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Chapter 1
Measurements

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Content

أولا
01

Physical Quantities

Physical Quantities :

Definition: A physical quantity is one that can be measured and consists of a **magnitude** and **unit**

Physical Quantity (Q) = Numerical Value (magnitude) * Units (U)

Example:

magnitude **unit**

Length of the pencil = 12 cm

Temperature of our classroom = 25 °C

we have two kinds of **physical quantities**

1-Fundamental physical quantities /basic physical quantities

The basic physical quantities are those quantities which do not need other physical quantities to define them .

There are only 7 fundamental physical quantities:

(Length , Mass , Time , Temperature , Electric current , Amount of substance , Luminous intensity).

2-Derived physical quantities

Derived physical quantities are those , which can be expressed by more than one basic physical quantity, this means that they need to be defined more than one physical quantity.

Some examples : (Speed or Velocity , Density , Volume)

ثانيا 02

The international system of Units (SI)

The international system of Units (**SI**):

Previously, every country or continent, has different measurement units of a physical quantity, for example it was used to measure length in some countries, mile, meter, foot, arm, inch, and ... etc..

When science prospered and trade developed between nations, the urgent need to agree on unit of measurement in all countries of the world. And the group of scientists in the world are agree to divide the physics units into two parts:

1- Base units.

2- Derived units.

The international system of Units (**SI**):

1- Base unis :

There are seven base units in the International System of units to measure seven fundamental quantities

Base Quantities	Symbol of Quantities	Name of Unit	Symbol of Unit
Length	ℓ	Meter	m
Mass	m	Kilogram	Kg
Time	t	second	s
Electric current	I	Ampere	A
Temperature	T	Kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I	Candela	Cd

2-Derived Units:

The remaining physical units are derived units, which can be expressed by more than one base units.

Example 1: derive the unit of area from base units ,if you know the formula for area is:

Area= Length x Width

The Solution

Area= Length x Width

= m x m

= m^2

Example 2: derive the unit of volume from base units ,if you know the formula for volume is:

Volume= Length X Width X Height

The Solution

Volume= Length X Width X Height

= m X m X m

= m^3

Example 3: derive the unit of velocity from base units ,if you know the formula for velocity is:

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

The Solution

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

$$= \frac{m}{sec}$$

So, the unit can be written as: $m \, . \, sec^{-1}$

Example 4: derive the unit of acceleration from base units ,if you know the formula for acceleration is:

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

The Solution

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

$$\text{Velocity} = \frac{\text{Displasment}}{\text{Time}} = \frac{m}{sec}$$

Time= sec

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

$$= \frac{\frac{m}{sec}}{sec} = \frac{m}{sec \times sec} = \frac{m}{sec^2}$$

So, the unit can be written as: $m \, . \, sec^{-2}$

Example 5: derive the unit of force from base units ,if you know the formula for force is:

Force = Mass X Acceleration

The Solution

Force = Mass X Acceleration

Mass = kg

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}} = \frac{\frac{m}{sec}}{sec} = \frac{m}{sec \times sec} = \frac{m}{sec^2}$$

Force = Mass X Acceleration

$$= kg \times \frac{m}{sec^2}$$ → Newton (N)

So, the unit can be written as: $Kg \cdot m \cdot sec^{-2}$

Example 6: derive the unit of pressure from base units ,if you know the formula for pressure is:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

The Solution

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Force} = \text{Mass X Acceleration} = kg \times \frac{m}{sec^2}$$

$$\text{Area} = \text{Length x Width} = m \times m = m^2$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{kg \times \frac{m}{sec^2}}{m^2} = \frac{kg \times m}{sec^2 \times m^2} = \frac{kg}{sec^2 \times m}$$

Pascal(Pa)=N/ m^2

So, the unit can be written as: $Kg \cdot m^{-1} \cdot sec^{-2}$

Example 7: derive the unit of work from base units ,if you know the formula for work is:

Work= Force X Displasment

The Solution

Work= Force X Displasment

Force = Mass X Acceleration = $kg \cdot \frac{m}{sec^2}$

Displasment = m

Work= Force X displasment

$= kg \times \frac{m}{sec^2} \times m$

$= \frac{kg \times m^2}{sec^2}$ → Joule(J)=N . m

So, the unit can be written as: $Kg \cdot m^2 \cdot sec^{-2}$

Example 8: derive the unit of power from base units ,if you know the formula for power is:

$$Power = \frac{Work}{Time}$$

The Solution

$$Power = \frac{Work}{Time}$$

Work= Force X Displasment = $kg \times \frac{m}{sec^2} \times m = \frac{kg \times m^2}{sec^2}$

Time = sec

$$Power = \frac{Work}{Time} = \frac{\frac{kg \times m^2}{sec^2}}{sec} = \frac{kg \times m^2}{sec \times sec^2} = \frac{kg \times m^2}{sec^3}$$ → Watt(w)=J/ sec

So, the unit can be written as: $Kg \cdot m^2 \cdot sec^{-3}$

ثالثا

03

The other systems of units

The other systems of units:

There are three other old and famous system of units : Metric system (French system) , Gaussian system(German system) and British system. Each of these systems uses four fundamental (base) quantities (Length , Mass, Time , Temperature).

Fundamental quantities	1-Metric System (MKS):	2-Gaussian System (CGS):	3- British System (FPS):
Length	meter, m	centimeter, cm	foot, ft
Mass	kilogram, Kg	gram, g	pound, Pd
Time	second, s	second, s	Second, s
Temperature	Kelvin, K	Kelvin, K	Fahrenheit, °F

رابعا
04

Conversion between systems

Conversion between systems (MKS, CGS and FPS) by using units analysis :

1-Units of Length:

	Systems of Units	Name of Unit	Symbol of Unit
Units of Length	Metric system	Kilogram	kg
		Meter	m
	Gaussian system	Centimeter	cm
	British system	Mile	mi
		Foot	Ft
		Inch	in

Conversion Factors
1km =1000m
1 m = 100 cm
1mi=1.609 km
1 mi= 1609 m
1 mi=160900 cm
1 m= 3.281 ft
1 m= 39.3 in
1 ft= 12 in
1ft=30.48cm
1in=2.54cm

Example 1: Convert the Following Operations by using unit's analysis :

A- Convert 160 into m.

The Solution

$160\ in \longrightarrow m$

$1m = 39.3\ in$

$$160\ in = \frac{160\ \cancel{in}}{1} \times \frac{1m}{39.3\ \cancel{in}}$$

$$160\ in = \frac{160}{39.3}\ m$$

$$160\ in = 4.07\ m$$

∴ 160 in is equal 4.07 m

B- Convert 3 m to in.

The Solution

$3m \longrightarrow in$

$1m = 39.3\ in$

$$3\ m = \frac{3\ \cancel{m}}{1} \times \frac{39.3\ in}{1\cancel{m}}$$

$$3\ m = \frac{3}{1} \times \frac{39.3\ in}{1}$$

$$3\ m = 3 \times 39.3\ in$$

$$3\ m = 117.9\ in$$

∴ 3 m is equal 117.9 in

C- Convert 2 m to ft.

The Solution

2 m ⟶ ft

1m= 3.281ft

$$2m = \frac{2\ m}{1} X \frac{3.281\ ft}{1m}$$

$$2m = \frac{2\ x\ 3.281}{1\ x1}\ ft$$

2m = 2 x 3.281 ft

2 m=6.562 ft

∴ 2 m is equal 6.562 ft

D- Convert 400 cm to m.

The Solution

400 cm ⟶ m

1m= 100 cm

$$400\ cm = \frac{400\ cm}{1} X \frac{1m}{100\ cm}$$

$$400\ cm = \frac{400}{1} X \frac{1m}{100}$$

$$400\ cm = \frac{400}{100} m$$

400 cm= 4 m

∴ 400 cm is equal 4 m

E- Convert 36 into cm

The Solution

36 in → cm

1 in= 2.54 cm

$$36\text{ in} = \frac{36\ \cancel{\text{in}}}{1} \times \frac{2.54\text{ cm}}{1\ \cancel{\text{in}}}$$

$$36\text{ in} = \frac{36}{1} \times \frac{2.54\text{ cm}}{1}$$

36 in = 36 X 2.54 cm

36 in = 91.44 cm

∴ 400 in is equal 91.44 cm

Example 2: a plane is flying away from the ground at an altitude of 15000 ft , what is the altitude of plane in meter?, (using unit's analysis).

The Solution

15000 ft → m

1m= 3.281ft

$$15000\text{ ft} = \frac{15000\ \cancel{\text{ft}}}{1} \times \frac{1\text{m}}{3.281\ \cancel{\text{ft}}}$$

$$15000\text{ ft} = \frac{15000}{1} \times \frac{1m}{3.281}$$

$$15000\text{ ft} = \frac{15000}{3.281}\text{ m}$$

15000 ft = 4572 m

∴ 15000 ft is equal 4572 m

Example 3: A Park has an area of 2 km^2 , what is the area in m^2? , (Using units' analysis)

The Solution

$$2\ km^2 \longrightarrow m^2$$

$$(1\ km)^2 = (1000\ m)^2$$

$$1\ km^2 = 1000000\ m^2$$

$$2\ km^2 = \frac{2\ \cancel{km^2}}{1} \times \frac{1000000\ m^2}{1\ \cancel{km^2}}$$

$$2\ km^2 = \frac{2}{1} \times \frac{1000000\ m^2}{1}$$

$$2\ km^2 = 2 \times 1000000\ m^2$$

$$2\ km^2 = 2000000\ m^2$$

$\therefore$ 2 km^2 is equal 2000000 m^2

2- Units of Mass:

	Systems of Units	Name of Unit	Symbol of Unit
Units of Mass	Metric system	Ton	ton
		Kilogram	Kg
	Gaussian system	Gram	g
	British system	Pound	ib

Conversion Factors
1ton = 1000kg
1 kg = 1000g
1kg= 2.2 Ib
1Ib= 454.5g

Example 1: Convert 5ton to kg , by using units analysis.

The Solution

5 ton ⟶ kg

1ton = 1000kg

$$5\text{ ton}= \frac{5\text{ tan}}{1} X \frac{1000\text{kg}}{1\text{ tan}}$$

$$5\text{ ton}= \frac{5}{1} X \frac{1000\text{kg}}{1}$$

$$5\text{ ton}= \frac{5\ x\ 1000\ kg}{1}$$

5 ton= 5 x 1000 kg

5 ton= 5000 kg

∴ 5 ton is equal 5000 kg

Example 2: A box of wood has a mass of 40 kg , what is this mass in Ib?
(using units' analysis) The Solution

40kg → Ib

1 kg= 2.2 lb

$$40 \text{ kg} = \frac{40 \text{ kg}}{1} \text{X} \frac{2.2 \text{ Ib}}{1\text{kg}}$$

$$40 \text{ kg} = \frac{40}{1} \text{X} \frac{2.2\ Ib}{1}$$

$$40 \text{ kg} = \frac{40 \text{ x } 2.2\ Ib}{1}$$

$$40 \text{ kg} = 40 \text{ x } 2.2 \text{ Ib}$$

$$40 \text{ kg} = 88 \text{ Ib}$$

∴ 40 kg is equal 88 Ib

3- Units of Time:

Conversion Factors
1 year= 365 day
1 day= 24 hour
1 hour= 60 min
1min= 60 second

Example 1: convert the time 1 year to seconds , by using unit's analysis .

The Solution

1year ⟶ sec

$$1\ yr = \frac{1\ yr}{1} X \frac{365\ day}{1yr} X \frac{24\ h}{1\ day} X \frac{60\ min}{1h} X \frac{60\ sec}{1\ min}$$

$$1\ yr = \frac{1}{1} X \frac{365}{1} X \frac{24}{1} X \frac{60}{1} X \frac{60\ sec}{1}$$

$$1\ yr = 1X(365\ X\ 24\ X\ 60\ X\ 60)\ \ sec$$

$$1\ yr = 31536000\ sec$$

∴ 1 yr. is equal 31536000 sec

Example 2 : convert the time 1440 minutes to days, by using unit's analysis

The Solution

1440 min → day

1 day= 24 hour

1 hour=60 min

$$1440\ \text{min} = \frac{1440\ \text{min}}{1} \times \frac{1\ \text{h}}{60\ \text{min}} \times \frac{1\ \text{day}}{24\ \text{h}}$$

$$1440\ \text{min} = \frac{1440}{1} \times \frac{1}{60} \times \frac{1\ \text{day}}{24}$$

$$1440\ \text{min} = \frac{1440\ \text{day}}{60 \times 24}$$

$$1440\ \text{min} = \frac{1440\ \text{day}}{1440}$$

$$1440\ \text{min} = 1\ \text{day}$$

∴ 1440 min is equal 1 day

Compound units:

Example 1 : A car moves with a speed of 120 $\frac{\text{mil}}{\text{h}}$, what is its speed in $\frac{\text{km}}{\text{sec}}$? , (using units' analysis).

The Solution

$$120\ \frac{\text{mil}}{\text{h}} \longrightarrow \frac{\text{km}}{\text{sec}}$$

1mil = 1.609 km

$$120\ \frac{\text{mil}}{\text{h}} = 120\ \frac{\cancel{\text{mil}}}{\cancel{\text{h}}}\ \text{X}\ \frac{1.609\ \text{km}}{1\ \cancel{\text{mil}}}\ \text{X}\ \frac{1\ \cancel{\text{h}}}{3600\ \text{sec}}$$

$$120\ \frac{\text{mil}}{\text{h}} = \frac{120}{1}\ \text{X}\ \frac{1.609\ \text{km}}{3600\ \text{sec}}$$

$$120\ \frac{\text{mil}}{\text{h}} = \frac{120\text{x}\ 1.609\ \text{km}}{3600\ sec}$$

$$120\ \frac{\text{mil}}{\text{h}} = 0.053\ \frac{\text{km}}{\text{sec}}$$

$$\therefore 120\ \frac{\text{mil}}{\text{h}}\ \text{ is equal }\ 0.053\ \frac{\text{km}}{\text{sec}}$$

Example 2 : Radar indicates a car is traveling at 90 $\frac{\text{km}}{\text{min}}$, how fast is the car traveling in $\frac{\text{mil}}{\text{h}}$? , (using units' analysis).

The Solution

$$90\ \frac{\text{Km}}{\text{h}} \longrightarrow \frac{\text{m}}{\text{sec}}$$

1mil = 1.609 m ‘ 1h=60 min

$$90\ \frac{\text{Km}}{\text{min}} = 90\ \frac{\cancel{\text{Km}}}{\cancel{\text{min}}}\ \text{X}\ \frac{1\ mil}{1.609\ \cancel{\text{km}}}\ \text{X}\ \frac{60\ \cancel{\text{min}}}{1\ \text{h}}$$

$$90\ \frac{\text{Km}}{\text{min}} = \frac{90}{1}\ \text{X}\ \frac{1\ \text{mil}}{1.609}\ \text{X}\ \frac{60}{1\ \text{h}}$$

$$90\ \frac{\text{Km}}{\text{min}} = \frac{90\ \text{x}\ 1\ \text{mil}\ \text{x}\ 60}{1.609\ \text{x}\ 1\ \text{h}}$$

$$90\ \frac{\text{Km}}{\text{min}} = \frac{5400\ \text{m}}{1.609\ \text{sec}}$$

$$90\ \frac{\text{Km}}{\text{min}} = 3356.12\ \frac{\text{mil}}{\text{h}}$$

$$\therefore 90\ \frac{\text{Km}}{\text{min}}\ \text{ is equal }3356.12\ \frac{\text{mil}}{\text{h}}$$

4- Units of Temperature :

Temperature Measurement Systems (T_C, T_F andT_K):

System	unit	Freezing Point of Water	Boiling Point of Water
Celsius	$^\circ C$	0	100
Fahrenheit	$^\circ F$	32	212
Kelvin	K	273	373

A- Relationship Between (T_C,T_F):

$$T_C = \frac{T_F - 32}{1.8}$$

$$T_F = 1.8\, T_C + 32$$

B- Relationship Between (T_C,T_K):

$$T_K = T_C + 273$$

$$T_C = T_K - 273$$

C- Relationship Between T_F and T_K:

$$T_F = 1.8(T_K - 273) + 32$$

$$T_K = 273 + \frac{T_F - 32}{1.8}$$

Example 1: Convert the Following Operations:

A- Convert 300 K to T_C.

The Solution

$300\ K \longrightarrow T_C$

$T_C = T_k - 273$

$= 300 - 273$

$= 27°C$

B- Convert 10°Cto T_K .

The Solution

$10°C \longrightarrow T_K$

$T_K = 273 + T_C$

$= 273 + 10$

$= 283\ k^o$

C- Convert 40°F to T_C.

The Solution

$40°F \longrightarrow T_C$

$$T_C = \frac{T_F - 32}{1.8}$$

$$= \frac{40 - 32}{1.8}$$

$$= \frac{8}{1.8}$$

$= 4.4°C$

D- Convert 20°C to T_F.

The Solution

$20°C \longrightarrow T_F$

$$T_F = 1.8\, T_C + 32$$

= 1.8 X 20 + 32

= 36 + 32

=68 °F

E- Convert 40°F to T_K.

The Solution

$40°F \longrightarrow T_K$

$$T_K = 273 + \frac{T_F - 32}{1.8}$$

$$= 273 + \frac{40 - 32}{1.8}$$

$$= 273 + \frac{8}{1.8}$$

= 273 + 4.4

= 277.4 K

Example 2: Body temperature is 90°F, what is the temperature in Celsius scale ?

The Solution

$$90°F \longrightarrow T_C$$

$$T_C = \frac{T_F - 32}{1.8}$$

$$= \frac{90 - 32}{1.8}$$

$$= \frac{58}{1.8}$$

$$= 32.2°C$$

Example 3: Room temperature is often used in calculations as 300 K . What is the temperature in Fahrenheit scale ?

The Solution

$$300\ K \longrightarrow T_F$$

$$T_F = 1.8(T_K - 273) + 32$$

$$= 1.8\,(300 - 273) + 32$$

$$= 1.8\,(27) + 32$$

$$= 48.6 + 32$$

$$= 80.6°F$$

خامسا

05

Prefixes

Prefixes:

The prefixes used to indicate multiples or fractions of the units.

Example :

Magnitude → 1000, Prefix → K, unit → m

The distance from ARAR to Riyadh = 1000 Km = 1000 X 10^3 m = 1X 10^6 m.

The distance from ARAR to Jeddah = 1222 km = 1222 X10^3 m = 1.222 X 10^6 m. (Scientific notation)

The Length of bacteria = 5 μm = 5 X 10^{-6} m.

Prefixes for (SI) units

Prefix	Abbreviation	Factor	Factor	Abbreviation	Prefix
yotta	Y	10^{24}	10^{-24}	y	yocto
zetta	Z	10^{21}	10^{-21}	z	zepto
exa	E	10^{18}	10^{-18}	a	atto
peta	P	10^{15}	10^{-15}	f	femto
tera	T	10^{12}	10^{-12}	p	pico
giga	G	10^{9}	10^{-9}	n	nano
mega	M	10^{6}	10^{-6}	µ	micro
Kilo	k	10^{3}	10^{-3}	m	milli
hecto	h	10^{2}	10^{-2}	c	centi
deka	da	10^{1}	10^{-1}	d	deci

Example 1: Convert the Following Operations by using unit analysis:

A- Convert 3 Gm to m.

The Solution

3 Gm ⟶ m

$1\ \text{Gm} = 10^9\text{m}$

$3\ \text{Gm} = \frac{3\ \text{Gm}}{1} \times \frac{10^9\text{m}}{1\ \text{Gm}}$

$3\ \text{Gm} = \frac{3}{1} \times \frac{10^9\text{m}}{1}$

$3\ \text{Gm} = \frac{3 \times 10^9}{1}\text{m}$

$3\ \text{Gm} = 3 \times 10^9\text{m}$

$3\ \text{Gm} = 3000{,}000{,}000\ \text{m}$

$\therefore$ 3 Gm is equal $3 \times 10^9\text{m}$

B- Convert 17 μm to m.

The Solution

17μm ⟶ m

$1\ \text{m} = 10^6\mu\text{m}$

$17\ \mu\text{m} = \frac{17\ \mu\text{m}}{1} \times \frac{1\ \text{m}}{10^6\mu\text{m}}$

$17\ \mu\text{m} = \frac{17}{1} \times \frac{1\ \text{m}}{10^6}$

$17\ \mu\text{m} = \frac{17}{10^6}\ \text{m}$

$17\ \mu\text{m} = 17 \times 10^{-6}\text{m}$

$17\ \mu\text{m} = 0.000017\text{m}$

$\therefore$ 17 μm is equal $17 \times 10^{-6}\text{m}$

C- Convert 9 kΩ to cΩ.

The Solution

$9k\Omega \longrightarrow C\Omega$

$1\ K\Omega = 10^3\ \Omega$

$1\ \Omega = 10^2 C\Omega$

$9\ K\Omega = \frac{9\ K\Omega}{1} X \frac{10^3 \Omega}{1\ K\Omega} X \frac{10^2 C\Omega}{1\ \Omega}$

$9\ K\Omega = \frac{9}{1} X \frac{10^3}{1} X \frac{10^2 C\Omega}{1}$

$9\ K\Omega = \frac{9}{1} X \frac{10^3}{1} X \frac{10^2 C\Omega}{1}$

$9\ K\Omega = 9\ X\ 10^3 X\ 10^2\ C\Omega$

$9\ K\Omega = 9\ X\ 10^5\ C\Omega$

$9\ K\Omega = 900000\ C\Omega$

$\therefore$ 9 KΩ is equal $9\ X\ 10^5\ C\Omega$

D- Convert 100 mA to nA.

The Solution

$100mA \longrightarrow nA$

$1\ A = 10^3 mA$

$1\ A = 10^9 nA$

$100\ mA = \frac{100\ mA}{1} X \frac{1A}{10^3 mA} X \frac{10^9 nA}{1\ A}$

$100\ mA = \frac{100}{1} X \frac{1}{10^3} X \frac{10^9 nA}{1}$

$100\ mA = \frac{100\ X 10^9}{10^3} nA$

$100\ mA = 100\ X\ 10^9 X\ 10^{-3} nA$

$100\ mA = 100\ X\ 10^6 nA$

$100\ mA = 1\ X\ 10^8 nA$

$100\ mA = 100000000\ nA$

$\therefore$ 100 mA is equal $1\ X\ 10^8 nA$

E- change 4 MW to kw.

The Solution

4MW ⟶ kW

$1\ MW = 10^6 W$

$1\ KW = 10^3 W$

$$4\ Mw = \frac{4\ MW}{1} X \frac{10^6 W}{1\ MW} X \frac{1KW}{10^3 W}$$

$$4\ Mw = \frac{4}{1} X \frac{10^6}{1} X \frac{1KW}{10^3}$$

$$4\ Mw = \frac{4\ X 10^6}{10^3} kW$$

$$4\ Mw = 4X10^3\ kW$$

$$4\ Mw = 4000kW$$

$\therefore$ 4 Mw is equal $4X10^3$ kW

F- Radio frequency is 1800000 Hz , change in MHz

The Solution

1800000 Hz ⟶ MHz

$1\ MHZ = 10^6 HZ$

$$1800000Hz = \frac{1800000\ HZ}{1} X \frac{1\ MHz}{10^6\ HZ}$$

$$1800000Hz = \frac{1800000}{1} X \frac{1\ MHz}{10^6}$$

$$1800000Hz = \frac{1800000}{10^6} MHz$$

$$1800000Hz = 1800000\ X10^{-6} MHz$$

$$1800000Hz = 1.8MHz$$

$\therefore$ 1800000Hz is equal 1.8MHz

Example 2: length of a piece of metal is 10 cm , how much its length in unit of mm?, (using unit's analysis)

The Solution

$$10cm \longrightarrow mm$$

$$1\ m = 10^2 cm$$

$$1m = 10^3 mm$$

$$10cm = \frac{10cm}{1} X \frac{1m}{10^2 cm} X \frac{10^3 mm}{1m}$$

$$10cm = \frac{10}{1} X \frac{1}{10^2} X \frac{10^3 mm}{1}$$

$$10cm = \frac{10x10^3}{10^2} mm$$

$$10cm = 10x10^1 mm$$

$$10cm = 100mm$$

$\therefore$ 10 cm is equal 100 mm

Example 3: Convert the Following Operations by using power of 10:

A- Convert 6MJ to J.

The Solution

$6MJ \longrightarrow J$

$6MJ = 6 \times 10^{6} J$

6MJ = 6000000 J

$\therefore$ 6 MJ is equal $6 \times 10^{6} J$

B- Convert 50000 ns to s

The Solution

$50000ns \longrightarrow s$

$50000ns = 50000 \times 10^{-9}\ s$

$50000ns = \frac{50000}{10^{9}}\ S$

$50000ns = \frac{\cancel{50000}}{10000\cancel{0000}}\ s$

$50000ns = \frac{5}{100000}\ S$

$50000ns = 5 \times 10^{-5} s$

50000ns = 0.00005 s

$\therefore$ 50000ns is equal $5 \times 10^{-5} s$

C- Convert the mass from kilogram (0.964 kg)to milligrams (mg).

The Solution

0.964kg $\longrightarrow$ mg

0.964 kg= 0.964 X 10^3X 10^3mg

0.964 kg= 0.964 X 10^3X 10^3mg

0.964 kg= 0.964 X 10^6mg

0.964 kg= 964000 mg

$\therefore$ 0.964 kg is equal 0.964 X 10^6mg

Example 4: The diameter of a carbon atom is 0.000182 nm, what is the diameter in µm, by using power of 10?

The Solution

0.000182nm ⟶ µm

$0.000182\ nm = 0.000182 \times 10^{-9} \times 10^{6}\ \mu m$

$0.000182\ nm = 0.000182 \times 10^{-3}\ \mu m$

$0.000182\ nm = 1.82 \times 10^{-7}\ \mu m$

$0.000182\ nm = 0.000000182\ \mu m$

$\therefore$ 0.000182 nm is equal $1.82 \times 10^{-7}\ \mu m$

Example 5: Wavelength of yellow light is 589×10^{-9} m. what is this number expressed in nanometer(nm), (using power of 10)

The Solution

589×10^{-9} m ⟶ nm

$589 \times 10^{-9}\ m = 589 \times 10^{-9} \times 10^{9}\ nm$

$\therefore$ 589×10^{-9} m is equal 589 nm

Angles measurement:

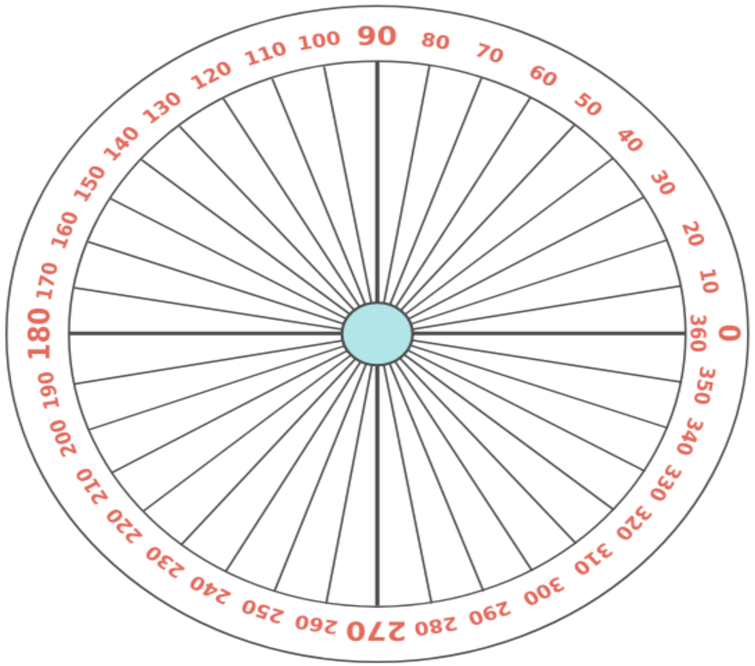
There are tow systems for angles measurement:

1- Degrees System

2- Radians System.

1- Degrees System :

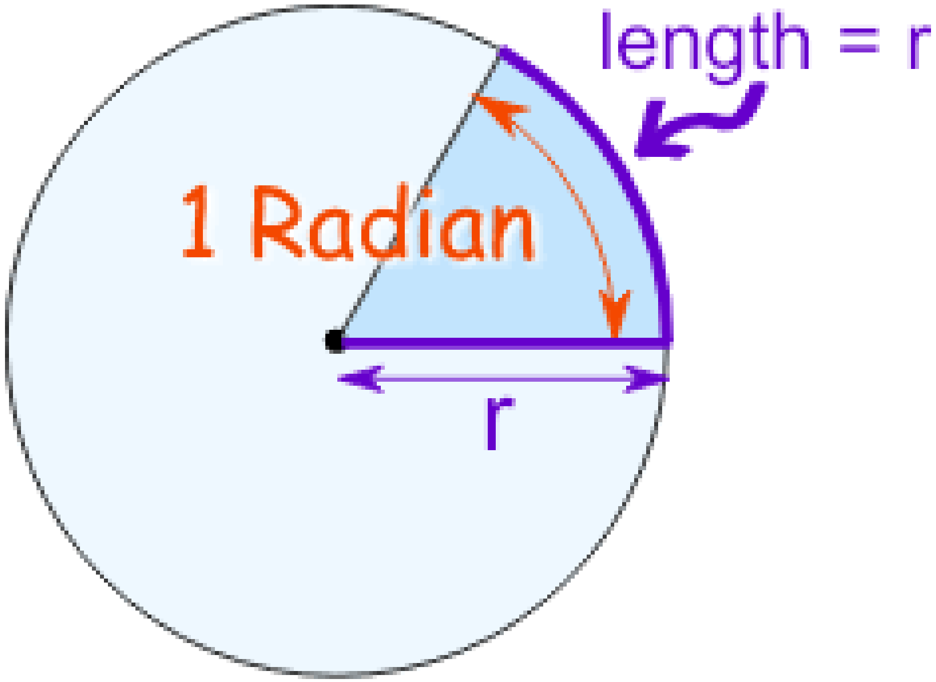
In degrees system the circle is divided into 360 parts each part called degree and its symbol (º).



2- Circular system (Radian):

A radian is the central angle that inserts an arc of a circle whose length corresponds to the radius of the circle.

(1 radian = 57.3°)



Convert methods:

1- To convert from Degree to radian we use the following equation:

$$\text{Rad} = \text{degree} \times \frac{2\pi}{360^\circ} \rightarrow \text{Rad} = \text{Degree} \times \frac{\pi}{180^\circ}$$

2- To convert from radian to degree we use the following equation:

$$\text{Degree} = \text{Rad} \times \frac{360^\circ}{2\pi} \rightarrow \text{Degree} = \text{Rad} \times \frac{180^\circ}{\pi}$$

Some special angles

Degree	Radian
360°	2π
270°	$\frac{3\pi}{2}$
180°	π
90°	$\frac{\pi}{2}$
60°	$\frac{\pi}{3}$
45°	$\frac{\pi}{4}$
30°	$\frac{\pi}{6}$

Example 1: Convert the angle ($\frac{\pi}{3}$ rad) from the radian system to the degree system?

The Solution

Rad ⟶ Degree

$$\text{Degree} = \text{rad} \times \frac{180°}{\pi} = \frac{\pi}{3} \times \frac{180°}{\pi} = \frac{180°}{3} = 60°$$

Example 2: Convert the angle ($\frac{4}{5}\pi$ rad) from the radian system to degree system?

The Solution

Rad ⟶ Degree

$$\text{Degree} = \text{Rad} \times \frac{180°}{\pi} = \frac{4\pi}{5} \times \frac{180°}{\pi} = \frac{4 \times 180°}{5} = 4 \times 36° = 144°$$

Example 3: Convert the angle 30° from the degree system to the radian system?

The Solution

Degree ⟶ rad

$$\text{Rad} = \text{Degree} \times \frac{\pi}{180°} = 30° \times \frac{\pi}{180°} = \frac{3\pi}{18} = \frac{\pi}{6}\ \text{Rad}$$

Example 4: Convert the angle 150° from the degree system to the radian system?

The Solution

Degree ⟶ Rad

$$\text{Rad} = \text{Degree} \times \frac{\pi}{180°} = 150° \times \frac{\pi}{180°} = \frac{15\pi}{18} = \frac{5\pi}{6}\ \text{Rad}$$

سادسا

06

Dimensions Theory

Dimensions Theory :

Each basic measureable physical quantity represented by a specific symbol written within square brackets is called a dimension . All other physical quantities can be derived as combination of the basic dimension.

The goal of dimensional theory:

We use dimensions theory to verify that our equations are correct (that means both sides of equation must have the same dimensions) . Also, to make sure of the correctness and determination of a unit of measurement for each physical quantity.

Note that: numerical constants (2 , $\frac{1}{2}$, π ,...etc.) and the trigonometric functions (cos, sin, tan, … etc.) in physical equations do not affect and have no value when applying the dimensional theory on both sides of the equation.

A-Fundamental Dimensions in SI:

Fundamental Dimension	Symbol	Base Unit
length	[L]	meter (m)
mass	[M]	kilogram (kg)
time	[T]	second (s)
absolute temperature	[K]	kelvin (K)
electric current	[A]	ampere (A)
luminous intensity	[Cd]	candela (cd)
amount of substance	[Mol]	mole (Mol)

B -Derived dimensions:

All other physical quantities can be derived as combination of the basic dimension.

Example 1: Find the dimensions of area from base dimensions , and cheek the unit ,if you know the formula for area is :

Area = Length X Width

The Solution

Area = Length X Width

= [L] X [L]

= $[L^2] = m^2$

Example 2: Find the dimensions of volume from base dimensions, and cheek the unit , if you know the formula for volume is :

Volume= Length X Width X Height

The Solution

Volume= Length X Width X Height

= [L] X [L] X [L]

= $[L^3] = m^3$

Example 3: Find the dimensions of velocity from base dimensions, and cheek the unit ,if you know the formula for velocity is :

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

The Solution

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

$$= \frac{[L]}{[T]} = \frac{m}{sec} \rightarrow m \,.\, sec^{-1}$$

So, the dimension can be written as: $[L \,.\, T^{-1}]$

Example 4: Find the dimensions of acceleration from base dimensions , and cheek the unit ,if you know the formula for acceleration is :

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

The Solution

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

$$\text{Velocity} = \frac{\text{Displasment}}{\text{Time}} = \frac{[L]}{[T]}$$

$$\text{Time} = [T]$$

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

$$= \frac{\frac{[L]}{[T]}}{[T]} = \frac{[L]}{[T]X[T]} = \frac{[L]}{[T^2]} = \frac{m}{sec^2} \rightarrow m \,.\, sec^{-2}$$

So, the dimension can be written as: $[L \,.\, T^{-2}]$

Example 5: Find the dimensions of force from base dimensions , and cheek the unit ,if you know the formula for force is :

Force = Mass X Acceleration

The Solution

Force = Mass X Acceleration

Mass =[M]

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}} = \frac{\frac{[L]}{[T]}}{[T]} = \frac{[L]}{[T]\ [T]} = \frac{[L]}{[T^2]}$$

Force = Mass X Acceleration

$$= [M] \times \frac{[L]}{[T^2]} = \text{Kg} \times \frac{\text{m}}{\text{sec}^2} \rightarrow \text{Kg .m . sec}^{-2}$$

So, the dimension can be written as: $[M\ L\ T^{-2}]$

Example 6: Find the dimensions of pressure from base dimensions, and cheek the unit ,if you know the formula for pressure is :

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

The Solution

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Force} = \text{Mass X Acceleration} = \frac{[M]\ [L]}{[T^2]}$$

$$\text{Area} = \text{Length X Width} = [L]\ \times\ [L] = [L^2]$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{\frac{[M]\ [L]}{[T^2]}}{[L^2]} = \frac{[M]\ [L]}{[T^2]\ [L^2]} = \frac{[M]}{[T^2]\ [L]} = \frac{\text{Kg}}{\text{sec}^2 \times \text{m}} \rightarrow \text{Kg .m}^{-1}\text{ .sec}^{-2}$$

So, the dimension can be written as: $[M\ L^{-1}\ T^{-2}]$

Example 7: Find the dimensions of work from base dimensions , and cheek the unit ,if you know the formula for work is :

Work= Force X Displasment

The Solution

Work= Force X Displasment

Force = Mass X Acceleration $= \frac{[M]\,[L]}{[T^2]}$

Distance= [L]

Work= Force X Distance

$= \frac{[M]\,[L]}{[T^2]}$ X [L]

$= \frac{[M]\,[L^2]}{[T^2]} = \frac{Kg \times m^2}{sec^2}$ → $Kg\ .m^2\ .sec^{-2}$

Joule(J) = N . m

So, the dimension can be written as: $[M\ L^2\ T^{-2}]$

Example 8: Find the dimensions of power from base dimensions, and cheek the unit ,if you know the formula for power is :

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

The Solution

$\text{Power} = \frac{\text{Work}}{\text{Time}}$

Work= Force X Displasment $= \frac{[M]\,[L]}{[T^2]}$ X [L] $= \frac{[M]\,[L^2]}{[T^2]}$

Time = [T]

$\text{Power} = \frac{\text{Work}}{\text{Time}}$

$= \frac{\frac{[M]\,[L^2]}{[T^2]}}{[T]} = \frac{[M]\,[L^2]}{[T]\,[T^2]} = \frac{[M]\,[L^2]}{[T^3]} = \frac{Kg \times m^2}{sec^3}$ → $kg\ .m^2\ .sec^{-3}$

So, the dimension can be written as: $[M\ L^2\ T^{-3}]$

Example 1: verify the validity of the following equation by using the theory of dimensions:

$$F = \frac{m}{a}$$

Where (F) is the force, (m) is mass and (a) is the acceleration.

The Solution

L.H.S , $F = ma = [M]\left(\frac{[L]}{[T^2]}\right)$

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

Acceleration $= \frac{\text{velocity}}{\text{Time}} = \frac{\frac{[L]}{[T]}}{[T]} = \frac{[L]}{[T][T]} = \frac{L}{T^2}$

Mass = [M]

R.H.S, $\frac{M}{a} = \frac{[M]}{\frac{[L]}{[T^2]}} = \frac{[M][T^2]}{[L]}$

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

$\therefore$ R.H.S $\neq$ L.H.S

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

So, the equation is incorrect because the left side is not equal the right side.

Example 2: verify the validity of Simple pendulum equation by using the theory of dimensions:

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

Where: (T) is Periodic time ,(L) is Length and (g) is acceleration.

The Solution

L. H.S, T = [T]

R. H.S, $2\pi\sqrt{\frac{L}{g}} = \sqrt{\frac{[L]}{[L\ .\ T^{-2}]}}$

$= \sqrt{\frac{1}{[T^{-2}]}}$

$= \sqrt{[T^2]}$

$= [T]$

$\therefore$ L. H.S = R . H.S

[T] = [T]

Time = [T]

length = [L]

Acceleration $= \frac{\text{velocity}}{\text{Time}} = \frac{\frac{[L]}{[T]}}{[T]} = \frac{[L]}{[T]\ [T]} = \frac{[L]}{[T^2]}$

$= [L\ .\ T^{-2}]$

So, the equation is correct because the left side is equal the right side.

Example3: verify the validity of the following equation by using the theory of dimensions.

$$V=\pi r^2 h$$

Where: (v) is volume of cylinder ,(r) is radius and (h) is cylinder height.

The Solution

L.H.S , Volume= Length X Width X Height

= [L] X [L] X [L]

= $[L^3]$

R.H.S , $r^2 h$ = $(\text{Length})^2$ X Height

= $[L^2]$ X [L]

= $[L^3]$

∴ L.H.S = R.H.S

$[L^3] = [L^3]$

So, the equation is correct because the left side equal the right side.

Thank you