Today, we will:

- Continue to discuss how to match required fan pressure to available fan pressure
- Do an example problem – hood/exhaust duct fan selection
- If time, begin to discuss **Particle Motion** [Chapter 8]

\[ \Delta P_{\text{fan,req}} = [P_i - P_j] + \left[ \alpha_r (VP)_i - \alpha_r (VP)_j \right] + \rho g h_L \]

**CAUTION** - Pumps or fans manufactured advertise like this:
- Maximum pressure \( \Delta P \) = __________ 
- Maximum flow rate = __________
Example

Given: Air is drawn into a 45° tapered hood, and then goes through a damper, several long sections of pipe, and three elbows, as sketched. The air is exhausted by a fan.

- duct length = 100 ft
- duct dia. = 6 in
- duct roughness = 0.006 in
- \( C_{o, \text{hood}} = 0.15 \)
- \( C_{o, \text{damper}} = 0.50 \) when fully open
- elbows are 5-gore, 90° CD3-9 with \( R/D = 1.5 \)
- \( \rho_{\text{air}} = 1.2 \text{ kg/m}^3 \)
- \( \nu_{\text{air}} = 1.5 \times 10^{-5} \text{ m}^2/\text{s} \)
- \( Q = 1200 \text{ CFM} \)

(a) To do: Calculate the required pressure rise across the fan

\[
\Delta P = P_i - P_e = \frac{\rho Q^2}{2A}
\]

(b) To do: Select an appropriate fan from a family of available fans (shown below).

Solution:

\[
\ln \frac{51}{5} = \frac{D}{D} = 0.1524 \text{ m} \\
L = 30.49 \text{ m} \\
\frac{\nu}{D} = \frac{0.006}{6 = 0.001} \\
Q = 1200 \text{ CFM} = 0.56634 \text{ m}^3/\text{s}
\]
. Ellbow - Fig 6.29 - C0.3 elbow e D=150 mm

\[ C_0_{\text{elbow}} = K = 0.28 \]

. Apply energy for the CV

\( 0 = \text{inlet} \quad 0 = \text{outlet} \)

\[
\left( \delta P_{\text{inlet}} \right) \text{required} = \left[ P_i - P_o \right] + \left[ \alpha_1 (VP)_2 - \alpha_2 (VP)_1 \right] + \rho g h + \eta_{\text{inlet}}
\]

- \( P_i = P_o = P_{\text{atm}} \)
- \( V_i = 0 \)
- \( V_o = 0 \)

\( (VP)_2 = \frac{1}{2} \rho V_i^2 \geq 0 \)

\[
\left( \delta P_{\text{inlet}} \right) \text{required} = d_2 (VP)_2 + \rho g h_{\text{inlet}} + \eta_{\text{inlet}}
\]

\[
\sum \delta P_{\text{major}} + \sum \delta P_{\text{minor}}
\]

. Major loss

\[
V = \frac{Q}{A} = \frac{4Q}{\pi D^2} = \frac{4 \times 0.86634 \, \text{m}^3}{\pi \times (0.1524 \, \text{m})^2} = 31.066 \, \text{m}^3
\]

\[
Re = \frac{V \cdot D}{\nu} = 2.154 \times 10^5 \geq 2300
\]

\[
\frac{\varepsilon}{D} = 0.001
\]

Need to calc f Darcy friction factor
How to get f?  

- Moody chart @ this Re = \( \frac{3}{D} \)

\[ f = 0.0206 \]

OR

- Colebrook eq \( \frac{1}{f} \) implicit in \( f \)

(must iterate)

OR

- Churchill eq \( f = 0.02069 f \)

\[ \approx 0.0207 \]

\[ \sum \Delta P_{\text{major loss}} = f \left( \frac{L}{D} \right) (VP) \]

Here \[ VP = \frac{1}{2} \rho V^2 = \frac{1}{2} \left( \frac{1.2 \text{ kg} / \text{m}^3}{(31.048 \text{ m}^3 / \text{min})} \right) \left( \frac{N \cdot \text{m}^2}{\text{kg} \cdot \text{m}} \right) \left( \frac{Pa \cdot m^2}{N} \right) \]

\[ VP = 578.2 \text{ Pa} \]

\[ = VP e^{2(\text{leat})} \approx \text{allergy to the kpc} \]

\[ (VP)_1 = 0 \]

\[ \sum \Delta P_{\text{major loss}} = f \left( \frac{L}{D} \right) (VP) = 2394 \text{ Pa} = \text{major loss} \]

Minor loss:

\[ \Delta P_{\text{minor loss}} = \sum C_0 (VP) \]

At the hood

\[ V^2 = 0 \]

we get higher \( V \) with a change of direction

Thus \( V = V_2 \) in the kpc

(same VP as major loss)
\[
\sum \Delta P_{\text{minor lost}} = (\Sigma C_0)(VP) \quad (Fy \: 6.25)
\]
\[
= (0.15 + 0.50 + 3 \times (0.28)) \times \frac{1}{1} \times \frac{1}{1} \times \frac{1}{1} \frac{578.3 \: Pa}{\text{full} \: \text{open}} \times \frac{1}{3} \text{closed}
\]
\[
\sum \Delta P_{\text{minor lost}} = 861.7 \: Pa = 862 \: Pa
\]

\[
\delta P_{\text{fan, required}} = \sum (VP) + \sum \Delta P_{\text{major loss}} + \sum \Delta P_{\text{minor loss}}
\]
\[
= 1.05 \times (578.3 \: Pa) + 2394 \: Pa + 861.7 \: Pa
\]
\[
= 3863 \: Pa
\]
\[
\delta P_{\text{fan, required}} = 3900 \: Pa
\]

\[
\text{required pressure rise by the fan to give } \: Q = 1200 \: \text{cfm}
\]

I used Excel to repeat at various Q values to get the curve.
(b) To do: Select an appropriate fan from a family of available fans (shown below).

Solution:

Which fan?

Fan A is not strong enough → too small
Fan C is overkill → too big

Fan B is the best choice → just right

If I close the damper, I can increase the $\delta P$ @ the desired $Q = 1200$ CFM (I would operate @ the green pt.)

CHAPTER 8 - MOTION OF PARTICLES

Sec 8.1 - Intro. i. Particleility
**FUNDAMENTAL DIFFERENCE BETWEEN VAPORS & PARTICLES**

**VAPORS** move with the air

**PARTICLES** have inertia. Are heavier than air.

Trajectory of particle depends on:
- particle size
- density
- shape
- fluid properties (k, μ, etc.)
- fluid flow field (streamlines)

Particles cross streamlines → **INERTIAL SEPARATION**