Fluid Mechanics

References

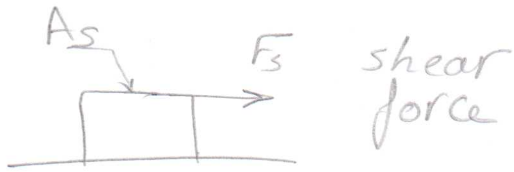
1- "Fluid Mechanics", By J.F. Douglas, J.M. Gasiore, and J.A. swaffield.

2- "Fluid Mechanics and applications", By Frank M. White

3- "Fluid Mechanics Fundamentals and applications" By Yunus A. Çengel and John M. Cimbala

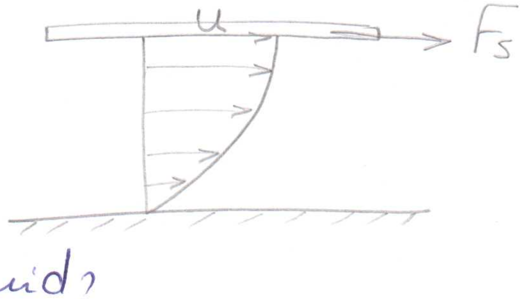
4- "Fluid Mechanics and Fluid power engineering", By D.S. Kumar

Fluid: is a substance which deforms continuously under the action of shearing forces, however small they are. This deformation is permanent even if the force is removed.



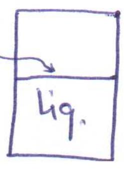
$$\tau = \frac{F_s}{A_s}$$

= shear stress



* difference between solid & Fluid?
* difference between liquid & gas ??

incompressible & free surface



Compressible & has no free surface

Units

	B.S. units	C.GS	S.I
force	Ib_f	dyne	N
mass	Ib	gm	Kg
distance	ft	Cm	m
time	S	S	S

* SI units
& M, L, T, θ Dimensions

		Dim.	S.I unit
الوحدات الأساسية	Mass	M	Kg
	Length	L	m
	time	T	S
	temperature	θ	°K
الوحدات المشتقة	velocity	L/T	m/s
	accel.	L/T^2	m/s^2
	force	MLT^{-2}	$Kg\,m/s^2 = N$
	pressure	$ML^{-1}T^{-2}$	$N/m^2 = P_a = Kg/m\,s^2$

(work, energy, torque) $= N.m =$ Joule

power $= \frac{N.m}{S} = \frac{J}{S} =$ Watt

* units Conversion

$1\,ft = 0.3049\,m$

$1\,Ib_f = 4.448\,N$ & $1N = 10^5$ dyne

$1\,KW = 1.36\,HP$ & $1\,bar = 10^5\,Pa$

$1\,Kg = 2.2\,Ib$

$1\,Kg_f = 9.81\,N$

properties of fluids

* **Density** : mass per unit volume $\rho = \frac{m}{V}$ Kg/m^3

DIM $\frac{M}{L^3}$, for water $\rho = 1000\ Kg/m^3$ gm/cm^3

Ib/ft^3

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* **specific weight** : weight per unit volume

$$w = \frac{weight}{Volume} = \frac{m * g}{V} = \rho g$$ N/m^3

$dyne/cm^3$

Dim. $\frac{ML}{T^2} * \frac{1}{T^3}$, for water $w = 1000 * 9.8\ \frac{N}{m^3}$ Ib_f/ft^3

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* **specific volume** : volume per unit mass

$$v = \frac{Volume}{mass} = \frac{1}{\rho}$$ m^3/Kg

for water $v = 0.001\ m^3/Kg$

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* **specific gravity** : $\gamma = \frac{sp.\ weight\ of\ fluid}{sp.\ weight\ of\ water}$

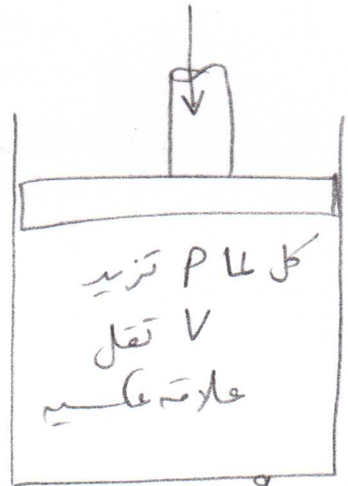
$$= \frac{w_f}{w_w} = \frac{\rho_f\ g}{\rho_w\ g} = \frac{\rho_f}{\rho_w}$$

γ dimensionless ليس لها ابعاد

for water $\gamma_w = 1$

* Bulk modulus of elasticity (K)

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



large value of K means that
big change of pressure
Causes small ~ ~ volume

∴ The fluid is incompressible $K = ---\times 10^9$ (Pa)

small value of K means that small change of pressure
Causes a large ~ ~ volume

∴ The fluid is Compressible $K = ---\times 10^6$ (Pa)

* Vapour pressure of liquids ($P_{vap.}$) : It is the pressure at which a liquid starts to boil at working temperature.

Boiling temp. increases by increasing pressure on liq. surface
~ ~ decreases ~ decreasing ~ ~ ~ ~

P	0.3	0.5	1	4	10	atm
boiling temp	40	70	100°	120	180	°C

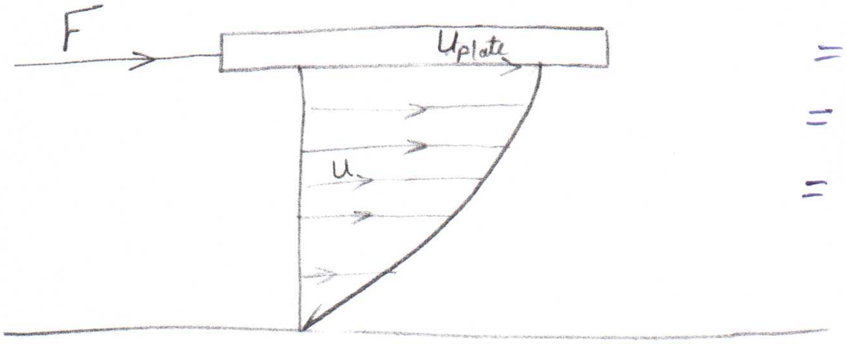
to avoid vapor formation $\boxed{P_{min} > V_{vap.}}$

اقل ضغط موجود

ضغط البخار

* Viscosity(μ) : The property which causes friction between Fluid and boundary or between fluid layers if there is velocity difference.

μ = Viscosity
= Absolute viscosity
= Dynamic viscosity
= Coefficient of ~



$$F_{viscous} = F$$

$$F_{viscous} \propto A_{friction} \frac{du}{dy}$$

$$\boxed{F_{vis.} = Const.\ A_{friction} \frac{du}{dy}}$$

$$\boxed{F_{vis.} = \mu\ A_{\substack{friction \\ moving}} \frac{du}{dy}}$$ ← Newton's law of viscosity

μ: Coefficient of viscosity depends on type of fluid and its temperature.

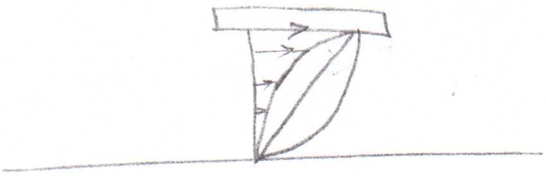
$$\mu = \frac{F_{vis.}}{A_{friction}} * \frac{dy}{dV}$$

$$= \frac{N}{m^2} * \frac{m}{m/s} = Pa.S$$

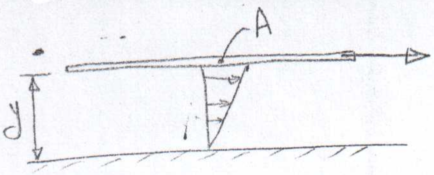
for water $\mu = 0.001 \frac{N.s}{m^2}$
$= 0.01 \frac{dyne.s}{cm^2}$
$= 0.01$ (poise)
$= 1$ centi poise

* For a small thickness of fluid layer, velocity distribution can be assumed straight line

$$\frac{du}{dy} = \frac{U}{y}$$



1)



$$\tau \propto \frac{du}{dy}$$

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

$$F = \mu A \frac{du}{dy}$$

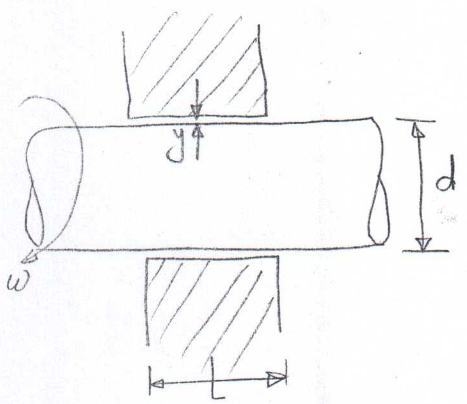
as: τ : shear stress

μ : Viscosity

$\frac{du}{dy}$: rate of shear strain

F : Viscous force

2)



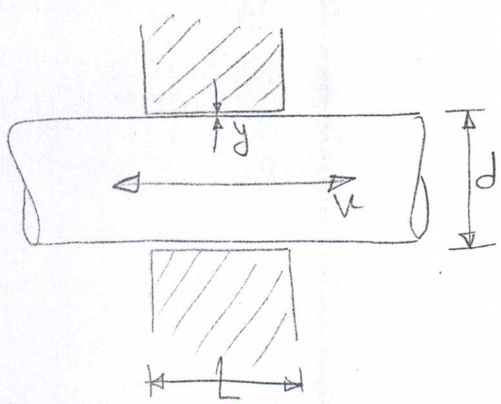
$$F = \mu A \frac{u}{y}$$

where $A = \pi d L$

$u = \omega r$

$r = \frac{d}{2}$

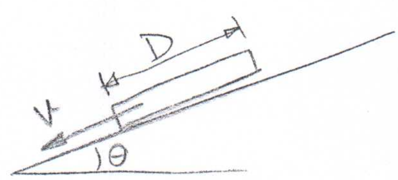
3)



$$F = \mu A \frac{u}{y}$$

4)

$$A = \frac{\pi}{4} D^2$$



if N is given $\therefore \omega = \frac{2 \pi N}{60}$

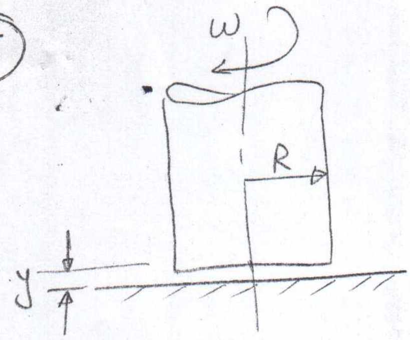
as N : rpm

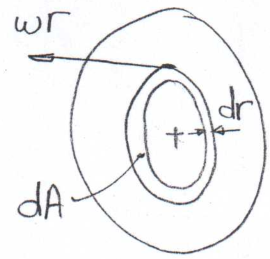
ω : rad/sec

if ω rps $\xrightarrow{\text{Convert}}$ rad/sec

as 1 rev = 2π rad

(5)





$$dA = 2\pi r\,dr \quad \& \quad v = \omega r$$

$F = \mu A \frac{v}{y}$

$$dF = \mu\,(2\pi r\,dr) * \frac{\omega r}{y}$$

$$F = \frac{\mu \cdot 2\pi\omega}{y} \int_0^R r^2\,dr$$

$$\boxed{F = \frac{2\pi\omega\mu}{3y} R^3}$$

$T = F.r$

$$dT = r.\,dF$$

$$= r * \frac{2\pi\mu r\,dr\,\omega r}{y}$$

$$\int_0^T dT = \frac{2\pi\mu\omega}{y} \int_0^R r^3\,dr$$

$$\boxed{T = \frac{2\pi\mu\omega}{4y} R^4}$$

* Power $= T * \omega$

$= F * r * \omega$

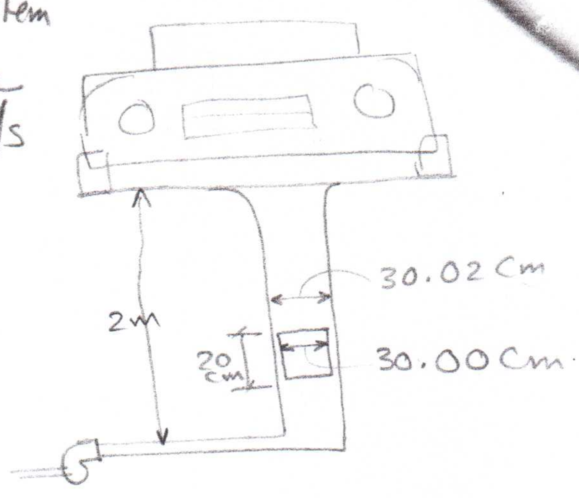
$= F * v$

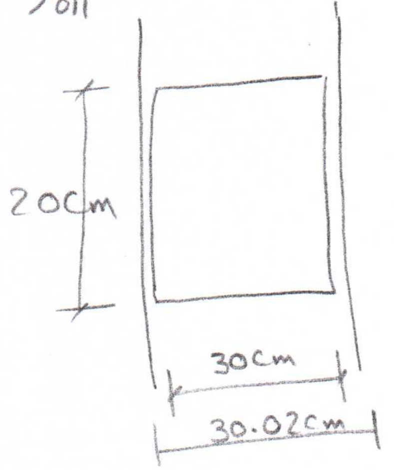
Ex.

For the shown position of car lifting system

Calculate: the force required to overcome friction when the piston moves at 2 m/s

take $\mu_{oil} = 0.02$ Pa.s





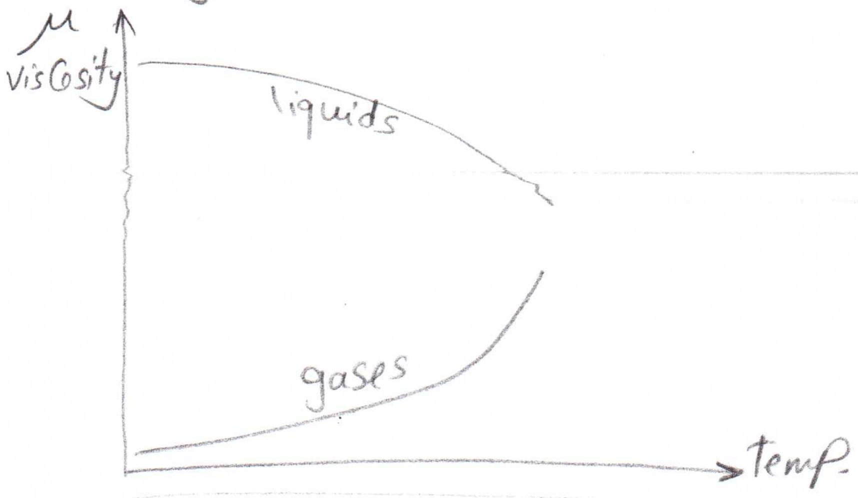
$$F_{vis.} = \mu A \frac{du}{dy}$$

$$= 0.02 * (\pi d l) * \frac{u}{\left(\frac{D-d}{2}\right)}$$

$$= 0.02 * \left(\pi * \frac{30}{100} * \frac{20}{100}\right) * \frac{2}{\left(\frac{30.02-30}{200}\right)}$$

$$= \checkmark \quad \text{Newton}$$

* Relation between viscosity and temperature for a certain fluid.



* Kinematic viscosity (ν): is defined as the ratio of dynamic viscosity to density

for water

$\nu = 0.01\ cm^2/s$

$= 0.01$ stoke

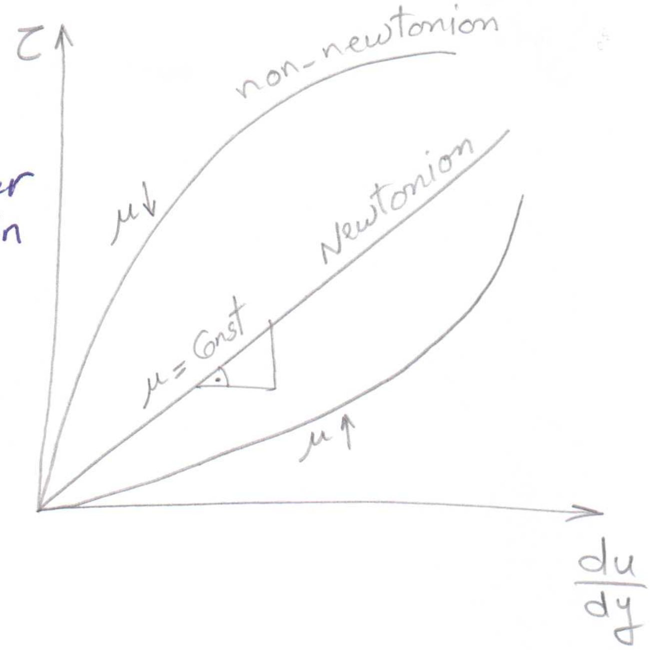
$= 1$ centistoke

$$\boxed{\nu = \frac{\mu}{\rho}} = \frac{Pa.s}{kg/m^3} = \frac{kg.m\ .s\ m^3}{s^2\ m^2\ .\ kg} = (m^2/s)$$

stoke $= cm^2/s$

* Newtonion & Non-newtonion :

$$\underset{\text{shear stress}}{\tau} = \frac{F_{vis}}{A} = \mu \underset{\text{rate of shear strain}}{\frac{du}{dy}}$$



If $\tau \propto \frac{du}{dy}$

$\therefore \mu = Const.$

$\therefore$ It is a newtonion fluid

$\mu = 0 \longrightarrow$ Ideal Fluid

$\mu = Const. \longrightarrow$ Newtonion Fluid

$\mu \uparrow \downarrow \longrightarrow$ Non-newtonion Fluid

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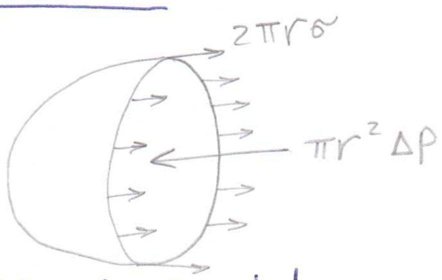
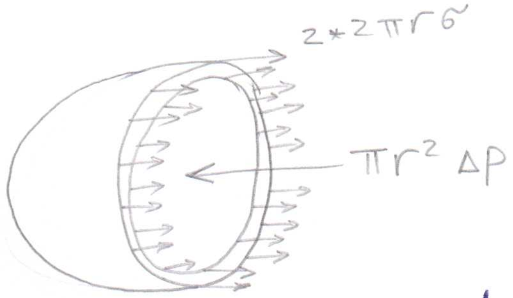
* surface tension



half of droplet

$$2\pi r \sigma = \pi r^2 \Delta P$$

$$\boxed{\Delta P = \frac{2\pi r \sigma}{\pi r^2} = \frac{2\sigma}{r}}$$



half of a soap bubble

$$4\pi r \sigma = \pi r^2 \Delta P$$

$$\boxed{\Delta P = \frac{4\sigma}{r}}$$