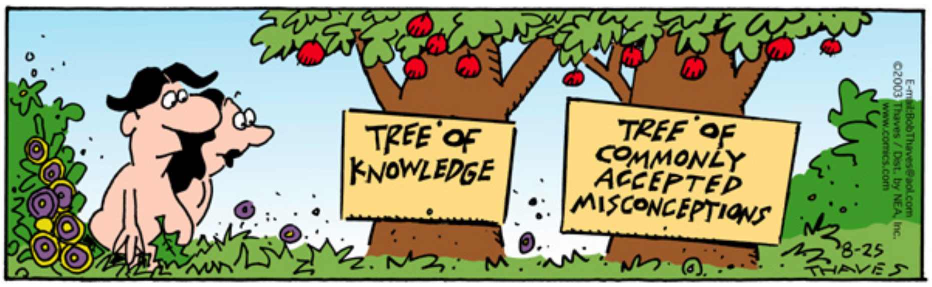
November 9, 2016 Physics 131 Prof. E. F. Redish

- **<u>Theme Music:</u> Bill Staines**
  River
- **<u>Cartoon:</u> Bob Thaves**
  Frank & Ernest



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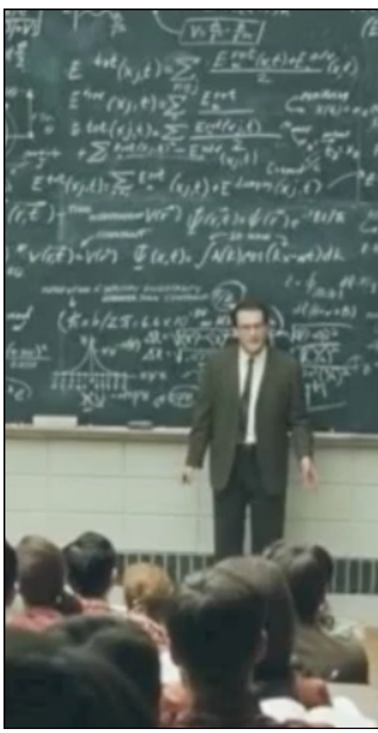

The Equation of the Day

Incompressible flow

$$A_1 v_1 = A_2 v_2$$

The H-P equation

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

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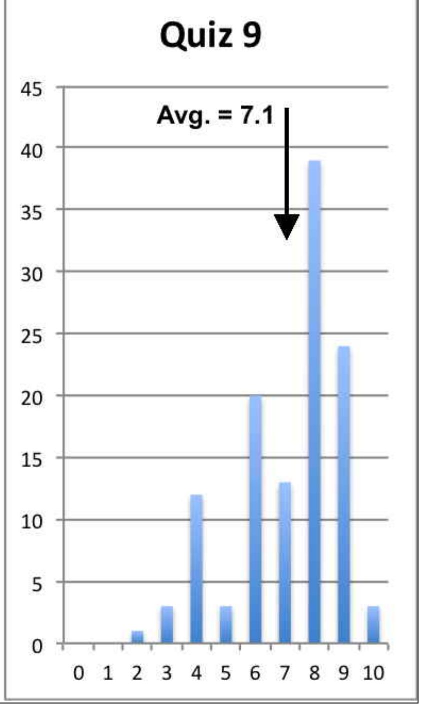
Quiz 9

	1.1	*1.2*		*2.1*	*2.2*
A>B>C>D	10%	1%	**A**	**83%**	**81%**
D>C>B>A	8%	**83%**	**B**	1%	3%
A=B=C=D	**45%**	1%	**C**	16%	16%
B=C=D>A	**25%**	0%			
A>B=C=D	1%	1%			
D>B>C>A	0%	8%			
D>B=C>A	2%	**6%**			

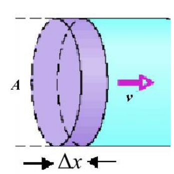


Foothold ideas: Matter Current (incompressible)

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

$$[Q] = L^3/T$$

$$\vec{Q} = \frac{(A\Delta\vec{x})}{\Delta t} = \frac{(A\vec{v}\Delta t)}{\Delta t} = A\vec{v}$$

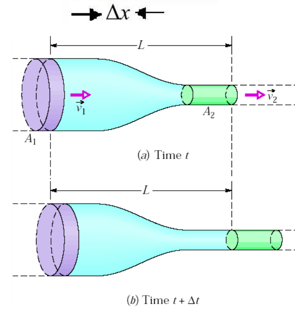


- Conservation of matter: "What goes in must come out."

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

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

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

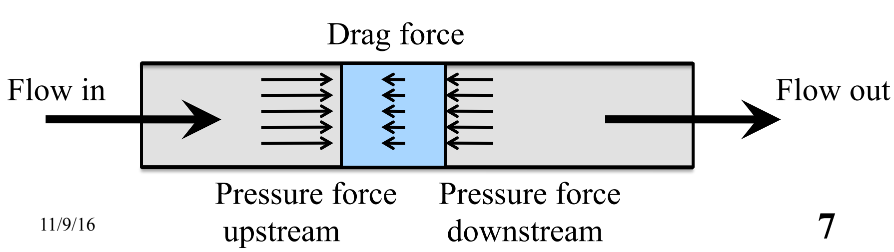


Remember: Viscous Drag

- 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. $F_{drag} = 8\pi\mu L v$

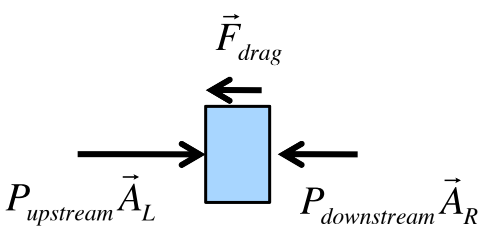
Implication: Pressure drop

- 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.



The Hagen-Poiseuille Law

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



$$\Delta P\, A = 8\pi\mu L v$$

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

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

$$\Delta P = ZQ$$

H-P as gradient driven flow

- Note if we consider our pressure change over a small distance, $L \rightarrow dx$, the H-P law looks a lot like Fick's law.

$$Q = -\left(\frac{\pi R^4}{8\mu}\right)\frac{dP}{dx}$$

- Fick's law looks like

$$J = -D\frac{dn}{dx}$$

- In both equations, a flow = a constant times a gradient.

Dimensions of flows

- J – (diffusion) number flow/area/time

$$J = -(D)\frac{dn}{dx} \qquad [J] = \#/\mathrm{L}^2\mathrm{T}$$

- Q – (fluid flow) volume flow/time

$$Q = -\left(\frac{\pi R^4}{8\mu}\right)\frac{dp}{dx} \qquad [Q] = \mathrm{L}^3/\mathrm{T}$$

- Q – (heat flow) energy flow/time

$$Q = -\left(\frac{A}{R}\right)\frac{dT}{dx} \qquad [Q] = \mathrm{ML}^2/\mathrm{T}^3$$

- I – (electric current) charge/time

$$I = -\left(\frac{q^2 nA}{b}\right)\frac{dV}{dx} \qquad [I] = \mathrm{Q/T}$$

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