Introduction

1-Definition:

Fluid mechanics is a study of the behavior of fluids (liquid and gases)and applications where fluid systems are used. Fluid mechanics is divided into two subjects fluid statics and fluid dynamics. Statics deals with fluid systems where the fluid isat rest, whereas dynamics deals with flowing fluids.

2-Fluid:

Is a substance that cannot resist a shearing force and cannot remain at rest. The term fluid refers to both gases and liquids. In liquids, the space between adjacent molecules is much larger than for solids. Thus liquid molecules move much more freely than solids. In gases the space between adjacent molecules is much larger than that for liquids, thus gases flow more readily than liquids and are also very compressible.

3-Fundamental units:

Two primary systems are widespread the U.S. system and the International System (SI)

Fundamental units	symbol	U.S	SI
Length	L	Ft	M
Force	F	Ib	N
Mass	M	Slug	Kg
time	T	s	s

Force and weight versus mass:Depending on Newton's law of motion, force equals mass times acceleration F=M*g, but all objects are pulled toward the center of Earth by force of attraction, this force is called the weight of the object :

W= F = M*g

The table below gives an abbreviated listing of the conversion factors:

Parameter	U.S.(united state)	SI(international standard)
length	1ft (foot)	0.3048 m
force	1lb (pound)	4.448 N
mass	1 slug	14.59 kg

length	1ft=12 in	
mass	1slug = 32.2 lb	
Vol.	1000 liter	1 m^3
mass	1lb	0.4536 kg
Vol.	1 gallon=231 in^3	
force	1 lb/in^2 (psi)pound/$inch^2$	6894.4 N/m^2
Weight		1 N=kg.m/s^2

4-Properties of fluids

4-1-Specific weight (weight density) (**γ**): is defined as weight per unit volume

$\gamma=\frac{W}{V}$ (N/m^3) or (lb/ft^3)

4-2-Density (mass density) (**ρ**): is defined as its mass per unit volume

$\rho=\frac{M}{V}$ (kg/m^3) or $(slug/ft^3)$

**note:

W=M*g. (weight=mass * gravity)

$\gamma V=\rho V*g \longrightarrow \rho=\gamma/g$

4-3-Specific gravity (relative density)(**S.g**): is defined as the specific weight of the fluid divided by the specific weight of water at 4◦ C

$S.g=\frac{\gamma}{\gamma w}$ or ρ/ρ_w (without unit)

4-4-Pressure (**P**): is defined as the magnitude of this normal force per unit area of the contacting surface.

$P=\frac{F}{A}$ (N/m^2) or Pascal (pa.).) or (lb/ft^2) pound per square foot (psf)

4-5-Bulk modulus (**β**): is defined as how much a fluid's volume and density change when the pressure changes?. The higher the value of the bulk modulus the less compressible and thus stiffer the fluid.

$\beta=\frac{-\Delta P}{\Delta V/V}$

β=bulk modulus (lb/in^2) or (N/m^2)

V=original volume (in^3) or (m^3)

ΔP=change in pressure (lb/in^2) or (N/m^2)

ΔV=change in volume (in^3) or (m^3)

4-6-Discharge (**Q**): is defined as the volume of fluid that flow in a certain time.

Q= velocity* area or volume / time (ft^3/s) or (m^3/s)

4-7-Viscosity :is that property as such it measures the sluggishness with which a fluid flows. When the viscosity is low indicative of a thin fluid like water the fluid flows easily, conversely, the thickest fluids such as certain types of oil, are the most viscous and do not flow readily. The cause of viscosity is the molecular attraction between adjacent layers of fluid. When fluid is at rest there is no resistance to an applied shear force.

Absolute viscosity(dynamic viscosity)	Kinematic viscosity
μ	(ν)
• $N.s/m^2$(Pa. s) or ($lb.s/ft^2$) • $1 N.s/m^2$= 10 poise, • 1poise =0.1 Pa.s • 1 centipoise (cp)= 0.001 pa.s	• m^2/s or ft^2/s • 1 m^2/s = 10^4 stokes.

4-8-Shear stress (**τ**):is a tangent force acting tangentially on the fluid surface area

T=F/A (N/m^2).

Information:

- ρ_w=1000kg/m^3=1.94 $slug/ft^3$,
- γ_w=9800 N/m^3=62.4lb/ft^3.
- g=9.81m/s^2=32.2 ft/s^2

5-Shear stress and velocity gradient

F/A is the shear stress developed in the fluids and acting on the bottom surface of the moving plate in the direction opposing the plate motion . The slope of the velocity profile is also called the velocity gradient (fig.1) :

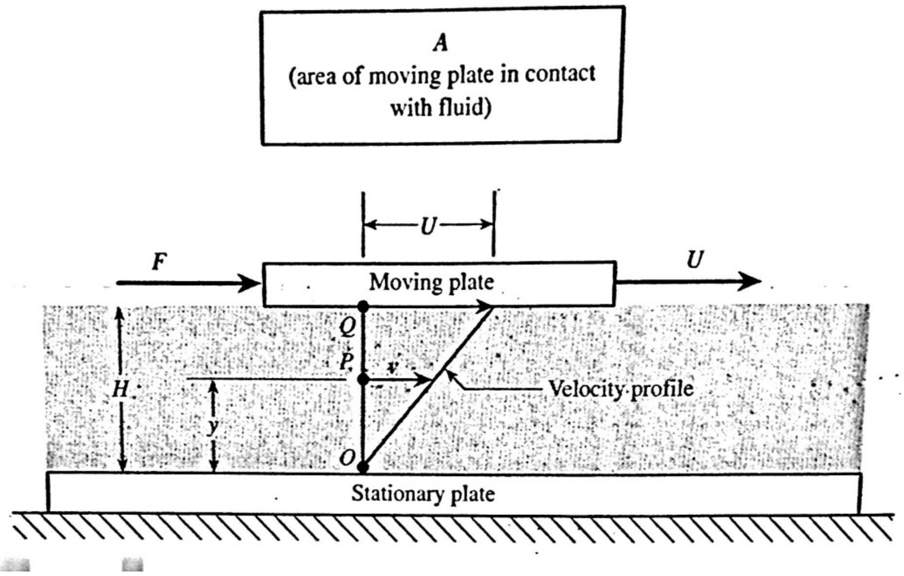

Fig.1

$$\mu = \frac{shear\ stress}{velocity\ gradient} = \frac{\tau}{v/y}$$

$$\tau = \mu \frac{dv}{dy}$$

where:

τ : shear stress, μ:dynamic viscosity N.s/m^2, $dv: vilositygagiant(m/s)$,

$dy(mm)$:distance between the stationary and fixed plates

Examples:

Ex.1

A quart (1/4) of SAE oil weighs about 1.85 lb. Calculate the oil's specific weight, density and specific gravity?

V=$\frac{231\ in^3}{4\times1728\ in^3}$=0.0334 ft^3

γ= W/V=1.85/0.0334=55.4 lb/ft^3

ρ= γ/g=55.4/32.2= 1.72 $slug/ft^3$

s.g= γ_{oil}/γ_w=55.4/62.4= 0.888

Ex.2

Knowing that the viscosity of water is 2 cp, calculate the corresponding :absolute viscosity in $lb.s/ft^2$, and kinematic viscosity in ft^2/s ? the density of water is 1.94 $slug/ft^3$.

1 cp= 0.001 $N.s/m^2$ thus 2 cp = 0.002 $N.s/m^2$

μ= 0.002 *$(0.3048)^2$ *4.448 = 8.2 *10^{-4} $lb.s/ft^2$

ν= μ/ρ

ν= 8.2 *10^{-4}/1.94 = 4.2 *$10^{-4}ft^2/s$.

Ex.3:

A piston moves inside a cylinder at a velocity of 5 m/s (fig.2), the 150mm diameter piston is centrally located within 150.2 mm inside diameter. The film of oil separating the piston from the cylinder has an absolute viscosity of 0.4 $N.s/m^2$. Assuming a linear velocity profile, find a-Shear stress, and b-force F required to maintain the given motion.

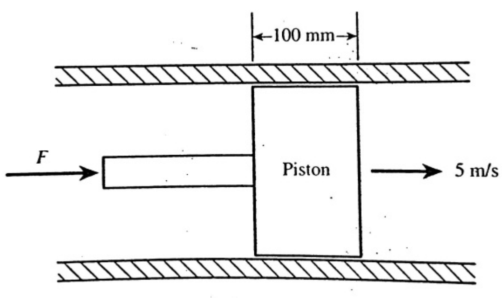

Fig.2

$\tau=\mu\frac{dv}{dy}$

$dy = \frac{150.2-150}{2} = 0.1$ mm

$=0.4*5/0.0001=20000$ N/m^2

$F=\tau*A=20000*\pi*0.15*0.1=942$ N

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Ex4.

A block of dimensions 300mm*300mm*300mm and weight 150 N slides down a plane inclined at 20◦ to the horizontal , a thin film of oil is between the block and surface with viscosity $2.3*10^{-3}$pa.s. Determine the film thickness if the speed is 0.8m/s (fig.3)?

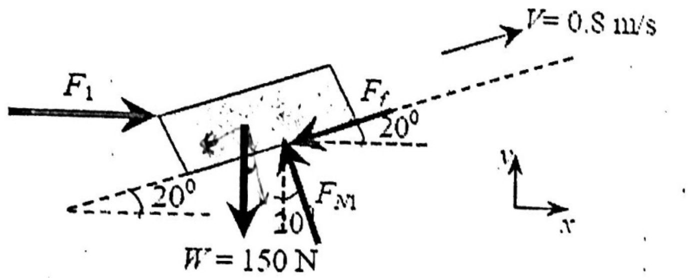

Fig.3

$\tau=\mu\frac{dv}{dy}$

$F=\mu\frac{dv}{dy}*A$ ((F=W sin 20◦))

$150 * \sin 20^\circ=2.3*10^{-3}(0.8/dy)(0.3*0.3)$

$dy=\frac{2.3\times10^{-3}\times0.8\times0.3\times0.3}{150\times\sin 20}$

dy=0.0000032 m.= 0.0032 mm