November 14, 2012   Physics 131   Prof. E. F. Redish

■ **Theme Music:** **Sons of the Pioneers**
        Cool Water
■ **Cartoon: Wiley Miller**
        Non-Sequitur

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Foothold ideas:
Matter Current (incompressible)

■ Q = Current = (volume crossing a surface)/s

$$[Q] = \text{m}^3/\text{s}$$

$$\vec{Q} = \frac{(A\Delta\vec{x})}{\Delta t} = \frac{(A\vec{v}\Delta t)}{\Delta t} = A\vec{v}$$
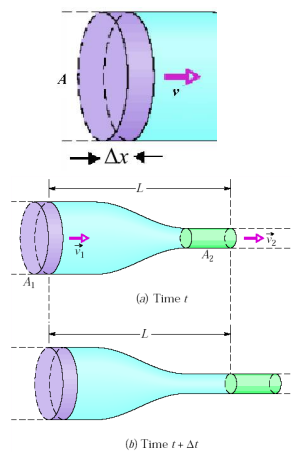
■ Conservation of matter:
    "What goes in must come out."

$$\Delta V_{in} = \Delta V_{out}$$

$$A_1\left(v_1\Delta t\right) = A_2\left(v_2\Delta t\right)$$

$$Q = Av = \text{constant}$$

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Reading questions

■ I am confused as to how flow rate increases with the fourth power of the tube radius. Intuition seems to say that if you have a larger tube than the flow will be lower since the pressure is lower. I can see from the equation why it makes sense, but I do not understand physically why it is this way.

■ The reading says: " fluid keeps moving at a constant speed, the pressure must drop as we go downstream." I don't see why the pressure must go down as we move downstream. what makes the pressure different? For example in a hose when water is moving through, shouldn't the water have the same pressure throughout the whole tube?until the very end in which the water come out?

Viscous Drag

■ A fluid flowing in a pipe doesn't slip through the pipe frictionlessly.

■ The fluid sticks to the walls moves faster at the middle of the pipe than at the edges.
As a result, it has to "slide over itself" (shear).

■ There is friction between layers of fluid moving at different speeds that creates a viscous drag force, trying to reduce the sliding.

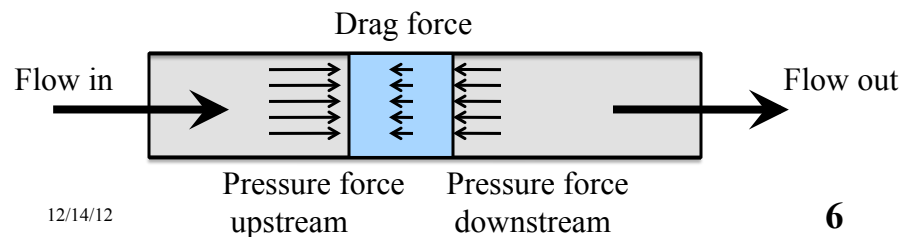■ The drag is proportional to the speed and the length of pipe.

$$F_{drag} = 8\pi\mu Lv$$

Implication: Pressure drop

■ If we have a fluid moving at a constant rate and there is drag, N2 tells us there must be another force to balance the drag.

■ The internal pressure in the fluid must drop in the direction of the flow to balance drag.

Drag force

Flow in   Flow out

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                    upstream   downstream

The Hagen-Poiseuille Law

■ If the pressure drop balances the drag (and thereby maintains a constant flow) N2 tells us

$\vec{F}_{drag}$

$P_{upstream}\vec{A}_L$ $P_{downstream}\vec{A}_R$
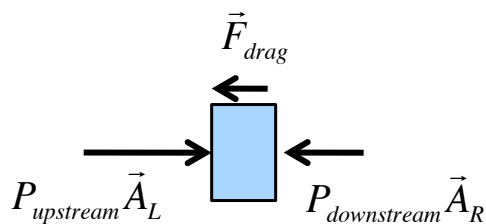
$$\Delta P\, A = 8\pi\mu L v$$

$$\Delta P\, A = 8\pi\mu L\left(\frac{Q}{A}\right)$$

$$\Delta P = \left(\frac{8\pi\mu L}{A^2}\right)Q = \left(\frac{8\mu L}{\pi R^4}\right)Q$$

$$\Delta P = ZQ$$

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