CHAPTER ONE

Dimensions and Units

1- Basic and Derived Units:

The flow velocity of the fluid for example water in a pipe can be described by the length of the pipe divided by the time required for the fluid to pass through that pipe,

Velocity = Distance/time

The velocity in the above equation represent a derived quantity, the distance and time are basic quantities. These quantities will be denoted by (L) AND (T).

The dimensions of velocity which is a rate of increase of distance with time can be written as $L\ T^{-1}$ or L/T. And by knowing the dimension of mass [M], the dimension of density as derived quantity is mass dimension divided by volume dimension [L^3], i.e [$M\ L^{-3}$].

The basic dimensions are [L], [T], [M] and [F] are enough to study the fluid flow relations. But when discussing thermodynamics together with fluid mechanics, the temperature will be another basic dimension and denoted by ϴ.

Newton's second law of thermodynamic involve the basic dimension in the form:

$$F = m\ a$$

As F = Force, m =mass and a=acceleration of gravity.

The relation can be represented dimensionally as:

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

where acceleration dimension is L/T^2.

2- Empirical Equations And Dimensionless Groups:-

empirical equations are equations which represent the experimental results and they do not based on any physical bases. These equations are very important in fluid mechanics.

There are some equation consist dimensionless groups such as (pvd/u) which called Reynolds Number.as the dimensions are cancel each other.

The value of Reynolds number (N_{Re}) is very important to know the type of fluid flow , i.e: Re < 2000 the flow is laminar and if Re > 4000 the flow is turbulent. See that: Re = pvd/u = [(kg/m^3*m/s*m)/kg/m·s] = without unit.

3- Systems of Units: The various systems of units and the basic quantities associated with them will now be considered :

a- The Centimeter-gram-second (c.g.s) system:-

In this system the basic dimension for length is [L], for mass is [M] and for time is [T] as follows:

Length Dimension L : Unit cm

Mass Dimension M : Unit g

Time Dimension T : Unit s

The unit of force that which gives a mass of 1 gm an acceleration of 1 cm/s^2. And it is known as the dyne (g.cm/s^2). Force dimension F = m a = [M L T^{-2}] unit of dyne.

b- The system international (SI) system:

This system is modification of c.g.s system but uses capital letters. The basic dimensions and units are again of L, M and T but their values are different As follows:

Length Dimension L : Unit m

Mass Dimension M : Unit Kg

Time Dimension T : Unit s

The unit of force known as Newton is that force which give a mass of one kg an acceleration of 1 m/s^2. Thus 1 N = 1 kg m/s^2 with dimensions [$M L T^{-2}$]

And 1 N=10^5 dyne.

Force Dimension is $M L T^{-2}$, Unit 1 N or $kg.m/s^2$.

Power Dimension is $M L^2 T^{-3}$, Unit 1 W or $kg.m^2/s^3$.

c- The Foot-Pound- Second (f.P.s):

The basic units used in this system are as follows: Length Dimension L : Unit foot (ft) , Mass Dimension M : Unit Pound (lb) Time Dimension T : Unit Second (s).

And the unit of force that which give a mass of 1 lb and an acceleration 1ft/s^2, it is known as poundal (lbal).

Another form of system which called **Engineering system** ,the unit of length is (ft) and time is (s) as original, but the third fundamental is a unit of force (F) instead of mass which known as pound force (lb_f). it is defined as the force which gives a mass of one pound and an acceleration of 32.1740 ft/s^2.

The unit of mass in this system is known as (slug) and it's the mass which gives an acceleration of 1 ft/s^2 by one pound force.

1 Slug =(1 $lb_f/(ft/s^2)$)

4- Derived Units:

The three fundamental units of the Sl and of the c.g.s systems are length, mass and time. it has been shown that force can be regarded as having the dimension of MLT^{-2}. The dimensions of many other parameters may be worked out in terms of the basic (MLT) system. For example:-

Energy = (Force) (Distance) = m.a.L = $M L^2 T^{-2}$

Pressure = F/A with dimension $M L^{-1} T^{-2}$

Viscosity it is shear stress per unit velocity gradient. With dimension $(MLT^{-2})/(LT^{-1}) = ML^{-1}T^{-2}$.

Kinematic viscosity is the viscosity divided by the density with dimension $ML^{-1}T^{-1}/ML^{-3} = L^2T^{-1}$.

The following table have some of physical quantities with units in (SI) system and dimensions.

Quantity	Unit	Dimension	in term of SI system
Force	Newton	MLT^{-2}	kg m/s^2
Pressure	Pascal	$ML^{-1}T^{-2}$	$kg/m.s^2 = (N/m^2)$
Energy	Joule	ML^2T^{-2}	$kg.m^2/s^2$=(Nm)
Power	watt	ML^2T^{-3}	$kg.m^2/s^3$= (J/s)
Viscosity	poise	$ML^{-1}T^{-1}$	kg /m.s=($N.s/m^2$)
Frequency	hertz	T^{-1}	s^{-1}

5- Thermal units:

Temperature is introduced with dimension (Ө) and thermal energy (H) which equal to:

H α (mass) (temperature)

H α (M) (Ө)

The proportionality constant is the <u>specific heat capacity</u> which various from material to material. It is there for necessary to define heat quantities in term of particular material.

Example:

$$H = m\ C_p\ \Delta T$$

$$= kg \times (kj/kmol.K) \times K = kJ$$

Unit of heat in SI system is (Joule)

Unit of heat in c.g.s system (Calories)

Unit of heat in f.p.s system (B.t.u) British thermal unit.

And 1 calorie = 4.1868 Joules

Specific heat has the dimension $M\ L^2\ T^{-2}/M\ \theta$.

6- Molar Units:

where chemical reactions are involved it is convenient to work in terms of molar units. Thus the mole is the quantity of substance where mass in grams is numerically equal to its molecular weight, the kilomole (Kmol) is the corresponding quantity in terms of kilograms and the pound mole (lbmol) in terms of Pounds.

No. of mole (n) = weight/molecular weight

7- Conversion of Units:-

Example 1/ convert 0.028 km to cm

Sol/

1 km= 1000 m,

1 m= 100 cm

Then, 0.028kmx1000= 28 m

28mx100=2800cm.

Example 2/convert 750000mL to m^3

Sol/

1L=1000mL

Then, 750000/1000= 750 L

And, $1m^3$ =1000 L

Then, 750/ 1000= 0.75 m^3

Example 3/ convert the speed of 30 m/s to km/hr

Sol/

1km= 1000 m

And,

1hr=60 m , 1m=60 s

Then 1 hr= 60x60=3600s

So, $\frac{30 \times 10^{-3}}{\frac{1}{3600}} = 3 \times 10^{-3} \times 3600 = 108\ km/hr$

Example 4/ convert 1 poise viscosity to British engineering unit and SI unit

Sol/ 1 poise= 1 g/ cm.s

Viscosity SI units are kg/m.s

1 kg= 1000g

1 m=100 cm

Then, $\frac{1\times10^{-3}}{10^{-2}} = 10^{-1} = 0.1\,\frac{kg}{m.s}$

Viscosity British Engineering units are lbf/ft.s

1 lbf= 453.6 gm

1 ft= 30.48 cm

Then, $\frac{\frac{1}{453.6}}{\frac{1}{30.48}} = \frac{30.48}{453.6} = 0.0672\,\frac{lbf}{ft.s}$

Example 5/ convert an acceleration of ($1m/s^2$) to british system ($mile/year^2$)

Sol/ 1mile= 1609.34 m

1year=365 day

1day= 24 hr

1 hr=60 min

1min= 60 s

Then, 1year= 365x24x3600=3.15×10^7 s

$1year^2 = (3.15\times10^7)^2 s^2$

So, $1m/s^2$= ? $mile/year^2$

Temperature: $K = 273 + C^0$ (Kelvin)

$F = 32 + 1.8C$ (Fahrenheit)

$R = 460 + F$ (Rankin)

Problems

1- **Convert 820cm to m**

2- **Convert 225 mL to L**

3- **Convert 0.028 km to cm**

4- **Convert 45 mile/hr to m/s**

5- **Convert the density from 5.6 g/mL to kg/m^3**

6- **Convert the acceleration of 1 m/s^2 to mile/$year^2$**

7- **Convert one newton to dyne**

8- **The density of propane is 36.28 lbf/ft^3 convert to kg/m^3**

Quantity	Dimension	Units		
		c.g.s	SI	British
Mass	[M]	g	kg	slug
Length	[L]	cm	m	foot
Time	[T]	s	s	s
Temperature	[θ]	C°	K°	R°
Force	[F]	$\frac{g}{cm.s^2}$	$\frac{kg}{m.s^2}$	$\frac{lbf}{ft.s^2}$

	Physical Quantity	symbol	Units	Dimensions
1	Velocity or speed	u	m/s	$u = \frac{Distance}{Time} = \frac{[L]}{[T]} = LT^{-1}$
2	Acceleration	a	m/s^2	$a = \frac{speed}{Time} = \frac{[u]}{[T]} = LT^{-2}$
3	Density	ρ	kg/m^3	$\rho = \frac{Mass}{volume} = \frac{[M]}{[L^3]} = ML^{-3}$
4	Force	F	$kg \cdot m/s^2$	$F = ma \Rightarrow [F] = [M][LT^{-2}] = MLT$
5	Pressure	P	$kg/m.s^2$ (Pa)	$P = F/A = \frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$
6	Work	W	$N.m = J$	$W = F.d = [MLT^{-2}][L] = [ML^2T$
7	Viscosity	μ	$poise = \frac{g}{cm.s}$	$\mu = [ML^{-1}s^{-1}]$
8	Energy $KE = 1/2\, mu^2$	KE	$Joul = N.m$	$KE = [M][L^2][T^{-1}]^2 = [ML^2T^{-2}]$
	$PE = mgh$	PE	$Joul = N.m$	$PE = [M][LT^{-2}][L] = [ML^2T^{-2}]$
9	Power (Watt)	W	$Watt = J/s$	$W = \frac{E}{Time} = \frac{ML^2T^{-2}}{T} = [ML^2T^{-3}] = J/s$
10	Gravity acceleration	g	m/s^2	$g = [LT^{-2}]$
11	surface tension	S	kg/s^2	$S = N.m/m^2 = \frac{(\frac{kg.m}{s^2})(m)}{m^2} = kg/s^2 = [MT$