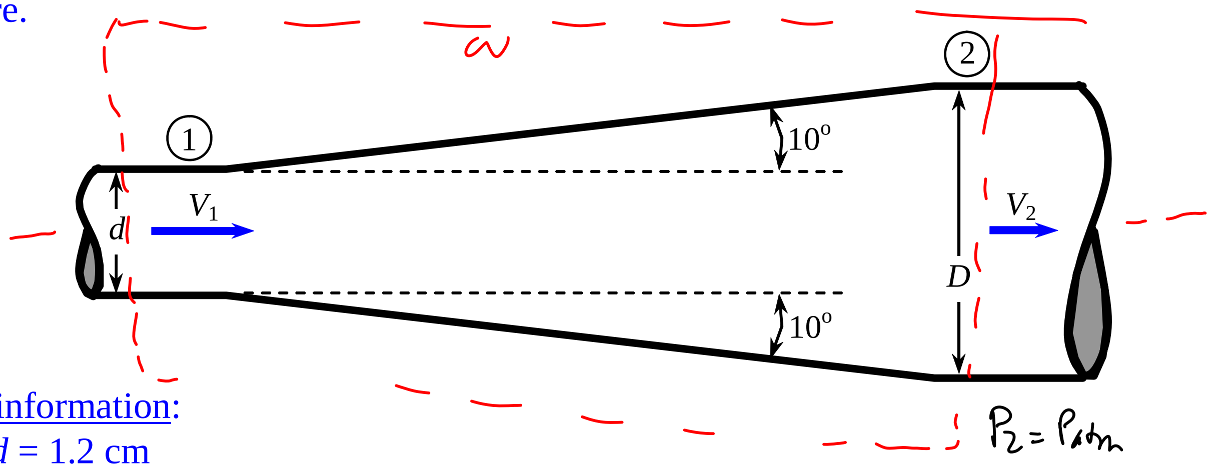
Today, we will:

- Do an example problem – diffuser
- Begin discussing ***pumps***, and how they are analyzed in pipe flow sytems

Example Problem – Diffuser

Given: Water (ρ = 1000 kg/m^3, μ = 1.00 × 10^{-3} kg/m·s) flows through a horizontal diffuser, as sketched. The flow is fully developed at both locations 1 and 2. The inner diameter changes from d to D through the diffuser. The outlet of the diffuser is open to atmospheric pressure.



Given information:

- d = 1.2 cm
- D = 2.0 cm
- $\theta = 2 \times 10^{\circ} = 20^{\circ}$ (θ is the total included angle)
- V_1 = 6.0 m/s
- $P_2 = P_{atm}$
- α_1 = 1.06 and α_2 = 1.06 (fully developed turbulent pipe flow)

To do: Calculate the gage pressure at location 1 and discuss.

Solution: *To be done in class.*

- Draw CV
- Energy eq.

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + \cancel{z_1} + \cancel{h_{pump,u}} = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + \cancel{z_2} + \cancel{h_{turbine,e}} + h_L$$

P_{atm}

horizontal

$$\boxed{P_{1,gage} = P_1 - P_{atm} = \rho\left(\frac{\alpha_2 V_2^2 - \alpha_1 V_1^2}{2}\right) + \rho g h_L} \qquad (1)$$

- Cons of mass $\quad V_2 A_2 = V_1 A_1 \rightarrow \boxed{V_2 = V_1\left(\frac{d}{D}\right)^2}$

- h_L = irrev. head loss = $\cancel{\text{major}}$ + minor = $K_L \frac{V^2}{2g}$ → we V_1 here

Table 8-4
@ $\theta = 20°$ $\frac{d}{D} = 0.6 \rightarrow \underline{K_L = 0.15}$

- Eq. (1) becomes

$$\boxed{P_{gage,1} = \frac{\rho V_1^2}{2}\left[\alpha_2\left(\frac{d}{D}\right)^4 - \alpha_1 + K_L\right]}$$ Answer

Plug in #s → $\boxed{P_{gage,1} = -13.9 \text{ kPa}}$

we have a pressure recovery ($P_2 > P_1$) through the diffuser.

E. Turbomachinery (Ch. 14)

1. Intro → terminology & types of pumps

See pdf file on website

---

recall $\boxed{\eta_{pump} = \frac{\text{useful power delivered by the pump}}{\text{shaft power required to run the pump}}}$

$$\boxed{\eta_{pump} = \frac{\dot{W}_{\text{water horsepower}}}{\text{bhp}} = \frac{\text{"water horsepower"}}{\text{"brake horsepower"}}}$$ ☆

$$\dot{W}_{water\text{-}horsepower} = \dot{m} g H \rightarrow H \text{ is same as our } h_{pump,u}$$

useful pump head

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

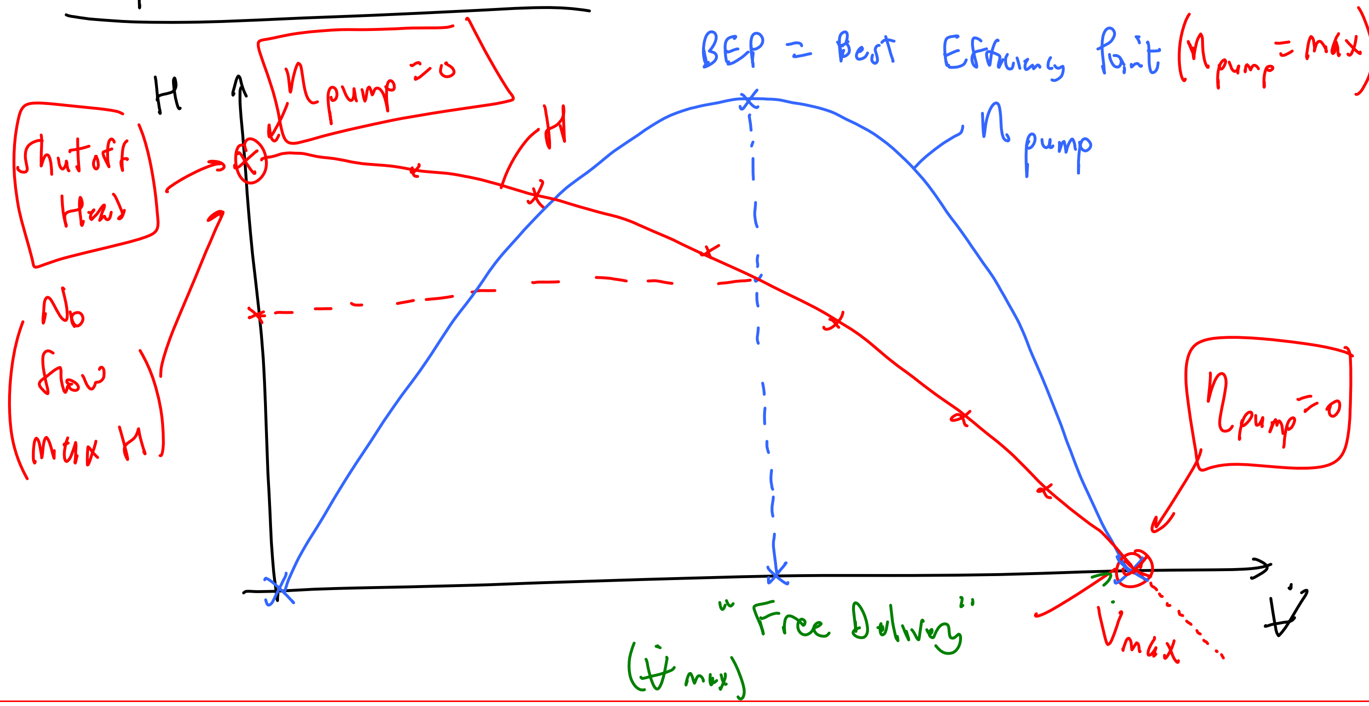
$$\boxed{\eta_{pump} = \frac{\rho \dot{V} g H}{bhp} = \frac{\rho \dot{V} g h_{pump,u}}{bhp}}$$

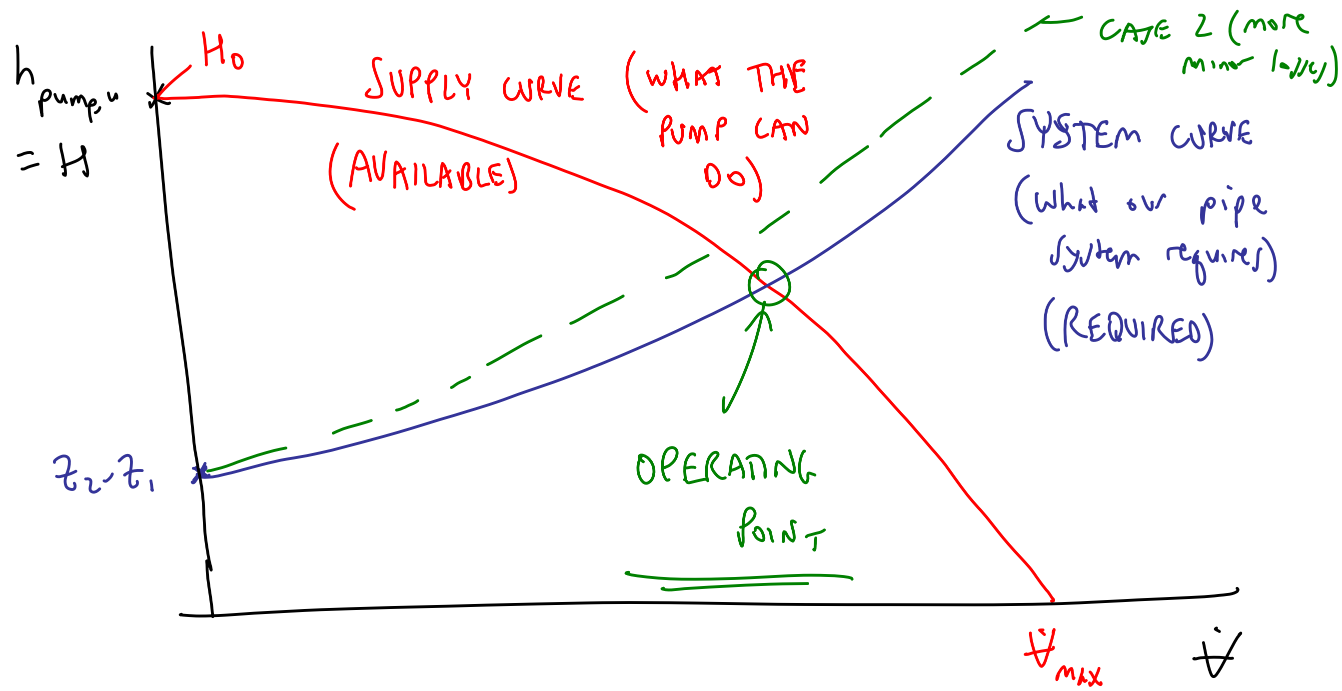
Some combination of $\dot{V}$ & $h_{pump,u}$ gives a maximum η_{pump}

- $\eta_{pump} = 0$ when $\dot{V} = 0$
- $\eta_{pump} = 0$ when $h_{pump,u} = 0$
- $\eta_{pump} = max$ somewhere in between

2. Pump Performance curves H (or $h_{pump,u}$) vs $\dot{V}$

BEP = Best Efficiency Point ($\eta_{pump} = max$)





b. Matching a pump to a piping system

recall, energy eq.

$$\boxed{\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_{pump,u} = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + \cancel{h_{turbine,e}} + h_L}$$

For a given pump,

match the required $h_{pump,u}$ (system curve)

and the available $h_{pump,u}$ (supply curve)

$$\boxed{h_{pump,u} = \underbrace{\frac{P_2}{\rho_2 g} - \frac{P_1}{\rho_1 g}}_{\text{pressure rise in the fluid}} + \underbrace{\frac{\alpha_2 V_2^2 - \alpha_1 V_1^2}{2g}}_{\Delta \text{ ke of the fluid}} + \underbrace{z_2 - z_1}_{\Delta \text{ elevation of the fluid}} + \underbrace{h_L}_{\text{irreversible losses}}}$$

The pump does 4 things →