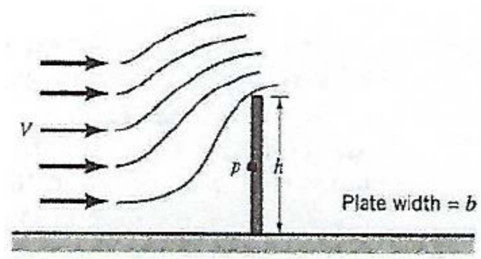
Name: ------------------ **Quiz 6** **Time: 20 minutes**

ME:5160 **Fall 2023**

The exam is closed book and closed notes.

When a fluid flows slowly past a vertical plate of height $\boldsymbol{h}$ and width $\boldsymbol{b}$, pressure develops on the face of the plate. Assume that the pressure, $\boldsymbol{p}$, at the midpoint of the plate is a function of plate height and width, the approach velocity $\boldsymbol{V}$, and the fluid viscosity $\boldsymbol{\mu}$ and fluid density $\boldsymbol{\rho}$. Find the dimensionless parameters.



		Dimensions	
Quantity	**Symbol**	***MLTΘ***	***FLTΘ***
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}

Solution:

KNOWN: dimensional parameters

FIND: Pi groups

ASSUMPTIONS: the problem is only a function of the given dimensional variables

ANALYSIS:

$$p = f(h, b, V, \mu, \rho)$$

$$n = 6 \qquad \textbf{(3)}$$

$$p = \{ML^{-1}T^{-2}\}; \quad h = \{L\}; \quad b = \{L\};$$

$$V = \{LT^{-1}\}; \mu = \{ML^{-1}T^{-1}\}; \quad \rho = \{ML^{-3}\}; \qquad \textbf{(1)}$$

$$j = 3 \;\rightarrow\; k = n - j = 6 - 3 = 3 \qquad \textbf{(2)}$$

The repeating variables are b, V, ρ adding each remaining variable in turn, we find the Pi groups:

$$\Pi_0 = b^a V^b \rho^c p = \{(L)^a (LT^{-1})^b (ML^{-3})^c (ML^{-1}T^{-2})\} = \{M^0 L^0 T^0\} \qquad \textbf{(1)}$$

$$a = 0, \qquad b = -2, \qquad c = -1$$

$$\Pi_0 = \frac{p}{V^2 \rho} \qquad \textbf{(0.5)}$$

$$\Pi_1 = b^a V^b \rho^c h = \{(L)^a (LT^{-1})^b (ML^{-3})^c (L)\} = \{M^0 L^0 T^0\} \qquad \textbf{(0.5)}$$

$$a = -1, \qquad b = 0, \qquad c = 0$$

$$\Pi_1 = \frac{h}{b} \qquad \textbf{(0.5)}$$

$$\Pi_2 = b^a V^b \rho^c \mu = \{(L)^a (LT^{-1})^b (ML^{-3})^c (ML^{-1}T^{-1})\} = \{M^0 L^0 T^0\} \qquad \textbf{(1)}$$

$$a = -1, \qquad b = -1, \qquad c = -1$$

$$\Pi_3 = \frac{\mu}{\rho b V} \rightarrow \frac{\rho V b}{\mu} = Re \qquad \textbf{(0.5)}$$

Thus the arrangement of the dimensionless variables is: $\Pi_0 = f(\Pi_1, \Pi_2)$