~~Somewhere~~

Last time

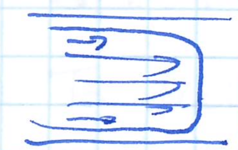
fluid flow dichotomies

- internal vs external flow
- passive vs active convection (demo in fishtank)
- turbulent vs laminar flow

Reynolds # $R = \frac{\rho v L}{\mu}$

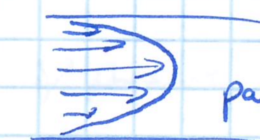
specifies for pipe flow

turbulent vel. profile



relatively flat vel. profile

laminar vel. profile



parabolic $v(r)$ profile

integrating over r, θ yields

$$\dot{V} = \frac{\pi D^4}{128\mu} \frac{\Delta p}{l}$$

pressure gradient

deceptive calculation from last time

find transition velocity for turbulent flow in pipe

$R = 2000$, $L = D = 1/2"$, $\rho = 1000\ kg/m^3$, $\mu = 1.12 \times 10^{-3}\ \frac{Ns}{m^2}$

$\longrightarrow v = 0.2\ m/s$

reason deceptive: find $\dot{V}$

Assume simplest (overly simple w/ error overestimating flow) model for $\dot{V}$ ie slug of water

w/ $D = 1/2"$, $v = 0.2\ m/s$

thus

$\dot{V}$ = area of pipe × V of center

$$= \pi \left(\frac{D}{2}\right)^2 \times V$$

$$= \pi \left(\frac{1.27\,cm}{2}\right)^2 20\,cm/s = 25\,\frac{cm^3}{s}$$

How Fast is this?

~~[illegible]~~

5cc = 1 tsp

a Typical person turns on a faucet to 1 - 1.5 $\frac{gal}{min}$ → $63\,\frac{cm^3}{s}$ - $95\,\frac{cm^3}{s}$

typical shower head is $2\,\frac{gal}{min}$ → $125\,\frac{cm^3}{s}$

• Full reasonable flow will be turbulent

To deal w/ the loss of pressure due to turbulence

in engineering texts this is called a head loss as in pressure head

recall Bernoulli's eq.

for laminar flow → $$P_1 + \frac{\rho V_1^2}{2} + \rho g h_1 = P_2 + \frac{\rho V_2^2}{2} + \rho g h_2$$

for turbulent flow $$\underbrace{P_1 + \frac{\rho V_1^2}{2} + \rho g h_1}_{\text{up stream location}} = \underbrace{P_2 + \frac{\rho V_2^2}{2} + \rho g h_2}_{\text{down stream location}} + \underbrace{\rho g h_L}_{\text{head loss}}$$

head loss has 2 sources

- the pipe itself (major head loss) $h_{L\,major}$
- fittings between pipe segments (minor head loss) $h_{L\,minor}$

fittings include elbows, Ts, valves unions etc.

$h_L = h_{L\,major} + h_{L\,minor}$

↑ we will only consider this

$$h_{L\,major} \equiv f \frac{l\, v^2}{D\, 2g}$$

(so that $\rho g\, h_{L\,major} = f \rho \frac{l\, v^2}{2D}$ or $= f \frac{Re\, l\, v\, \mu}{2D^2}$)

l = length of pipe
v = speed of fluid flow
D = diameter of pipe
g = accel. of gravity
f = friction factor ← set by empirical observations

f is found to depend on Reynolds # Re and the roughness of the pipe.

for <u>smooth</u> pipe (glass, plastic tubing)

$$f = \frac{0.316}{Re^{1/4}}$$

for other pipes consult table for roughness ϵ, calc. relative roughness ϵ/D and read Re from Moody Chart

Example pump water down & up a 300 ft ground source heat pump well through 3/4" galvinized pipe at a rate of 12 gal/min. find pressure needed to push water through this.

Conversion
$1\,gal \approx 3785\,cm^3$

so
$$\frac{12\,gal}{min} = 760\,\frac{cm^3}{s}$$

$$3/4" = 1.905\,cm$$

$$area \cdot V = \dot{V}$$

$$V = \frac{\dot{V}}{area} = \frac{760\,\frac{cm^3}{s}}{2.85\,cm^2} = 267\,\frac{cm}{s} = 2.67\,\frac{m}{s}$$

$$R_e = \frac{\rho V D}{\mu} = \frac{1000\,\frac{kg}{m^3} \cdot 2.67\,\frac{m}{s} \cdot 0.019\,m}{1.12 \times 10^{-3}\,\frac{Ns}{m^2}}$$

$$= 45{,}300$$

$\frac{\epsilon}{D}$ for galvanized pipe is

$$\frac{\epsilon}{D} = \frac{0.015\,cm}{1.905\,cm} = 0.008$$

$$\Rightarrow f = 0.036$$

$$l = 600\,ft \rightarrow 185\,m$$

$$h_L = \frac{0.036 \quad 185\,m \quad (2.67\,\frac{m}{s})^2}{1.9 \times 10^{-2}\,m \quad 2 \cdot 9.8\,m/s^2} = 127\,m$$

$$P_1 = P_2 + \rho g h_L \Rightarrow P_1 = \rho g h = 1000\,\frac{kg}{m^3}\; 9.8\,\frac{m}{s^2}\; 127\,m$$

$P_1 = 1246$ kPa

$= 12.3$ atmospheres

$= 181.5$ psi