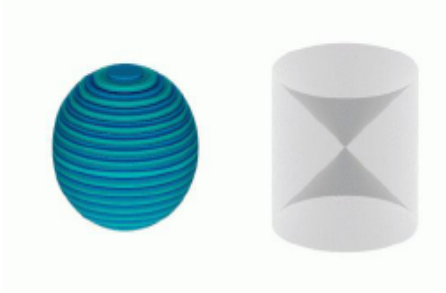
Units & Dimensions 1

Types of **Quantities**?

Physical Quantity

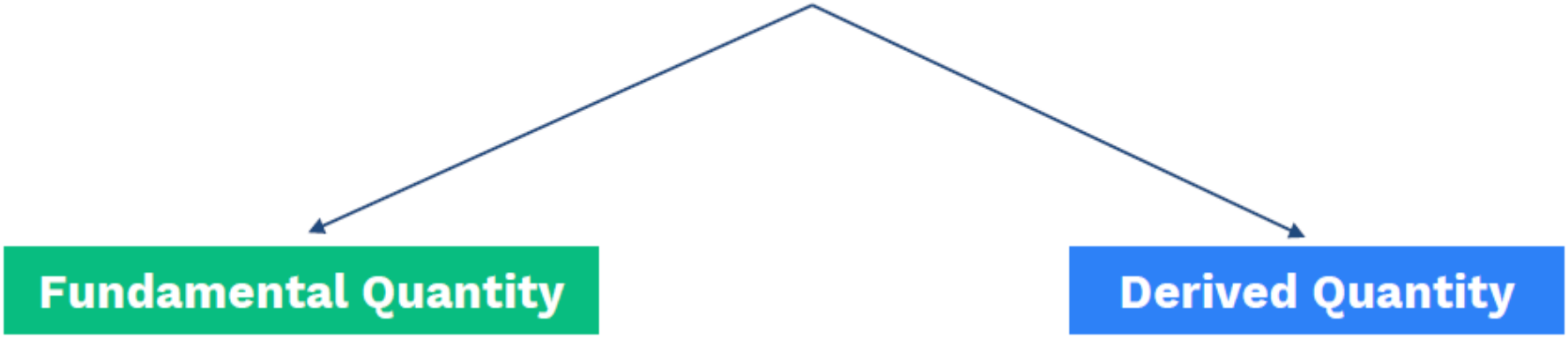


A Quantity that can be measured is called as Physical Quantity. **Length**, **Mass**, **Velocity**, **Temperature**, **Area**, **Volume**, **Density** Etc... Measurable Quantities

Non - Physical Quantity

A Quantity that cannot be measured is called as Non- Physical Quantity. **Building, Bus, Room, Road, Mumbai** Etc... Non-Measurable Quantities

How are **physical quantities** classified?



How are **physical quantities** classified?

Fundamental Quantity

A physical quantity which does not depend on any other physical quantity for its measurement.

Derived Quantity

The physical quantities which are expressed in terms of more than one fundamental quantities.

What are **Fundamental Quantities**?

There are **7** **fundamental quantities**		
Fundamental Quantity	S.I Unit	Symbol
Length	Meter	**m**
Mass	Kilogram	**kg**
Time	Second	**s**
Temperature	Kelvin	**K**
Electric current	Ampere	**A**
Luminous intensity	Candela	**Cd**
Amount of substance	Mole	**mol**

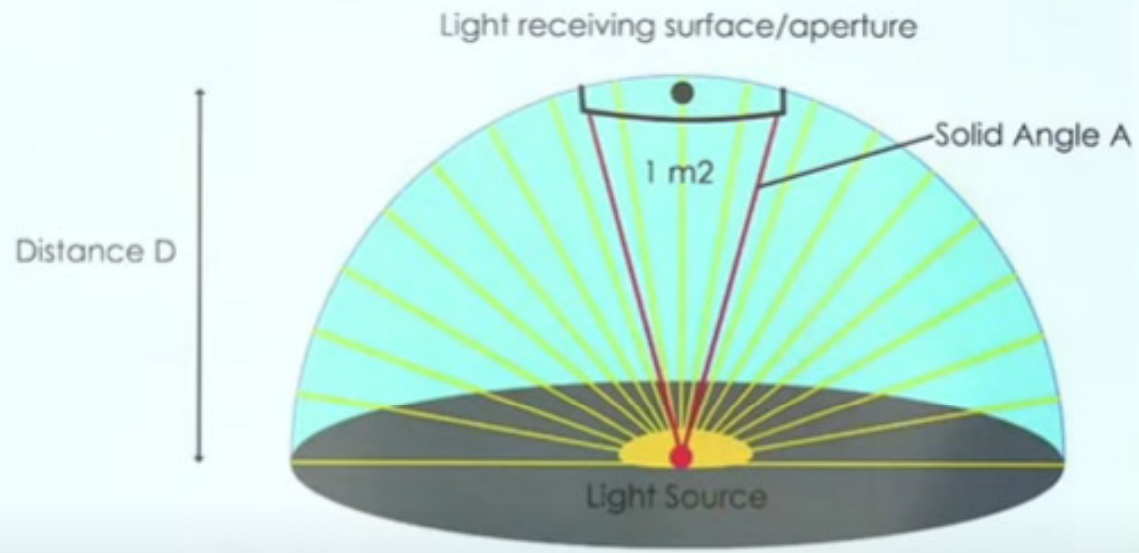
*** Candela is Measure of intensity or brightness of Light.

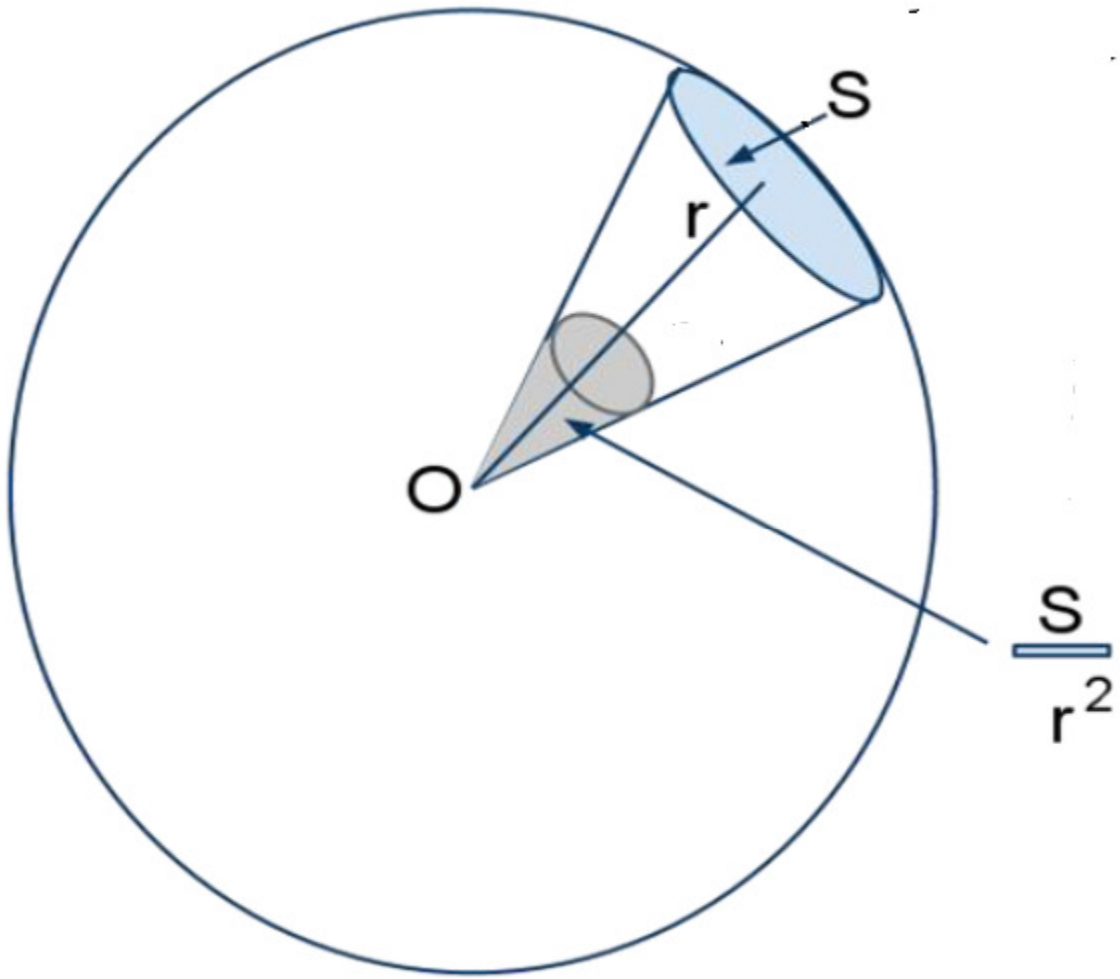
What are **Fundamental Quantities** ?

There are **2** **supplementary quantities**

Supplementary Quantity	S.I unit	Symbol
Plane angle	Radian	**rad**
Solid angle	Steradian	**sr**

Solid Angle Angle inscribed by surface at point is called solid angle.




S
r
O
S
r²

The **Derived Quantities**

The Physical quantities that depend upon other physical quantity for its measurement are known as derived quantities.

The measurement of derived quantities directly depends upon other quantities. So in order to measure the derived quantity, one must measure the quantities that it depends upon.

***** Except 7 fundamental quantities, all other quantities are derived quantities.**

The **Derived Quantities**

Velocity (m/s) ⇒ **Velocity** = $\frac{\text{displacement}}{\text{time}}$

Acceleration (m/s^2) ⇒ **Acceleration** = $\frac{\text{Velocity}}{\text{time}}$

Work ($kg\text{-}m^2/s^2$) or J ⇒ **Work** = **Force** x **displacement**

Pressure ($kg\ m^{-1}\ s^{-2}$) or Pa ⇒ **Pressure** = $\frac{\text{Force}}{\text{Area}}$

What are **units** and **system** of units?

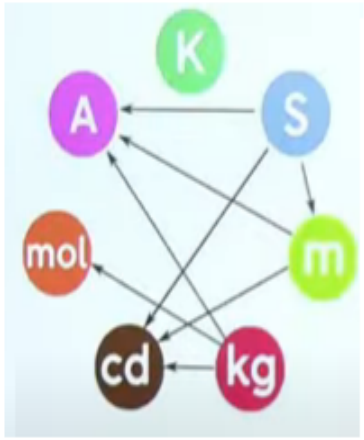
What are **units and system of units?**

Unit of a physical quantity is a standard used for the measurement of that physical quantity.

System of units

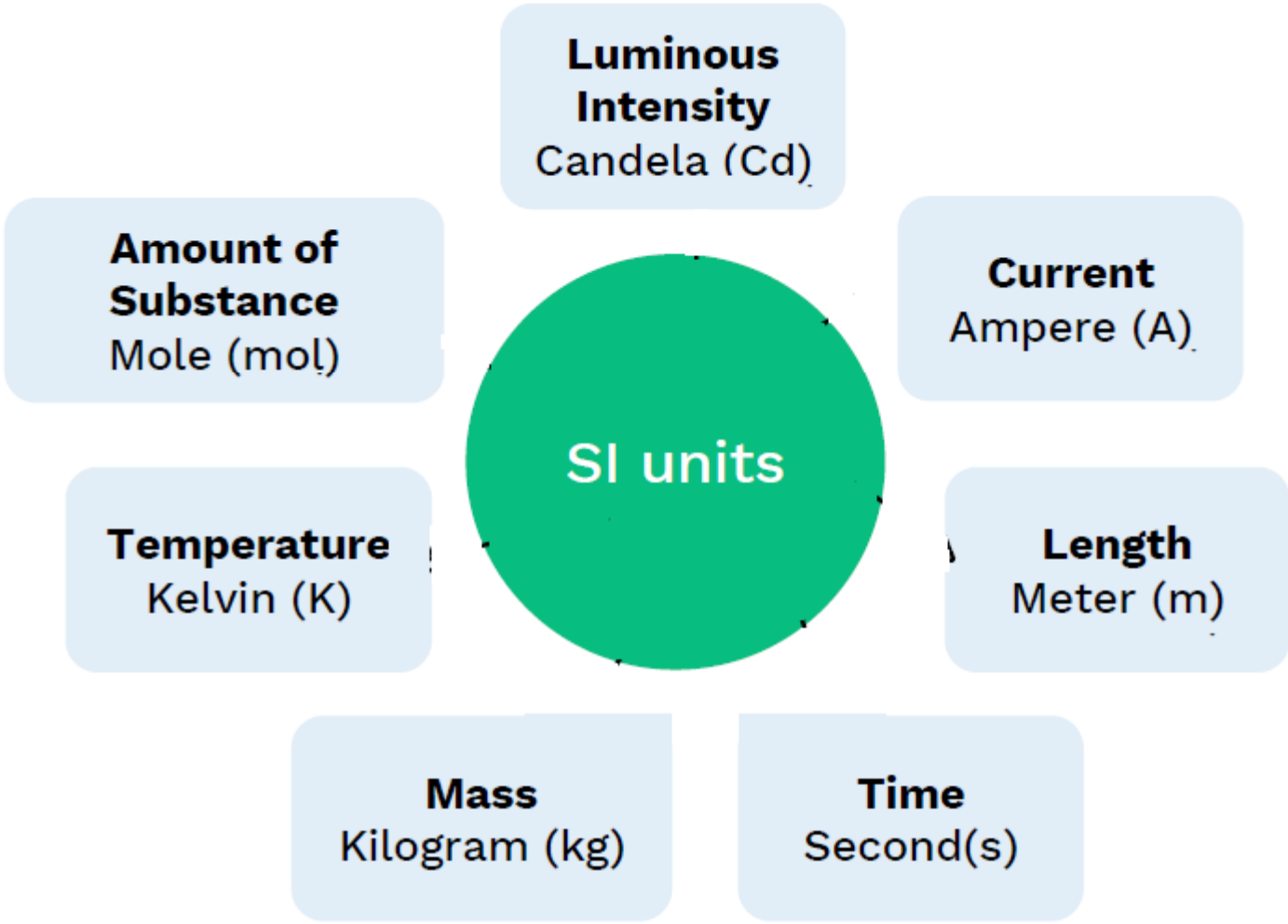
A set or collection of Fundamental & Derived Unit is called as system of unit.

What are **units** and **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

SI Units: International System of Units



What are **dimensions** and their **symbol** ?

Dimension

Power to which fundamental quantity must be raised in order to obtain the unit of the given quantity.

Symbol for Dimensions	General Form
	[LMT] or [MLT]
	[LMTKA] or [MLTKA]

What are **dimensions** and their **symbol** ?

Symbol for Dimensions		
Fundamental Quantity	**Dimension**	**Representation**
Length	$[M^0L^1T^0]$	**L**
Mass	$[M^1L^0T^0]$	**M**
Time	$[M^0L^0T^1]$	**T**
Temperature	$[M^0L^0T^0K^1A^0]$	**K**
Electric current	$[M^0L^0T^0K^0A^1]$	**A / I**

*** Luminous Intensity - C
*** Amount of Substance - mol

How to find **dimensions** of **derived quantities** ?

Dimension of Speed	
Step 1	$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$
Step 2	$\text{Speed} = \frac{[M^0L^1T^0]}{[M^0L^0T^1]}$
Step 3	$\text{Speed} = [M^0L^1T^{-1}]$

How to find **dimensions** of **derived quantities**?

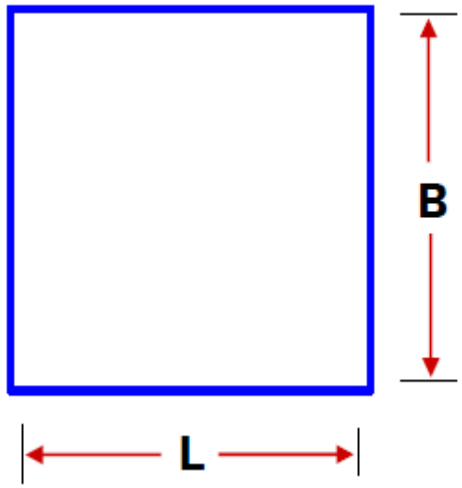
Dimension of Temperature Gradient

Step 1	$\text{Temp Gradient} = \frac{\text{Temp}}{\text{Distance}}$
Step 2	$\text{Temp Gradient} = \frac{[M^0L^0T^0K^1]}{[M^0L^1T^0K^0]}$
Step 3	$\text{Temp Gradient} = [M^0L^{-1}T^0K^1]$

Question

Find the **dimensions** of **Area.**

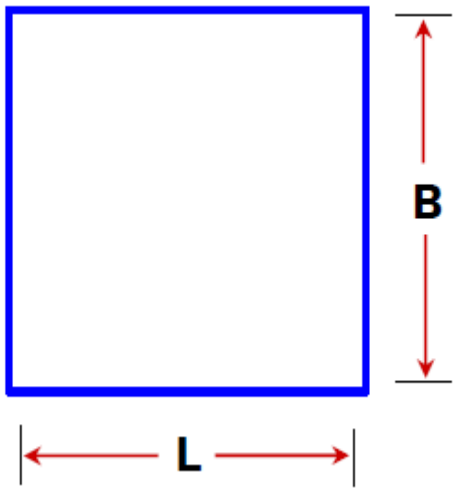
A. $[M^0 L^2 T^0]$
B. $[MLT^2]$
C. $[M^0L^0T^1]$
D. None of these



Question

Find the **dimensions** of **Area.**

Step 1	Area = Length x Breadth
Step 2	SI Unit = m x m = m^2
Step 3	Dimension = $[M^0 L^2 T^0]$



Question

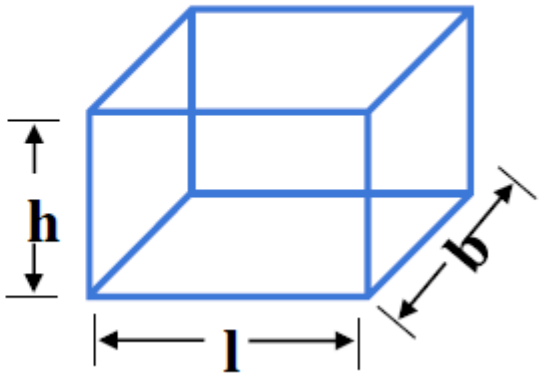
Find the **dimensions** of **Volume**

A. $[M^0 L^3 T^2]$

B. $[M^2 L^2 T^0]$

C. $[M^0 L^3 T^0]$

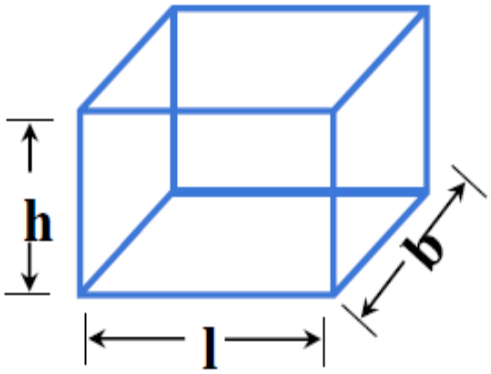
D. $[M^0 L^3 T^{-1}]$



Question

Find the **dimensions** of **Volume**.

Step 1	Volume = Length x Breadth x Height
Step 2	SI Unit = m x m x m = m^3
Step 3	Dimension = $[M^0 L^3 T^0]$



Question

Find the **dimension** of **Density**

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

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

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

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

Question

Find the **dimension** of **Density**.

Step 1	$\text{Density } (\rho) = \frac{\text{Mass}}{\text{Volume}}$
Step 2	$\text{Density } (\rho) = \frac{[M^1\ L^0\ T^0]}{[M^0\ L^3\ T^0]}$
Step 3	$\text{Density } (\rho) = [M^1\ L^{-3}\ T^0]$

Question

Find the **dimension** of **Momentum**

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

B. $[M^{0} L^{-1} T^{2}]$

C. $[M^{-2} L^{-3} T^{0}]$

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

How to find **dimensions** of **derived quantities** ?

Find the **dimension** of **Momentum**.

Step 1	Momentum (p) = Mass x Velocity
Step 2	Momentum (p) = $[M^1L^0T^0]$ $[M^0L^1T^{-1}]$
Step 3	Momentum (p) = $[M^1\ L^1\ T^{-1}]$

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

$$\text{Velocity} = \frac{[M^0\ L^1\ T^0]}{[M^0\ L^0\ T^1]}$$

Question

Find the **dimensions** of **Force**.

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

B. $[M^{0} L^{-1} T^{2}]$

C. $[M^{-2} L^{-3} T^{0}]$

D. $[M^{1} L^{1} T^{-2}]$

Find the **dimensions** of **Force**

Force = Mass × acceleration

= m × a

$$a = \frac{v_2 - v_1}{t}$$

Dimensions of Mass = $[M^1 L^0 T^0]$

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

Dimensions of Acceleration = $[M^0 L^1 T^{-2}]$

∴ Dimensions of Force = $[M^1 L^0 T^0]$ $[M^0 L^1 T^{-2}]$

Question

Find the **dimensions** of **Gravitational Constant**

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

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

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

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

Question Find the **dimensions** of **Gravitational Constant**

Formula of gravitational force,

$$F = \frac{Gm_1m_2}{r^2}$$

$$\therefore \quad G = \frac{Fr^2}{m_1m_2}$$

Where G ⟶ Universal constant of gravitation

m_1, m_2 ⟶ Masses

r ⟶ Distance between the two masses

Dimensions of Force = $[M^1 L^1 T^{-2}]$

Dimensions of Length = $[M^0 L^1 T^0]$

Dimensions of r^2 = $[M^0 L^2 T^0]$

Dimensions of Mass = $[M^1 L^0 T^0]$

$$\therefore \text{ Dimensions of } G = \frac{[M^1 L^1 T^{-2}] \quad [M^0 L^2 T^0]}{[M^2 L^0 T^0]}$$

$$= \frac{[M^1 L^3 T^{-2}]}{[M^2 L^0 T^0]}$$

Dimensions of G = $[M^{-1} L^3 T^{-2}]$

Question

Find the dimensions of **CHARGE.**

A. $[M^0\ L^0\ T^1\ A^1]$

B. $[M^0\ L^0\ T^1\ A^{-1}]$

C. $[M^{-1}\ L^1\ T^2\ A^1]$

D. None of these

Solution:

$$Q = \text{Current} \times \text{time}$$

$$Q = I \times t$$

$$\text{Dimensions of Current (I)} = [M^0 L^0 T^0 A^1]$$

$$\text{Dimensions of Time (t)} = [M^0 L^0 T^1]$$

$$\therefore \text{Dimensions of Q} = [M^0 L^0 T^0 A^1] \quad [M^0 L^0 T^1]$$

$$\text{Dimensions of Q} = [M^0 L^0 T^1 A^1]$$

Question

Find the **dimensions** of **Electric Potential**

A. $[M^0\ L^0\ T^1\ A^1]$

B. $[M^1\ L^2\ T^{-3}\ A^{-1}]$

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

D. None of these

Solution:

Energy (U) = charge (Q) × potential (V)

$$\therefore \quad V = \frac{U}{Q}$$

Dimensions of U = $[M^1 L^2 T^{-2}]$

Dimensions of Q = $[M^0 L^0 T^1 A^1]$

$$\therefore \text{ Dimensions of V} = \frac{[M^1 L^2 T^{-2}]}{[M^0 L^0 T^1 A^1]}$$

Dimensions of V = $[M^1 L^2 T^{-3} A^{-1}]$

Question

Find the dimensions of Resistance

A. $[M^1 L^0 T^1 A^1]$

B. $[M^1 L^2 T^{-3} A^{-1}]$

C. $[M^1 L^2 T^{-3} A^{-2}]$

D. None of these

Solution:

By Ohm's Law,

$$\text{Resistance} = \frac{\text{Potential}}{\text{Current}}$$

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

$$\text{Dimensions of } V = [M^1 L^2 T^{-3} A^{-1}]$$

$$\text{Dimensions of } I = A^1$$

$$\therefore \text{Dimensions of } R = \frac{[M^1 L^2 T^{-3} A^{-1}]}{[M^0 L^0 T^0 A^1]}$$

$$\text{Dimensions of } R = [M^1 L^2 T^{-3} A^{-2}]$$

Question

Of the following quantities, which one has dimension different from the remaining 2?

A. Energy per unit volume
B. Force per unit area
C. Angular momentum per unit mass
D. All A,B,C are same

Solution:

[energy per unit volume] $= \frac{M^1L^2T^{-2}}{L^3} = M^1L^{-1}T^{-2}$

[force per unit area] $= \frac{M^1L^1T^{-2}}{L^2} = M^1L^{-1}T^{-2}$

[angular momentum per unit mass] $= ML^2T^{-1} / M^1 = L^2T^{-1}$

Dimensions of commonly used Physical Quantities

S.No.	Physical Quantity (Mechanics)	SI Units	Dimensional formula
1.	Velocity = displacement/time	m/s	M^0LT^{-1}
2.	Acceleration = velocity/time	m/s^2	M^0LT^{-2}
3.	Force = mass × acceleration	$kg\text{-}m/s^2$ = Newton or N	MLT^{-2}
4.	Work = force × displacement	$kg\text{-}m^2/s^2$ = N-m = Joule or J	ML^2T^{-2}
5.	Energy	N-m	
6.	Torque = force × perpendicular distance		
7.	Power = work/time	J/s or watt	ML^2T^{-3}
8.	Momentum = mass × velocity	Kg-m/s	MLT^{-1}
9.	Impulse = force × time	Kg-m/s or N-s	MLT^{-1}

10.	Angle = arc/radius	radian or rad	$M^0L^0T^0$
11.	Strain = $\frac{\Delta L}{L}$ *or* $\frac{\Delta V}{V}$	no units	
12.	Stress = force/area	N/m^2	$ML^{-1}T^{-2}$
13.	Pressure = force/area	N/m^2	$ML^{-1}T^{-2}$
14.	Modulus of elasticity = stress/strain	N/m^2	$ML^{-1}T^{-2}$
15.	Frequency = 1/ time period	per sec or hertz (Hz)	$M^0L^0T^{-1}$
16.	Angular velocity = angle/time	rad/s	$M^0L^0T^{-1}$
17.	Moment of inertia = (mass) (distance) ^{2}	$kg\text{-}m^2$	ML^2T^0
18.	Surface tension = force/length	N/m	ML^0T^{-2}
19.	Gravitational constant $= \frac{\text{Force} \times (\text{distance})^2}{(\text{mass})^2}$	$N\text{-}m^2/kg^2$	$M^{-1}L^3T^{-2}$

S.No.	Physical Quantity	SI Units	Dimensional formula
1.	Thermodynamic temperature	kelvin (K)	$M^0L^0T^0K$
2.	Heat	joule	ML^2T^{-2}
3.	Specific heat	$Jkg^{-1}K^{-1}$	$M^0L^2T^{-2}K^{-1}$
4.	Latent heat	$J\ kg^{-1}$	$M^0L^2T^{-2}$
5.	Universal gas constant	$J\ mol^{-1}\ K^{-1}$	$ML^2T^{-2}\ K^{-1}mol^{-1}$
6.	Boltzmann's constant	JK^{-1}	$ML^2T^{-2}\ K^{-1}$
7.	Stefan's constant	$Js^{-1}m^{-2}\ K^{-4}$	$MT^{-3}K^{-4}$
8.	Planck's constant	Js	ML^2T^{-1}
9.	Solar constant	$J\ m^{-2}\ s^{-1}$	ML^0T^{-3}
10.	Thermal conductivity	$Js^{-1}m^{-1}\ K^{-1}$	$MLT^{-3}\ K^{-1}$
11.	Thermal resistance	$Kscal^{-1}$	$M^{-1}L^{-2}T^3K$
12.	Enthalpy	cal	ML^2T^{-2}
13.	Entropy	$cal\ K^{-1}$	$ML^2T^{-2}K^{-1}$

Quantities having same Dimensions

Dimension	Quantity
$[M^0L^0T^{-1}]$	Frequency, angular frequency, angular velocity, velocity gradient and decay constant
$[M^1L^2T^{-2}]$	Work, internal energy, potential energy, kinetic energy, torque, moment of force
$[M^1L^{-1}T^{-2}]$	Pressure, stress, Young's modulus, bulk modulus, modulus of rigidity, energy density
$[M^1L^1T^{-1}]$	Momentum, impulse
$[M^0L^1T^{-2}]$	Acceleration due to gravity, gravitational field intensity
$[M^1L^1T^{-2}]$	Thrust, force, weight, energy gradient
$[M^1L^2T^{-1}]$	Angular momentum and Planck's constant
$[M^1L^0T^{-2}]$	Surface tension, Surface energy (energy per unit area)
$[M^0L^0T^0]$	Strain, refractive index, relative density, angle, solid angle, distance gradient, relative permittivity (dielectric constant), relative permeability etc.
$[M^0L^2T^{-2}]$	Latent heat and gravitational potential
$[ML^2T^{-2}K^{-1}]$	Thermal capacity, gas constant, Boltzmann constant and entropy
$[M^0L^0T^1]$	$\sqrt{\frac{l}{g}}, \sqrt{\frac{m}{k}}, \sqrt{\frac{R}{g}}$, where l = length g = acceleration due to gravity, m = mass, k = spring constant, R = Radius of earth
$[M^0L^0T^1]$	$\frac{L}{R}, \sqrt{LC}, RC$ where L = inductance, R = resistance, C = capacitance
$[ML^2T^{-2}]$	$I^2Rt, \frac{V^2}{R}t, VIt, qV, LI^2, \frac{q^2}{C}, CV^2$ where I = current, t = time, q = charge, L = inductance, C = capacitance, R = resistance