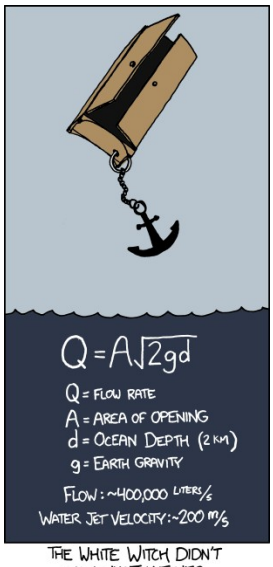
October 28, 2011 Physics 131 Prof. E. F. Redish

- **Theme Music:**
  Pearl Jam
  Even Flow

- **Cartoon:**
  Randall Munroe
  XKCD



THE WHITE WITCH DIDN'T KNOW WHAT HIT HER.

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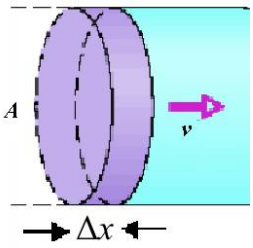
Current (Volume Flow)

- Assume a fluid that is moving uniformly without changing density (compressing or expanding).
- Q = Current = (volume crossing a surface) / s

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

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



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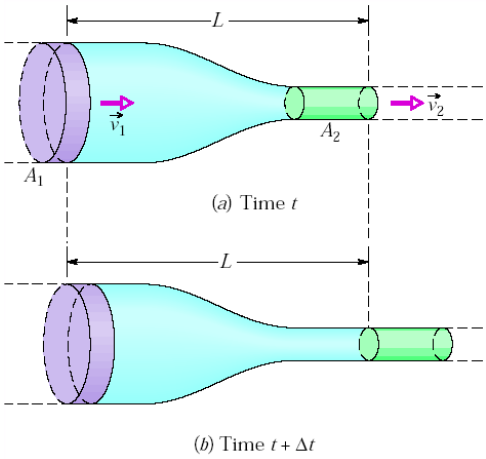
Implications of conservation of matter

- "What goes in must come out."
- Assume motion of a fluid of uniform density in a non-uniform tube.

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

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

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



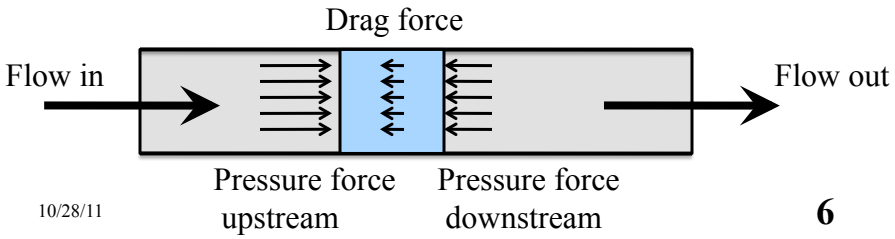
Viscous Drag

- 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.



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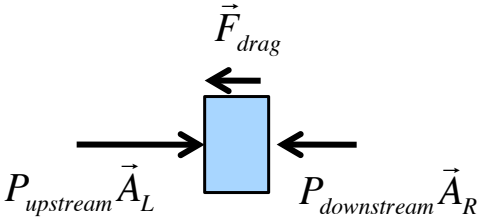
The Hagen-Poiseuille Law

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



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

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

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

$$\Delta P = ZQ$$

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Reading questions

- The H-P law says that flow rate increases with pressure difference, but how can you change pressure difference? If there is more pressure that is applied to the fluid at the pipe opening, wouldn't there be an increase in pressure downstream as well?
- I don't understand how the pressure needs to decrease so that the fluid can move at a constant speed, why can't the pressure just stay the same cause when pressure decrease doesn't that mean that the fluid can move more easily which would increase the speed of the flow?