• If c.v is moving:- c.v velo

$V_{rel} = V - V_s$

relative — fluid velo

Equation sheet :-

Chapter 3:-

mass conservation : $\dot{m}_{out} = \dot{m}_{in}$

$$(\rho V A)_{out} = (\rho V A)_{in}$$

→ if fluid is incompressible (liquid):-

$$Q_{out} = Q_{in}$$

$$(AV)_{out} = (AV)_{in}$$

linear momentum :

$$\sum F = \dot{m} V_{out} - \dot{m} V_{in}$$

- → Hydrostatic : $(\rho g \frac{h}{2})(A)$
- → pressure force : $(P - P_{atm})(A)$
- → Weight / External

Angular momentum:-

$$\sum M_o = \dot{m}_{out} (r \times V)_{out} - \dot{m}_{in} (r \times V)_{in}$$

Energy equation:-

$$\dot{Q} - \dot{W}_s - \dot{W}_V = \dot{m}_{out}\left(h + \frac{V^2}{2} + g z_1\right)_{out} - \dot{m}_{in}\left(h + \frac{V^2}{2} + g z_2\right)_{in}$$

$h = C_p T$: if ideal Gas

$h = P v = \frac{P}{\rho}$: if Temprature effect is negligible

Bernouli's equation:-

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gz_2 = \text{constant}$$

Restrictions: 1- Steady flow
2- Incompressible flow
3- frictionless flow
4- flow along a stream line

Friction and Shaft work in low speed flow: (pump or turbine)

$$\left(\frac{P}{\gamma} + \frac{V^2}{2g} + z\right)_{in} = \left(\frac{P}{\gamma} + \frac{V^2}{2g} + z\right)_{out} + h_f - h_p + h_T$$

Power of Pump or Turbine:-

$$P = \rho g Q \, h_p \text{ or } h_T$$

Units:-

- gal / min = 6.309×10^{-5} m^3/s
- $SG = \frac{\rho_{subst}}{\rho_{water}}$, $\gamma = \rho g$

Ideal Gas law
$P = \rho R T$

$[\rho] = kg/m^3$
$[Q] = m^3/s$
$[\dot{m}] = kg/s$
$[P] = KPa$
$[h_f] = [h_p] = [h_T] = m$

Chapter 5:-

- Basic Dimensions (next page)
- Dimensionless Groups in fluid mechanics (next page)

$Re = \frac{\rho U L}{\mu}$

ρ: Density , $U = V$: velocity , L: length
μ: vescosity

$Ma = \frac{U}{a}$, $U = V$: velocity , $a = \sqrt{kRT}$
or from Tables
or Given

- Cylinder length effect (next page)

- Geometrically and Dynamically Similar:-
  - Ma, Re matching for m & p
  - $(\pi)_m = (\pi)_p$

Quantity	Symbol	Dimensions: $MLT\Theta$	Dimensions: $FLT\Theta$
Length	L	L	L
Area	A	L^2	L^2
Volume	$\mathcal{V}$	L^3	L^3
Velocity	V	LT^{-1}	LT^{-1}
Acceleration	dV/dt	LT^{-2}	LT^{-2}
Speed of sound	a	LT^{-1}	LT^{-1}
Volume flow	Q	L^3T^{-1}	L^3T^{-1}
Mass flow	$\dot{m}$	MT^{-1}	FTL^{-1}
Pressure, stress	p, σ, τ	$ML^{-1}T^{-2}$	FL^{-2}
Strain rate	$\dot{\epsilon}$	T^{-1}	T^{-1}
Angle	θ	None	None
Angular velocity	ω, Ω	T^{-1}	T^{-1}
Viscosity	μ	$ML^{-1}T^{-1}$	FTL^{-2}
Kinematic viscosity	ν	L^2T^{-1}	L^2T^{-1}
Surface tension	Υ	MT^{-2}	FL^{-1}
Force	F	MLT^{-2}	F
Moment, torque	M	ML^2T^{-2}	FL
Power	P	ML^2T^{-3}	FLT^{-1}
Work, energy	W, E	ML^2T^{-2}	FL
Density	ρ	ML^{-3}	FT^2L^{-4}
Temperature	T	Θ	Θ
Specific heat	c_p, c_v	$L^2T^{-2}\Theta^{-1}$	$L^2T^{-2}\Theta^{-1}$
Specific weight	γ	$ML^{-2}T^{-2}$	FL^{-3}
Thermal conductivity	k	$MLT^{-3}\Theta^{-1}$	$FT^{-1}\Theta^{-1}$
Thermal expansion coefficient	β	Θ^{-1}	Θ^{-1}

Parameter	Defiition	Qualitative ratio of effects	Importance
Reynolds number	$\mathrm{Re} = \frac{\rho U L}{\mu}$	$\frac{\text{Inertia}}{\text{Viscosity}}$	Almost always
Mach number	$\mathrm{Ma} = \frac{U}{a}$	$\frac{\text{Flow speed}}{\text{Sound speed}}$	Compressible flow
Froude number	$\mathrm{Fr} = \frac{U^2}{gL}$	$\frac{\text{Inertia}}{\text{Gravity}}$	Free-surface flow
Weber number	$\mathrm{We} = \frac{\rho U^2 L}{Y}$	$\frac{\text{Inertia}}{\text{Surface tension}}$	Free-surface flow
Rossby number	$\mathrm{Ro} = \frac{U}{\Omega_{\text{earth}} L}$	$\frac{\text{Flow velocity}}{\text{Coriolis effect}}$	Geophysical flows
Cavitation number (Euler number)	$\mathrm{Ca} = \frac{p - p_v}{\rho U^2}$	$\frac{\text{Pressure}}{\text{Inertia}}$	Cavitation
Prandtl number	$\mathrm{Pr} = \frac{\mu c_p}{k}$	$\frac{\text{Dissipation}}{\text{Conduction}}$	Heat convection
Eckert number	$\mathrm{Ec} = \frac{U^2}{c_p T_0}$	$\frac{\text{Kinetic energy}}{\text{Enthalpy}}$	Dissipation
Specific-heat ratio	$k = \frac{c_p}{c_v}$	$\frac{\text{Enthalpy}}{\text{Internal energy}}$	Compressible flow
Strouhal number	$\mathrm{St} = \frac{\omega L}{U}$	$\frac{\text{Oscillation}}{\text{Mean speed}}$	Oscillating flow
Roughness ratio	$\frac{\epsilon}{L}$	$\frac{\text{Wall roughness}}{\text{Body length}}$	Turbulent, rough walls
Grashof number	$\mathrm{Gr} = \frac{\beta \Delta T g L^3 \rho^2}{\mu^2}$	$\frac{\text{Buoyancy}}{\text{Viscosity}}$	Natural convection
Rayleigh number	$\mathrm{Ra} = \frac{\beta \Delta T g L^3 \rho^2 c_p}{\mu k}$	$\frac{\text{Buoyancy}}{\text{Viscosity}}$	Natural convection
Temperature ratio	$\frac{T_w}{T_0}$	$\frac{\text{Wall temperature}}{\text{Stream temperature}}$	Heat transfer
Pressure coefficient	$C_p = \frac{p - p_\infty}{\frac{1}{2}\rho U^2}$	$\frac{\text{Static pressure}}{\text{Dynamic pressure}}$	Aerodynamics, hydrodynamics
Lift coefficient	$C_L = \frac{L}{\frac{1}{2}\rho U^2 A}$	$\frac{\text{Lift force}}{\text{Dynamic force}}$	Aerodynamics, hydrodynamics
Drag coefficient	$C_D = \frac{D}{\frac{1}{2}\rho U^2 A}$	$\frac{\text{Drag force}}{\text{Dynamic force}}$	Aerodynamics, hydrodynamics
Friction factor	$f = \frac{h_f}{(V^2/2g)(L/d)}$	$\frac{\text{Friction head loss}}{\text{Velocity head}}$	Pipe flow
Skin friction coefficient	$c_f = \frac{\tau_{\text{wall}}}{\rho V^2/2}$	$\frac{\text{Wall shear stress}}{\text{Dynamic pressure}}$	Boundary layer flow

Cylinder
length effect

($10^4 < Re < 10^5$)

L/d	C_D
∞	1.20
40	0.98
20	0.91
10	0.82
5	0.74
3	0.72
2	0.68
1	0.64

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