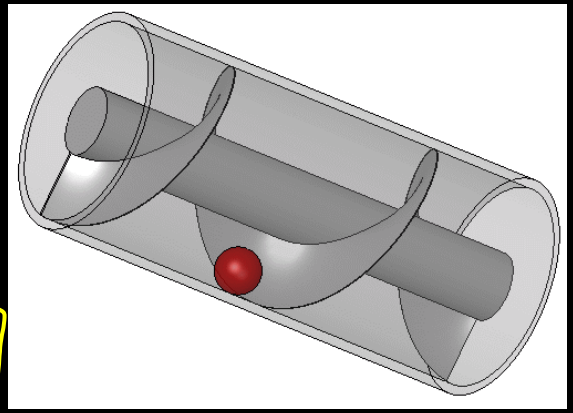

Locking Lever
Friction Screw
Thimble
Measuring Rods

Pitch

1 Rotation = 360°

Pitch ⇒ Distance moved by the screw in 1 Rotation

OR



Pitch

- The distance between two consecutive threads of the screw
- The distance moved by the screw due to one complete rotation of the cap.

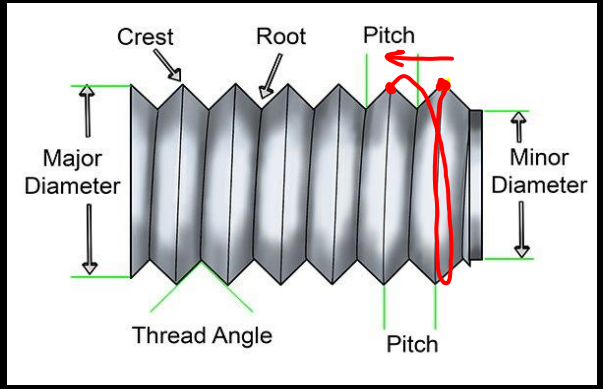
If the screw advances by 5 mm for 10 rotation

$$= \frac{5}{10} = 0.5 \text{ mm.}$$

10 R → 5mm

1R → $\frac{5}{10}$ mm

Pitch = 0.5mm



Least Count

Total cap division is 100, then least count =

0.5 mm/100 = 0.005 mm

$$\text{Least count (L.C.)} = \frac{\text{Pitch}}{\text{No. of circular scale divisions}}$$

$$LC = \frac{\text{Pitch}}{N} = \frac{0.5}{100}\ \text{mm} = 0.005\ \text{mm}$$

If the screw on a screw - gauge is given six rotations, it moves by 3 mm on the main scale. If there are 50 divisions on the circular scale the least count of the screw gauge is: [JEE Main 2020]

A. 0.001 cm
B. 0.02 mm
C. 0.01 cm
D. 0.001 mm

$6R \Rightarrow 3\,mm$

$1R \Rightarrow \frac{3}{6}\,mm$

$Pitch = 0.5\,mm$

$N = 50$

$LC = \frac{0.5\,mm}{50}$

$LC = 0.01\,mm$

$= 0.001\,cm$

Q

Using screw gauge of pitch 0.1 cm and 50 divisions on its circular scale, the thickness of an object is measured. It should correctly be recorded as [JEE Main 2020]

A. 2.121 cm
B. 2.124 cm
C. 2.125 cm
D. 2.123 cm

$$L.C = \frac{\text{pitch}}{N} = \frac{0.1\ \text{cm}}{50}$$

$L.C. = 0.002$ cm

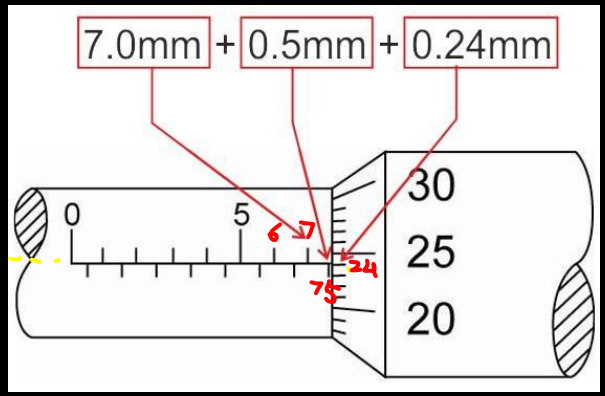
0.004
0.006
0.008

Reading

LSR = 7.5 mm

CSR = 24th

1. Note down Linear Scale Reading (LSR).
2. Now find the division on Circular scale that is aligned with axis to get Circular Scale Reading (CSR).
3. Apply the formula



LC = 0.01 mm

Reading

Total reading = LSR(mm) + (CSR x LC)

$= 7.5\,mm + (24 \times 0.01\,mm)$

$= 7.5 + 0.24$

$= 7.74\,mm$

Errors in Measuring Instruments

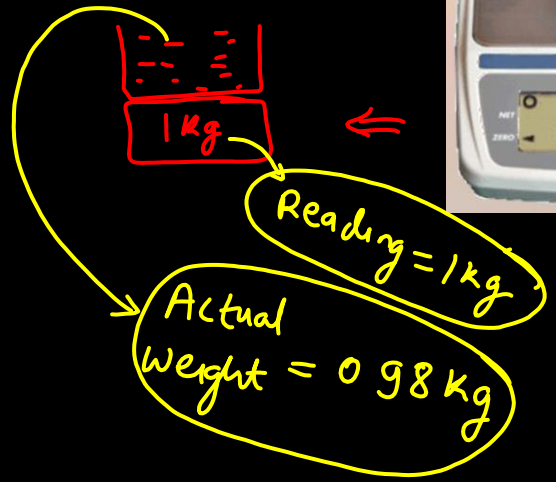
- Positive Error
- Negative Error

Positive Error

Positive error must be subtracted

Positive error = 0.02 kg

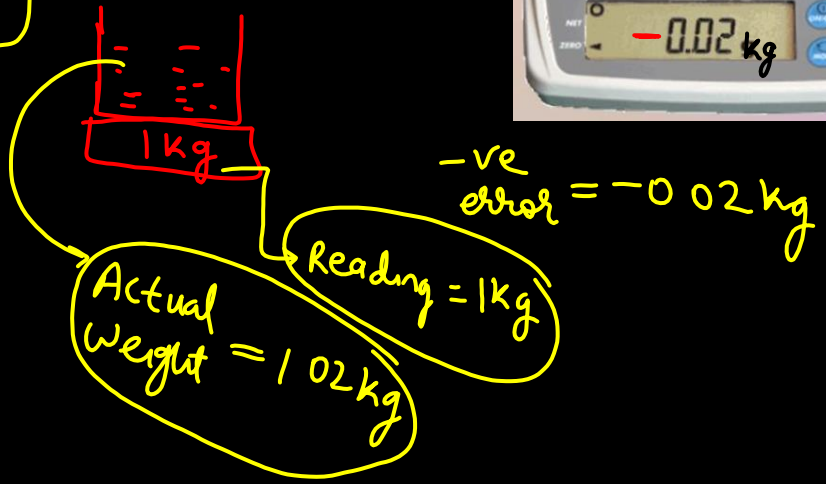
$$\text{Actual Value} = (\text{Reading}) - (+\text{ve error})$$



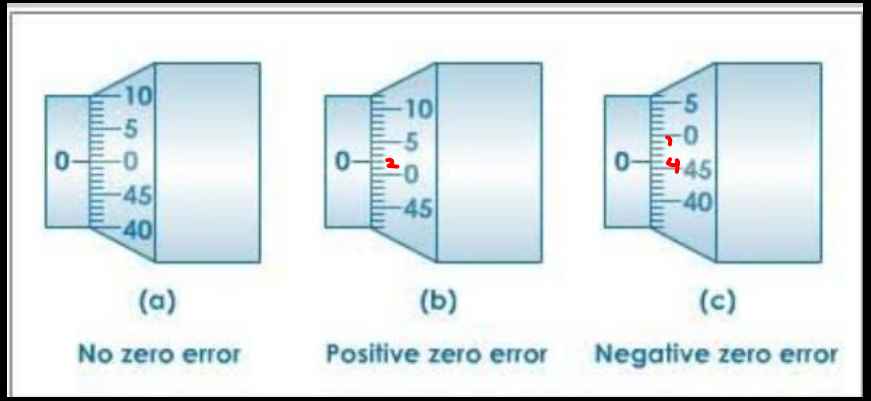
Negative Error

Magnitude of negative error must be added

$$\text{Actual Value} = \text{Reading} + |\text{-ve error}|$$



Errors in Screw Gauge



Unacademy Atoms

A screw gauge has 50 divisions on its circular scale. The circular scale is 4 units ahead of the pitch scale marking, prior to use. Upon one complete rotation of the circular scale, a displacement of 0.5 mm is noticed on the pitch scale. The nature of zero error involved, and the least count of the screw gauge are respectively.

[JEE Main 2020]

A. Negative, 2μm
B. Positive 10 μm
C. Positive, 0.1 mm
D. Positive 0.1 μm

$N = 50$

Positive Error

pitch $= 0.5$ mm

$$L.C. = \frac{0.5}{50}\ mm$$

$$= \frac{0.5}{50} \times 1000\ \mu m$$

Unacademy Atoms

Q

In an experiment to find out the diameter of wire using screw gauge, the following observations were noted

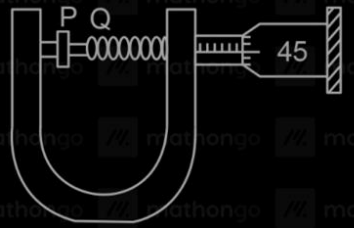
pitch = 0.5 mm ⇐ a. Screw moves 0.5 mm on main scale in one complete rotation

N = 50 ⇐ b. Total divisions on circular scale = 50

c. Main scale reading is 2.5 mm

d. 45th division of circular scale is in the pitch line

e. Instrument has 0.03 mm negative error



L.C = 0.5 mm / 50

L.C = 0.01 mm

Then the diameter of wire is : [JEE Main 2022]

A. 2.92 mm

B. 2.54 mm

C. 2.98 mm ✓

D. 3.45 mm

Reading = LSR + (CSR × LC)

= 2.5 + 45 × 0.01

Reading = 2.95 mm

Actual = 2 95 + 0 03

= 2 98 mm

HW

The pitch and the number of divisions, on the circular scale for given screw gauge are 0.5 mm and 100 respectively. When the screw gauge is fully tightened without any object, the zero of its circular scale lies 3 division below the mean line.

The readings of the main scale and the circular scale, for a thin sheet, are 5.5 mm and 48 respectively, the thickness of the sheet is:

A. 5.755 mm

B. 5.950 mm

C. 5.725 mm

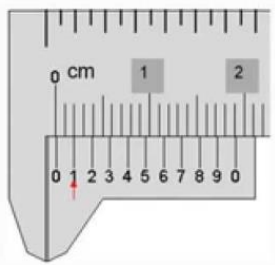
D. 5.740 mm

[JEE Main 2019]

Errors in Vernier Caliper

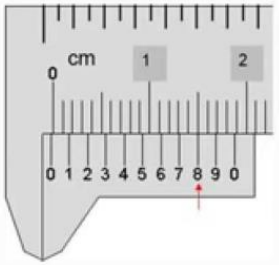
(For Advanced)

1.



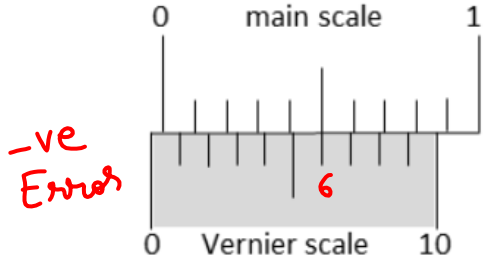
+0.01 cm

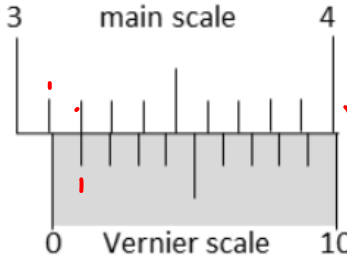
2.



-0.02 cm

The smallest division on the main scale of a Vernier calipers is 0.1 cm. Ten divisions of the Vernier scale correspond to nine divisions of the main scale. The figure below on the left shows the reading of this calipers with no gap between its two jaws. The figure on the right shows the reading with a solid sphere held between the jaws. The correct diameter of the sphere is





(A) 3.07 cm (B) 3.11 cm (C) 3.15 cm (D) 3.17 cm

[JEE Advanced 2021]

1 MSD = 0.1 cm

10 VSD = 9 MSD

1 VSD = 0.9 MSD

1 VSD = 0.9 × 0.1 cm

1 VSD = 0.09 cm

L.C. = 1 MSD − 1 VSD

= 0.1 cm − 0.09 cm

L.C. = 0.01 cm

-ve Error

MSR = 3.1 cm

VSR = 1st

Reading = 3.1 + 1 × 0.01

Reading = 3.11 cm

$x = e + 5MSD$

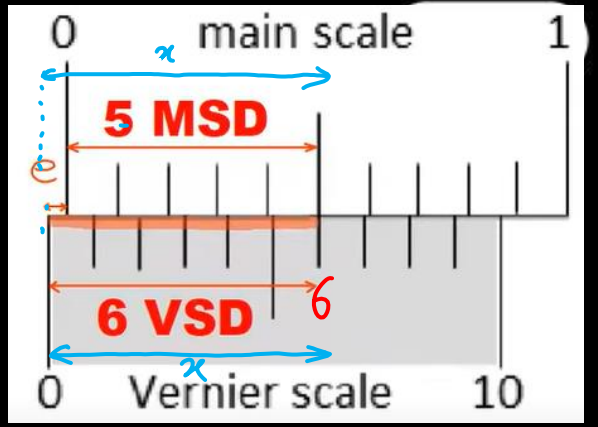
$6\,VSD = e + 5MSD$

$6VSD - 5MSD = e$

$6(0.09) - 5(0.1) = e$

$0.54 - 0.50 = e$

$0.04\,cm = e$



Actual = Reading + |-ve error|

= 3.11 + 0.04

AR = 3.15 cm

There are two Vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2, respectively, are

(A) 2.85 and 2.82 (B) 2.87 and 2.83 (C) 2.87 and 2.86 (D) 2.87 and 2.87

[JEE Advanced 2021]

1 MSD = 0.1 cm

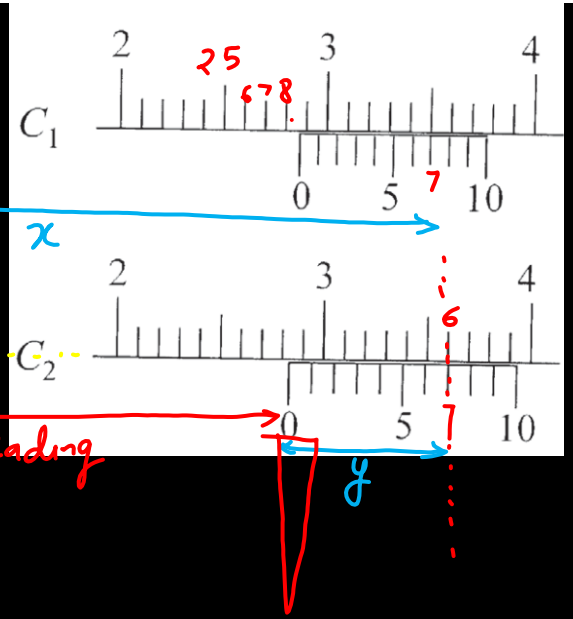
C_1

10 VSD = 9 MSD

1 VSD = 0.9 MSD

LC = 1 MSD − 1 VSD = 1 MSD − 0.9 MSD

= 0.1 MSD = 0.01 cm



MSR = 2.8 cm

VSR = 7th

Reading = 2.8cm + 7 × 0.01 cm

$R = 2.87$ cm

C2

10 VSD = 11 MSD

1 VSD = 1.1 MSD = 1.1 × 0.1 = 0.11 cm

LC = 1 MSD − 1 VSD

= 1 MSD − 1.1 MSD

= −0.1 MSD = −0.01 cm

formula cannot be used

$x = 3.6\,cm$

$y = 7 \text{ VSD} = 7 \times 0.11\,cm$

$y = 0.77\,cm$

$\text{Reading} = x - y$

$= 3.6 - 0.77$

$\boxed{\text{Reading} = 2.83\,cm}$

For Notes

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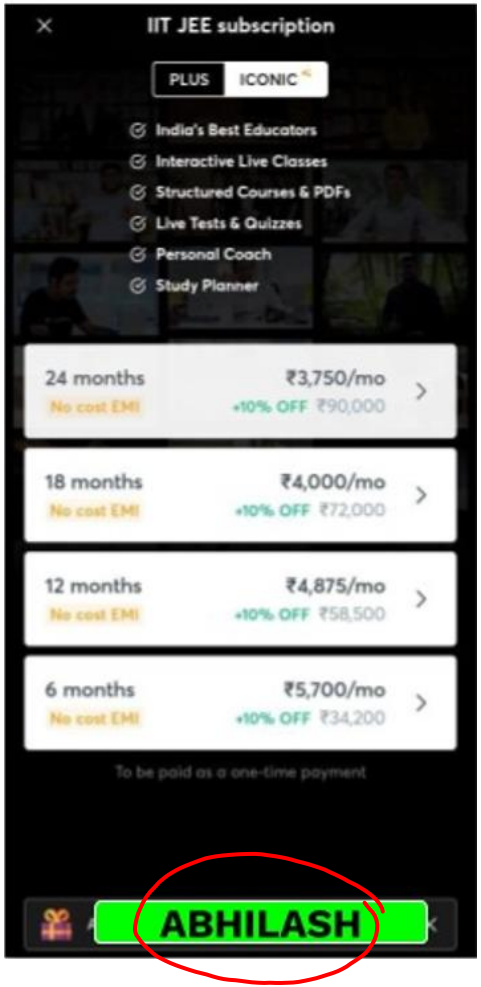
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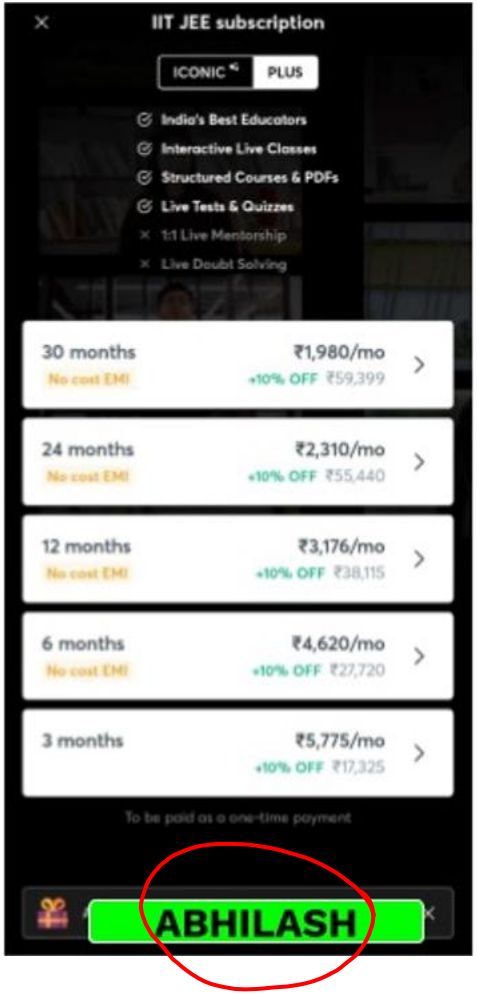
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