MRAHMEDMAHDY
ONLINE COURSES

MRAHMEDMAHDY
ONLINE COURSES

FLUID MECHANICS

COURSE OUTLINE

- Introduction
- Dimensions and Units
- Properties of Fluids
- Fluid Statics (Fluid in rest)
- Fluid Dynamics (Fluid in Motion) and the Conservation of Mass
- Energy Principle and its Applications
- Momentum Principle and its Applications
- Pipe Flow

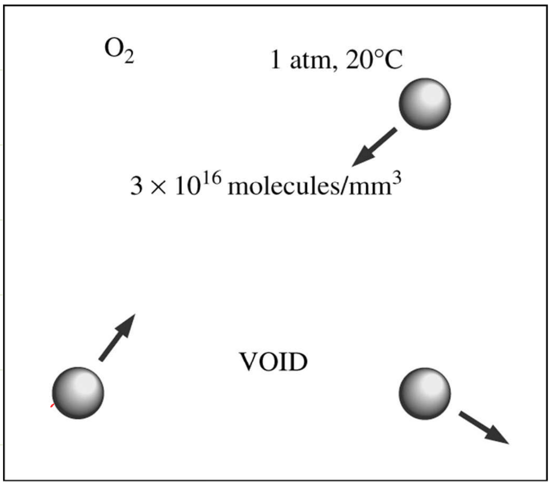
INTRODUCTION

- A fluid is defined as a substance that deforms continuously when acted on by a shearing stress of any magnitude.
- Fluids are mainly liquids and gases

- A liquid is virtually *incompressible* and has definite volume but no definite shape. (If you pour a liter of juice into several glasses, the shape of the juice has changed but the total volume hasn't.)

CONTINUUM

- A gas is easily compressed. It has neither definite shape nor definite volume. (If a container of CO2 is opened, it will diffuse throughout the room.)
- Atoms are widely spaced in the gas phase.
- However, we can disregard the atomic nature of a substance.
- View it as a continuous, homogeneous matter with no holes, that is, a continuum.
- This allows us to treat properties as smoothly varying quantities.



PHASE CHANGES

التبخر

Evaporation: Liquid → Gas

التكثف

Condensation: Gas → Liquid

الانصهار

Melting: Solid → Liquid

التجمد

Freezing: Liquid → Solid

التسامي

Sublimation: Solid → Gas

DIMENSIONS AND UNITS

- In fluid mechanics we must describe various fluid characteristics in terms of certain basic quantities such as length, time and mass
- A dimension is the measure by which a physical variable is expressed quantitatively, i.e. length is a dimension associated with distance, width, height, displacement.

➢ Basic dimensions: (or *primary quantities*)

- *Length, L*
- *Time, T*
- *Mass, M*
- *Temperature, Θ*

$V = \frac{L}{T} = L T^{-1}$

$a = (L T^{-1})/T = L T^{-2}$

$F = m \cdot a = M L T^{-2}$

- We can derive any *secondary quantity* from the primary quantities
  i.e. Force = (mass) x (acceleration) : $F = M L T^{-2}$
- A unit is a particular way of attaching a number to the quantitative dimension: Systems of units can vary from country to country, but dimensions do not

MRAHMEDMAHDY
ONLINE COURSES

DIMENSIONS AND UNITS

Primary Dimension	SI Unit	British Gravitational (BG) Unit	English Engineering (EE) Unit
Mass [M]	Kilogram (kg)	Slug	Pound-mass (lb_m)
Length [L]	Meter (m)	Foot (ft)	Foot (ft)
Time [T]	Second (s)	Second (s)	Second (s)
Temperature [Θ]	Kelvin (K)	Rankine (°R)	Rankine (°R)
Force [F]	Newton (1N=1 kg·m/s²)	Pound-force (lb_f)	Pound-force (lb_f)

Conversion factors are available in most textbook inside of front cover.

UNITS & NEWTON LAW

$$Force\ =\ mass\ x\ acceleration$$

- *SI Units:*

$$Newton = Kilogram\ x\ meter/second^2$$

$$N = kg\,.\,m/s^2$$

- *BG Units:*

$$Pound\text{-}Force = Slug\ x\ foot/second^2$$

$$lb_f\ =\ slug\,.\,ft/s^2$$

- *Note:* *Gravity acceleration in SI* $= 9.81\ m/s^2$
  Gravity acceleration in BG $= 32.2\ ft/s^2$

MRAHMEDMAHDY
ONLINE COURSES

UNITS CONVERSION TABLE

English to Metric				
inches (ins)	X	25.4	=	millimetres (mm)
feet (ft)	X	0.3	=	metres (m)
yards (yds)	X	0.9	=	metres (m)
miles (mi)	X	1.6	=	kilometres (km)
sq inch (in^2)	X	6.5	=	sq centimetre (cm^2)
sq feet (ft^2)	X	0.09	=	sq metres (m^2)
sq yard (yd^2)	X	0.8	=	sq metres (m^2)
cu. in (in^3)	X	16	=	cu.centimetres
cu. ft (ft^3)	X	0.03	=	cu.metres (m^3)
cu. yd (yd^3)	X	0.8	=	cu.metres (m^3)
(liq) quart (qt)	X	0.9	=	litre (l)
gallon (gal)	X	0.004	=	cu.metres (m^3)
(advp) ounce (oz)	X	28.3	=	grams (g)
(advp) pound (lb)	X	0.45	=	kilogram (kg)
horsepower (hp)	X	0.75	=	kilowatt (kW)
ft per second (ft/s)	X	0.304	=	met. Per second (m/s)
ounce-force (ozf)	X	0.278	=	newtons (N)
pound-force (lbf)	X	4.448	=	newtons (N)
foot pounds (ft.lb)	X	1.355	=	newtons-metres (N.m)
foot pounds (ft.lb)	X	1.355	=	joules (j)
in. pounds (in.lb)	X	0.112	=	newtons-metres (N.m)
lb per foot (lb/ft)	X	14.59	=	newtons-metres (N.m)
cycles per sec (cps)	X	1	=	hertz (Hz)
Brit therm unit (Btu)	X	1055	=	joules (j)

Metric to English				
mm	X	0.04	=	ins
m	X	3.3	=	ft
m	X	1.1	=	yds
km	X	0.6	=	mi
cm^2	X	0.16	=	in^2
m^2	X	11	=	ft^2
m^2	X	1.2	=	yd^2
cm^3	X	0.06	=	in^3
m^3	X	35	=	ft^3
m^3	X	1.3	=	yd^3
l	X	1.05	=	qt
m^3	X	264.2	=	gal
g	X	0.035	=	oz
kW	X	1.34	=	hp
kg	X	2.2	=	lb
m/s	X	3.28	=	ft/s
N	X	3.597	=	ozf
N	X	0.224	=	lbf
N.m	X	0.737	=	ft.lb
j	X	0.737	=	ft.lb
N.m	X	8.85	=	in.lb
N.m	X	0.068	=	lb/ft
Hz	X	1	=	cps
j	X	0.0009	=	Btu

FLUID PROPERTIES

Any characteristic of a system is called a *property*.

Familiar: pressure *P*, temperature *T*, volume *V*, and mass *m*.

Less familiar: viscosity, vapor pressure, surface tension.

- *Density,* the symbol for density is ρ "rho." Density is simply *mass per unit volume*. Water, for example, has a density of about 1 gram per milliliter. (It varies slightly with temperature and pressure.)

$$\rho = m / V$$

S.I unit for density is kg/m^3

- *Specific volume* is defined as $\mathbf{1/\rho = V/m}$.

- *Specific gravity, SG,* or relative density is defined as *the ratio of the density of a substance to the density of some standard substance at a specified temperature* (usually water at 4°C), i.e.,

$$SG = \rho / \rho_{H2O}$$

SG is a dimensionless quantity.

- *Specific weight,* γ *(Gamma),* is defined as the *weight per unit volume*, i.e.,

$$\gamma = \rho g$$

where g is the gravitational acceleration. γ has units of N/m^3.

PRESSURE / DENSITY QUESTIONS

1. Why do snowshoes keep you from sinking into the snow?

The snowshoes greatly increase the area over which your weight is distributed, thereby decreasing the pressure on the snow.

2. Why do swimmers float better in the ocean than in a lake?

Because of the salt dissolved in it, seawater is about 2.5% denser, making people (and fish) more buoyant in it.

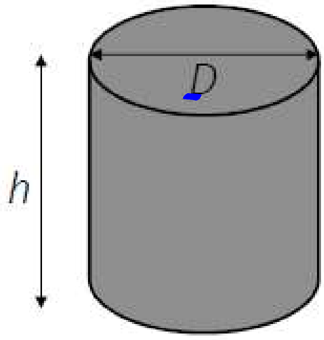
3. Why don't they make longer snorkels so that people could dive deeper without scuba gear?

The pressure difference just 6 m below water is great enough so that the air in the diver's lungs will be forced through the tube, collapsing his lungs.

MRAHMEDMAHDY
ONLINE COURSES

SOLVED EXAMPLE 1

Given that the density of Water is 1000 Kg/m³, calculate the mass and weight of a barrel full of water, assuming that the barrel has a diameter of 1.0 m and height of 1.5 m. (ignore the barrel weight)



$\rho = 1000\ kg/m^3$, $D = 1\ m$ معطى

$h = 1.5\ m$

m, w ?? مطلوب

الحل

$\rho = \frac{m}{V} \Rightarrow m = \rho \cdot V = 1000 \cdot (\pi r^2) h$

$m = 1000 * \pi (0.5^2) * 1.5 = 1178.01\ kg$

$w = m \cdot g = 1178.01 * 9.81 = 11557.13\ N$

MRAHMEDMAHDY
ONLINE COURSES

SOLVED EXAMPLE 2

- A body weighs 1000 lb_f when exposed to a standard earth gravity $g = 32.174\ ft/s^2$.

a) What is its mass in kg?

b) What will the weight of this body be in N if it is exposed to the moon's standard acceleration $g_{moon} = 1.62\ m/s^2$?

c) How fast will the body accelerate if a net force of 400 lb_f is applied to it on the moon or on the earth?

$w = 1000\ lb_f$, $g = 32.174\ ft/s^2$, $m\ (kg)$??

$w\ (N)$?? , a , $f = 400\ lb_f$

الحل

$w = 1000\ lb_f = m \cdot g \Rightarrow m = \frac{w}{g} = \frac{1000}{32.174} = 31.081\ sl$

$1\ slug = 14.59\ kg$

ⓐ $m = 31.081 * 14.59\ kg = 453.5\ kg$

ⓑ $w = mg = 453.5 * 1.62 = 734.6\ N$

ⓒ $f = ma \Rightarrow a = \frac{f}{m} = \frac{400}{31.081} = 12.87\ ft/s^2$

$a = 3.86\ m/s^2$