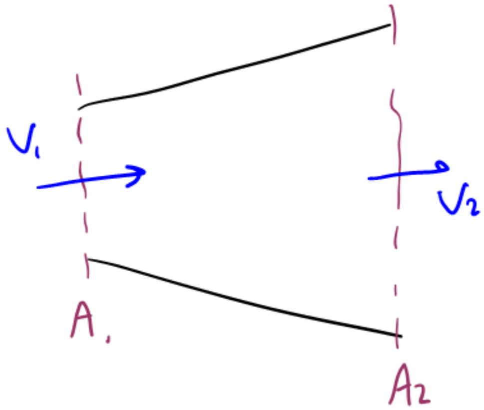
M E 420 – Compressible Flow

Today, we will:

- Introduce the course and instructor: **John M. Cimbala, 863-2739, jmc6@psu.edu**
- Briefly go over the course's websites:
    - Canvas website at **http://canvas.psu.edu**
    - MNE website at **https://www.me.psu.edu/cimbala/me420/**
- Begin a discussion of the differences between incompressible and compressible flow
- Begin a review of thermodynamics, including ideal gas equations and specific heats

Review Incomp. flow



Cons. of mass

$$\boxed{\dot{m} = \rho V A}$$

$$\dot{m}_1 = \dot{m}_2$$

If incompressible ($\rho \approx$ const)

$$\cancel{\rho_1} V_1 A_1 = \cancel{\rho_2} V_2 A_2$$

$\dot{V}$ or Q $\qquad \dot{V}_1 = \dot{V}_2$

$$\therefore V_1 A_1 = V_2 A_2$$

as $\boxed{A \uparrow V \downarrow}$ ★

Also, Beloved Bernoulli eq.

$$P_1 + \frac{1}{2}\rho_1 V_1^2 + \cancel{\rho g z_1} = P_2 + \frac{1}{2}\rho_2 V_2^2 + \cancel{\rho g z_2}$$

We always ignore grav. term in this course ★

★ Beloved Bernoulli: Does not apply in this course! ★

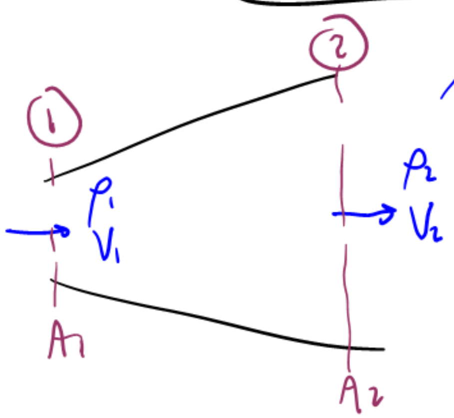
★ COMPRESSIBLE FLOW

Need more eq.'s

Eqs $\dot{m} = \rho V A = \text{const}$ (cons. of mass)

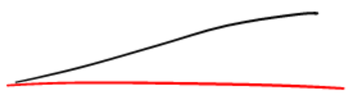
$$\boxed{\rho_1 V_1 A_1 = \rho_2 V_2 A_2}$$

steady flow
no leaks



$$\boxed{V_2 = \frac{\rho_1}{\rho_2}\,\frac{A_1}{A_2}\,V_1}$$

· if $\rho_2 > \rho_1$



<1 <1

$$\boxed{\therefore V_2 < V_1}$$

· If $\rho_2 < \rho_1$

>1 <1

?

$$V_2 \;\substack{<\\>\\=}\; V_1$$

We need some eq.s from Thermodynamics

Review

E = total energy of a system

e = specific total energy

"per unit mass"

$$\boxed{E = me}$$

$$e = u + ke + pe$$

u: spec. internal en.

ke: spec. kinetic energy

pe: specific potential energy

$$\boxed{e = u + \frac{V^2}{2}} + \cancel{gz}$$

ignore pe in this course (gases)

Define H = enthalpy

h = specific enthalpy $\{H = mh\}$

recall $\boxed{h = u + Pv}$ v = specific volume

$$\boxed{v = \frac{1}{\rho}}$$ ★

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

$$\boxed{h = u + \frac{P}{\rho}}$$ ★

★ IDEAL GAS ← all gases in this course are ideal gases

$\boxed{M = \text{molecular weight}}$ $[M] = \left[\frac{g}{mol}\right]$ or $\left[\frac{kg}{kmol}\right]$

$\{M\} = \left\{\frac{mass}{mole}\right\}$

"mole" is the dimension

"mol" is the unit

$\boxed{\#\text{moles} = n}$

one mol = Avogadro's # of molecules

= 6.0225×10^{23} molecules

★ $\boxed{m = n \cdot M}$

$$\boxed{M_{air} = 28.97 \frac{\text{g of air}}{\text{mol of air}}}$$ ★

Ideal gas Law

$$\boxed{P\forall = mRT} \quad \text{or} \quad \boxed{P\forall = nR_uT}$$

R_u = universal ideal gas const

(used for any ideal gas)

$$\boxed{R_u = 8.314 \frac{J}{mol \cdot K}}$$

R = specific ideal gas const

$$\boxed{R = \frac{R_u}{M}}$$

$$[R] = \left[\frac{R_u}{M}\right] = \left[\frac{kJ}{\cancel{kmol} \cdot K} \cdot \frac{\cancel{kmol}}{kg}\right] = \left[\frac{kJ}{kg \cdot K}\right]$$

Example: Air (we prefer to use R, not R_u)

$$R_{air} = \frac{R_u}{M_{air}} = \frac{8.314 \frac{kJ}{\cancel{kmol} \cdot K}}{28.97 \frac{kg}{\cancel{kmol}}} = \boxed{0.2870 \frac{kJ}{kg \cdot K} = R_{air}}$$

or

$$\boxed{R_{air} = 287.0 \frac{J}{kg \cdot K}}$$

IDEAL GAS LAW

$$\boxed{P\forall = mRT}$$

$$= (n\cancel{M})\left(\frac{R_u}{\cancel{M}}\right)T \rightarrow \boxed{P\forall = nR_uT}$$

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

$$P\frac{\forall}{m} = RT$$

v or $\frac{1}{\rho}$

$$\boxed{P = \rho RT}$$

Eq. that fluids people like most