UNIT – I – FLUID PROPERTIES AND FLOW CHARACTERISTICS

PROPERTIES OF FLUID:

MASS DESNITY (ρ):

$$\rho = \frac{m}{V}$$

Symbol		Description	Unit
ρ	⟶	Density	kg/m^3
m	⟶	Mass	Kg
V	⟶	Volume	m^3

SPECIFIC VOLUME (v):

$$v = \frac{V}{m} = \frac{1}{\rho}$$

Symbol		Description	Unit
ρ	⟶	Density	kg/m^3
m	⟶	Mass	Kg
V	⟶	Volume	m^3
v	⟶	Specific Volume	m^3/kg

SPECIFIC WEIGTH OR WEIGTH DENSITY (w):

$$w = \frac{W}{V} = \frac{mg}{V} = \rho g$$

$$Since\ W = mg\ and\ \rho = m/V$$

Symbol		Description	Unit
ρ	⟶	Density	kg/m^3
m	⟶	Mass	Kg
V	⟶	Volume	m^3

w	$\longrightarrow$	Specific Weight	N/m^3
g	$\longrightarrow$	Acceleration due to gravity	m/s^2

SPECIFIC GRAVITY (S):

$$S = \frac{Specific\ Weight\ of\ given\ fluid}{Specific\ Weight\ of\ standard\ fluid}$$

$$S = \frac{Mass\ Density\ of\ given\ fluid}{Mass\ Density\ of\ standard\ fluid}$$

Symbol		Description	Unit
S	$\longrightarrow$	Specific Gravity	No unit
ρ	$\longrightarrow$	Density or Mass Density	kg/m^3
w	$\longrightarrow$	Specific Weight	N/m^3
w_{water}	$\longrightarrow$	Specific Weight of Standard Fluid (Water) = 9.81	N/m^3
ρ_{water}	$\longrightarrow$	Mass Density of Standard Fluid (Water) = 1000	kg/m^3

VISCOSITY (μ):

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

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

Symbol		Description	Unit
τ	$\longrightarrow$	Shear Stress	N/m^2
μ	$\longrightarrow$	Viscosity	$N-s/m^2$
du	$\longrightarrow$	Change in Velocity	m/s
dy	$\longrightarrow$	Change in Distance	m

DYNAMIC VISCOSITY (μ):

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

Symbol	Description	Unit
τ →	Shear Stress	N/m^2
μ →	Dynamic Viscosity	$N-s/m^2$
du →	Change in Velocity	m/s
dy →	Change in Distance	m
du/dy →	Rate of Shear Strain	$1/s$

Unit Conversion:

$$1\ \frac{Ns}{m^2} = 10\ poise$$

$$1\ Centipoise = \frac{1}{100}\ poise$$

$$1\ poise = 0.1\ \frac{Ns}{m^2}$$

KINEMATIC VISCOSITY (γ):

$$\gamma = \frac{\mu}{\rho}$$

Symbol	Description	Unit
ρ →	Density	kg/m^3
μ →	Dynamic Viscosity	$N-s/m^2$
γ →	Kinematic Viscosity	m^2/s

Unit Conversion:

$$1\ stoke = 10^{-4}\ m^2/s$$

$$1\ Centistoke = \frac{1}{100}\ stoke$$

VISCOSITY PROBLEMS FOR PLATE TYPE:

FORCE (F):

$$\tau = \frac{F}{A}$$

Symbol		Description	Unit
τ	⟶	Shear Stress	N/m^2
F	⟶	Force	N
A	⟶	Area of the plate	m^2

POWER (P):

$$P = F * du$$

Symbol		Description	Unit
P	⟶	Power	W
F	⟶	Force	N
du	⟶	Change in Velocity	m/s

VISCOSITY PROBLEMS FOR SHAFT TYPE:

VELOCITY OF SHAFT (*u*):

$$u = \frac{\pi DN}{60}$$

Symbol		Description	Unit
D	⟶	Diameter of Shaft	m
N	⟶	Speed of Shaft	Rpm
u	⟶	Velocity	m/s

FORCE (F):

$$\tau = \frac{F}{A}$$

$$\tau = \pi DL$$

Symbol		Description	Unit
τ	⟶	Shear Stress	$N/_{m^2}$
F	⟶	Force	N
A	⟶	Circumference of Shaft	m^2
D	⟶	Diameter of Shaft	m
L	⟶	Length of Shaft	m

TORQUE ON SHAFT (T):

$$T = F * \frac{D}{2}$$

Symbol		Description	Unit
T	⟶	Torque	$N - m$
F	⟶	Force	N
D	⟶	Diameter of Shaft	m

POWER ON SHAFT (P):

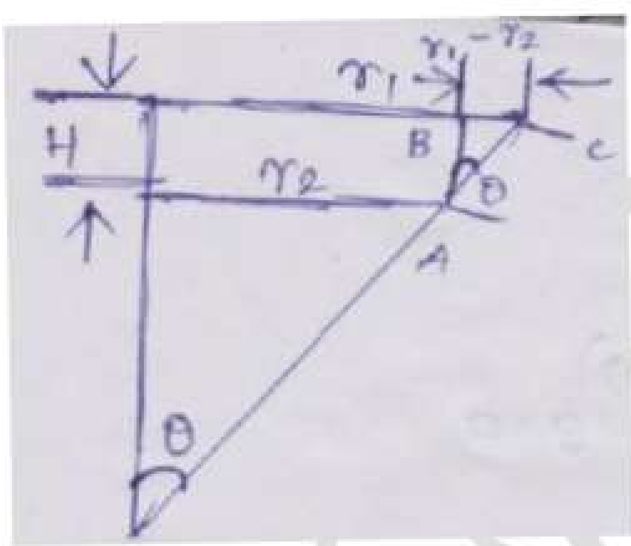
$$P = \frac{2\pi NT}{60}$$

Symbol		Description	Unit
P	⟶	Power	W
T	⟶	Torque	$N - m$
N	⟶	Speed of Shaft	Rpm

VISCOSITY PROBLEMS FOR CONICAL BEARING:

ANGULAR VELOCITY (ω):

$$\omega = \frac{2\pi N}{60}$$



Symbol		Description	Unit
ω	⟶	Angular Velocity	$rad/_{sec}$
N	⟶	Speed of Shaft	Rpm

ANGLE (θ):

$$tan\theta = \frac{r_1 - r_2}{H}$$

Symbol		Description	Unit
r_1	⟶	Outer Radius	m
r_2	⟶	Inner Radius	m
H	⟶	Height	m

POWER (P):

$$P = \frac{2\pi NT}{60}$$

Symbol		Description	Unit
P	⟶	Power	W
T	⟶	Torque	$N - m$

N	⟶	Speed of Shaft	Rpm

THICKNESS OF OIL (h):

$$T = \frac{\pi\mu\omega}{2h\sin\theta}\left({r_1}^4 - {r_2}^4\right)$$

Symbol		Description	Unit
μ	⟶	Dynamic Viscosity	$N-s/m^2$
T	⟶	Torque	$N-m$
ω	⟶	Angular Velocity	rad/sec
h	⟶	Thickness of Oil	m
r_1	⟶	Outer Radius	m
r_2	⟶	Inner Radius	m

CAPILLARITY:

HEIGHT OF LIQUID IN TUBE (h):

$$h = \frac{4\sigma\cos\theta}{\rho g d}$$

Symbol		Description	Unit
h	⟶	Height of Liquid in Tube	m
σ	⟶	Surface Tension	N/m
θ	⟶	Angle of Contact between Liquid and Tube	rad
ρ	⟶	Density of Liquid	kg/m^3
g	⟶	Acceleration due to gravity	m/s^2
d	⟶	Diameter of Tube	m

SURFACE TENSION:

PRESSURE IN LIQUID DROPLET (P):

$$P = \frac{4\sigma}{d}$$

Symbol		Description	Unit
P	$\longrightarrow$	Pressure	$N/_{m^2}$
σ	$\longrightarrow$	Surface Tension	$N/_{m}$
d	$\longrightarrow$	Diameter of Droplet	m

PRESSURE IN BUBBLE (P):

$$P = \frac{8\sigma}{d}$$

Symbol		Description	Unit
P	$\longrightarrow$	Pressure	$N/_{m^2}$
σ	$\longrightarrow$	Surface Tension	$N/_{m}$
d	$\longrightarrow$	Diameter of Bubble	m

PRESSURE IN LIQUID JET (P):

$$P = \frac{2\sigma}{d}$$

Symbol		Description	Unit
P	$\longrightarrow$	Pressure	$N/_{m^2}$
σ	$\longrightarrow$	Surface Tension	$N/_{m}$
d	$\longrightarrow$	Diameter of Jet	m

CONTINUITY EQUATION:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad [For\ 3 - D\ flow]$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + = 0 \qquad [For\ 2 - D\ flow]$$

$$\frac{\partial}{\partial r}(ru_r) + \frac{\partial}{\partial \theta}(u_\theta) = 0 [For\ polar\ coordinates]$$

BERNOULLI'S EQUATION:

$$\frac{\partial P}{\rho} + v.dv + g.dz = 0$$

$$\frac{P_1}{\rho g} + \frac{{v_1}^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{{v_2}^2}{2g} + z_2 + h_f$$

Symbol		Description	Unit
P_1 & P_2	$\longrightarrow$	Pressure at Section 1 & 2	$^N/_{m^2}$
v_1 & v_2	$\longrightarrow$	Velocity at Section 1 & 2	$^m/_s$
z_1 & z_2	$\longrightarrow$	Datum Head at Section 1 & 2	m
h_f	$\longrightarrow$	Head Loss	m
ρ	$\longrightarrow$	Density of Liquid	$^{kg}/_{m^3}$
g	$\longrightarrow$	Acceleration due to gravity	$^m/_{s^2}$

COEFFICIENT OF DISCHARGE:

$$C_d = \frac{Q_{Actual}}{Q_{Theoretical}}$$

COEFFICIENT OF VELOCITY:

$$C_v = \frac{v_{Actual}}{v_{Theoretical}}$$

DISCHARGE OF VENTURIMETER AND ORIFICEMETER:

$$Q = C_d \frac{a_1\, a_2}{\sqrt{({a_1}^2 - {a_1}^2)}} \sqrt{2gh}$$

Symbol		Description	Unit
a_1 & a_2	$\longrightarrow$	Area at Section 1 & 2	m^2
h	$\longrightarrow$	Pressure Difference between Section 1 & 2 $\left(\frac{P_1 - P_2}{\rho g}\right)$	m

C_d	$\longrightarrow$	Coefficient of Discharge	
x	$\longrightarrow$	Difference in Mercury Level	m

$$h = x\left(1 - \frac{S_m}{S}\right) \qquad [when\ S > S_m]$$

$$h = x\left(\frac{S_m}{S} - 1\right) \qquad [when\ S_m > S]$$

$$h = \left(\frac{P_1}{\rho g} + Z_1\right) - \left(\frac{P_2}{\rho g} + Z_2\right)\ [Inclined\ Venturimeter]$$

MOMENTUM EQUATION:

$$F = \frac{d\,(mv)}{dt}$$

FORCE ACTING IN X – DIRECTION:

$$F_x = \rho Q\,(v_1 - v_2 cos\theta) + P_1A_1 - P_2A_2cos\theta$$

FORCE ACTING IN Y – DIRECTION:

$$F_y = \rho Q\,(-v_2 sin\theta) - P_2A_2sin\theta$$

Symbol		Description	Unit
P_1 & P_2	$\longrightarrow$	Pressure at Section 1 & 2	N/m^2
v_1 & v_2	$\longrightarrow$	Velocity at Section 1 & 2	m/s
A_1 & A_2	$\longrightarrow$	Area at Section 1 & 2	m
θ	$\longrightarrow$	Angle of the Bend	$Degree$
Q	$\longrightarrow$	Discharge	m^3/s

RESULTANT FORCE:

$$F_R = \sqrt{{F_x}^2 + {F_y}^2}$$

ANGLE MADE BY RESULTANT FORCE:

$$\tan\theta = \frac{F_y}{F_x}$$

MOMENT OF MOMENTUM EQUATION:

$$T = \rho Q \left(v_2 r_2 - v_1 r_1\right)$$

Symbol		Description	Unit
T	⟶	Torque	$N - m$
v_1 & v_2	⟶	Velocity at Section 1 & 2	m/s
r_1 & r_2	⟶	Radius of Curvature at Section 1 & 2	m
Q	⟶	Discharge	m^3/s
ρ	⟶	Density of Liquid	kg/m^3