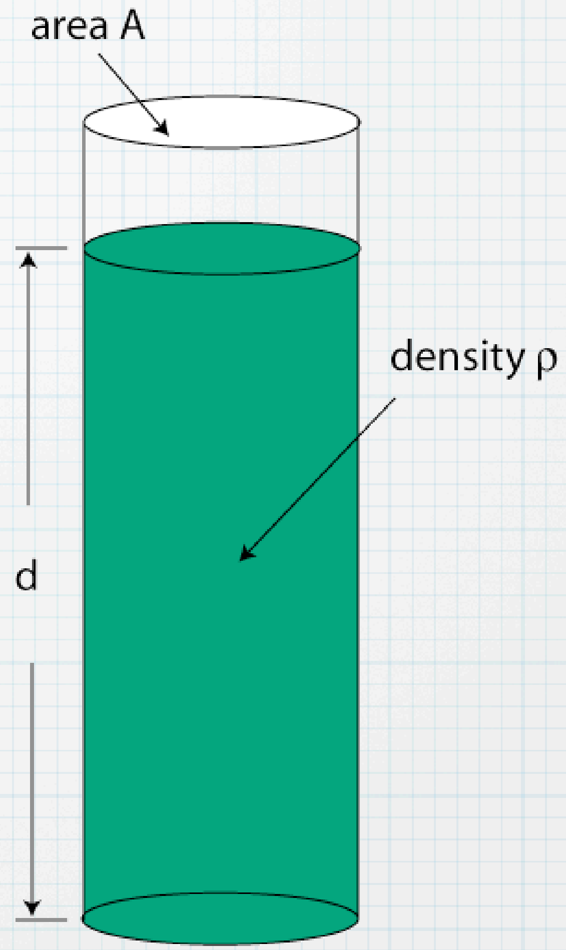
Fluids

Physics 7B - Lecture 6
Prof. John Conway

Pressure

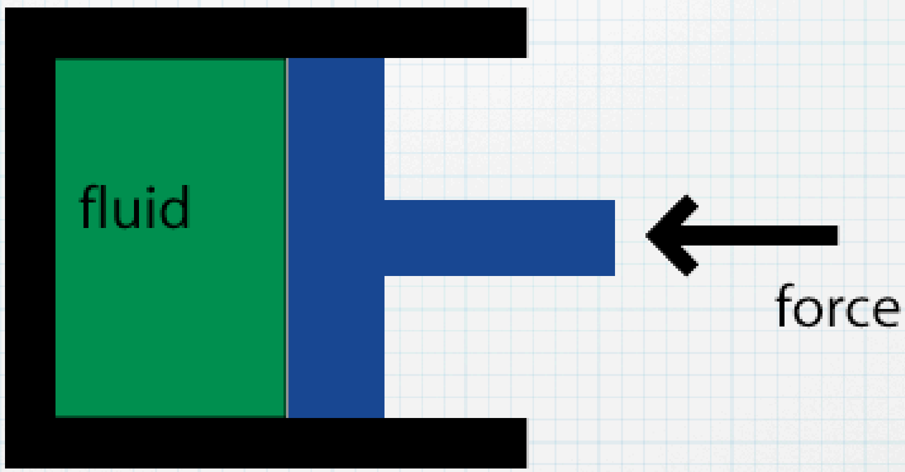
- pressure is force per unit area
- in a fluid, pressure pushes in all directions
- pressure varies with depth in a gravitational field: need to hold up column of fluid above!



force = weight = mg = ρAdg
pressure = force/area = ρdg

Pressure

- it takes energy to pressurize a fluid



- in our approximation, no change in density due to pressurization for an "incompressible" fluid (like water, not air!)

Buoyancy - PRS

- Why does a helium balloon float?

A. The air pressure on the bottom is greater than the air pressure on top, and helium is less dense than air.

B. Helium is less dense than air.

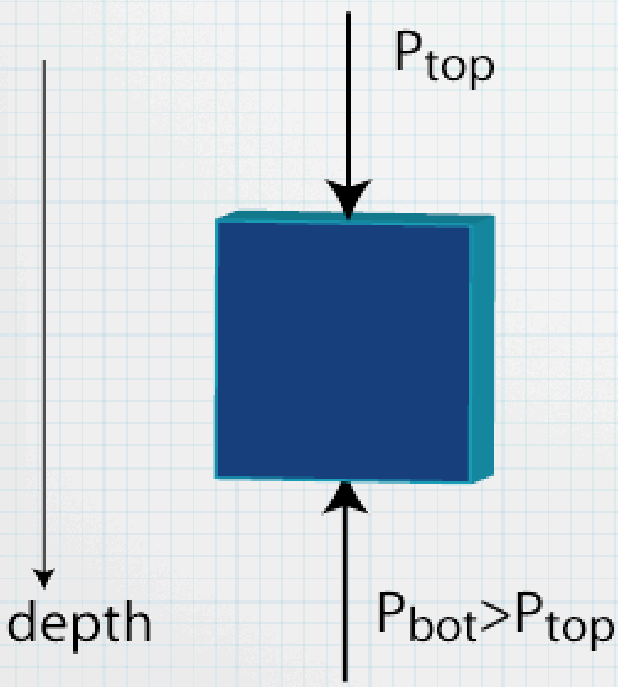
C. The air pressure on the bottom is greater than the air pressure on top, and the helium+rubber weighs less than the air the balloon displaces.

D. The helium+rubber weighs less than the air the balloon displaces.

E. The air pressure on the bottom is greater than the air pressure on top.

Buoyancy

- consider a cube of side ℓ submerged in a liquid
- density of liquid: ρ_{liq}
- density of cube: ρ_{cube} $\Rightarrow$ $m_{cube} = \ell^3 \rho_{cube} = V \rho_{cube}$



Force on top: $F_{top} = P_{top}\,\ell^2$

Force on bottom: $F_{bot} = P_{bot}\,\ell^2$

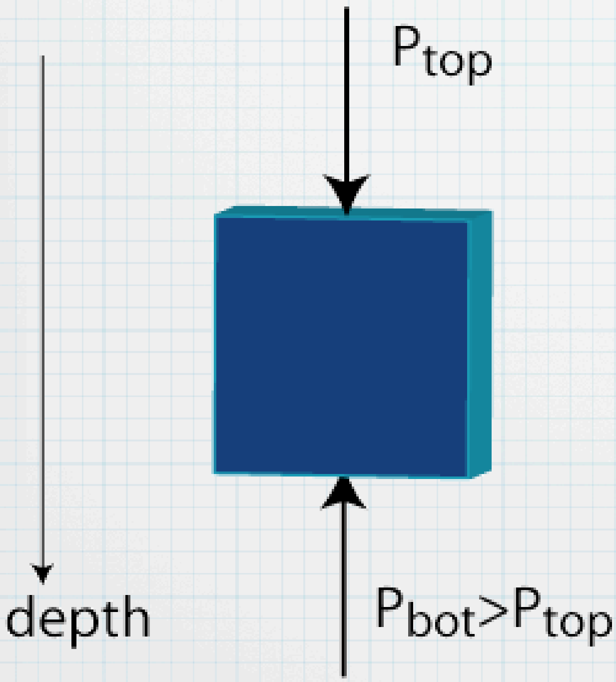
$$P_{top} = \rho_{liq}\, g\, d$$

$$P_{bot} = \rho_{liq}\, g\, (d+\ell)$$

$$F_{bot} - F_{top} = (\rho_{liq}\, g\, \ell) \cdot \ell^2$$

Buoyancy

- a submerged object feels a force upward!



Buoyant force is upward!

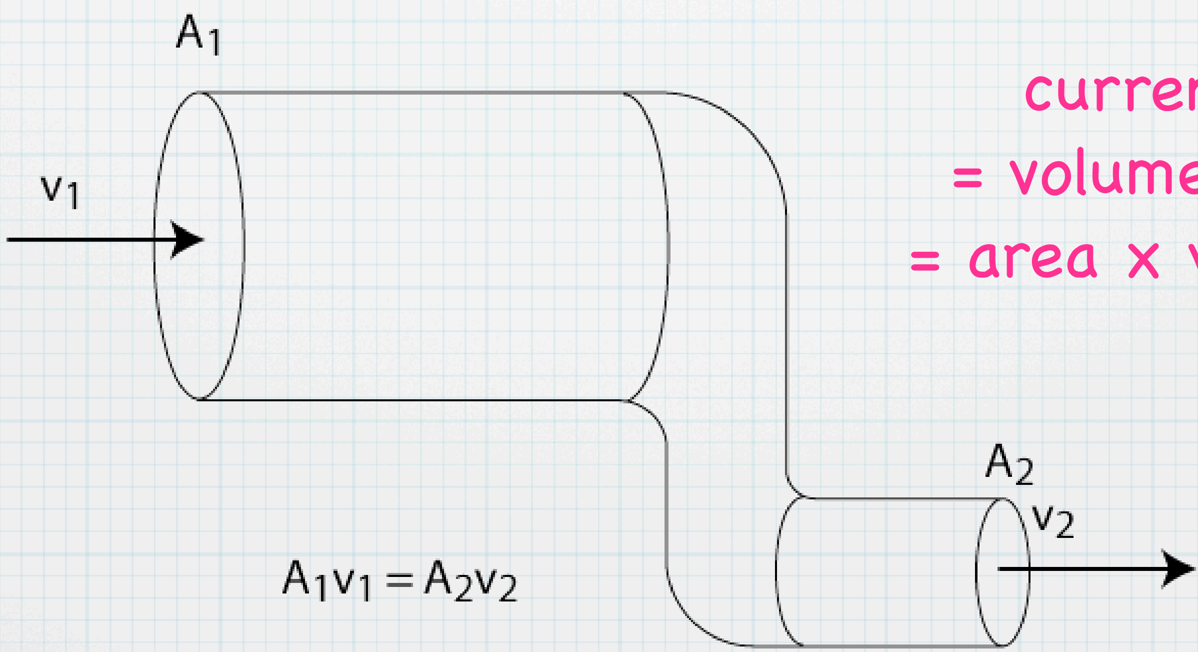
$$B = \rho_{liq} g V_{obj}$$

Gravity is downward!

Object will float only if B > mg !

Fluid Current

- incompressible fluid: what goes in one end must come out the other end!
- fluid current: volume per unit time passing a point in a fluid path



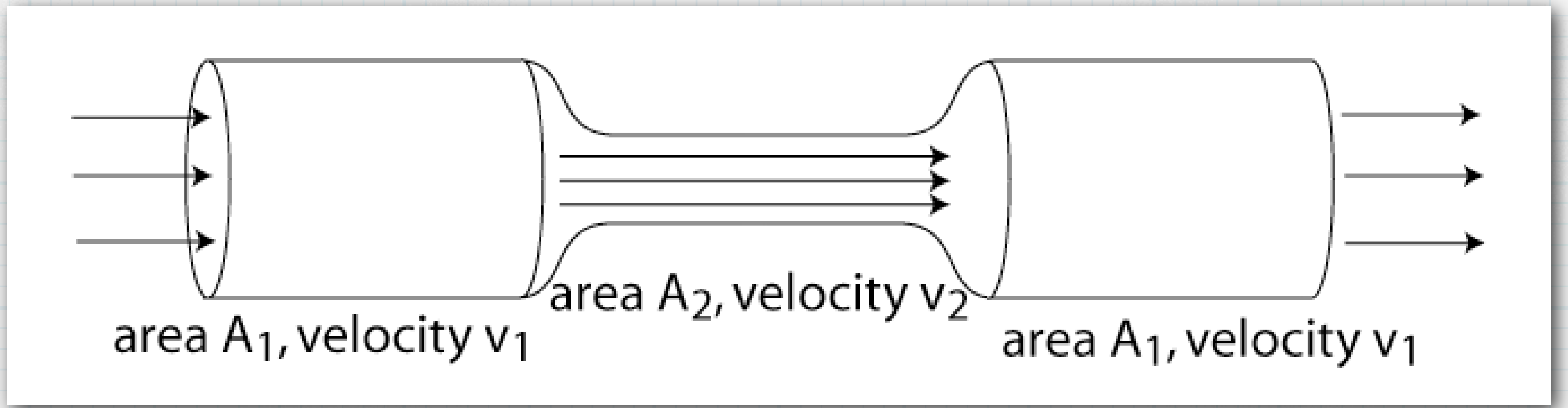
current I

= volume/time

= area x velocity

Venturi Tube (1)

- a venturi is simply a tube with a restriction:



- since current I = Av is constant, $A_1v_1=A_2v_2$

continuity equation
is always obeyed...
unless there is a leak!

Fluid Energy

- moving fluid has kinetic energy
- moving fluid has changes in potential energy
- energy density in fluid = energy/volume
- pressurization takes energy too!

kinetic energy density	potential energy density	pressure energy density
$1/2\ \rho v^2$	$\rho g h$	P

Bernoulli's Principle

- "The energy density in a fluid in equilibrium is the same everywhere."
- We express this in the form of Bernoulli's Equation:

$$P + \rho g h + \frac{1}{2}\rho v^2 = constant$$

or, comparing two points in a fluid path:

$$\Delta P + \Delta(\rho g h) + \Delta(\frac{1}{2}\rho v^2) = 0$$

Pressure - PRS

- Which statement is false about pressure?

a. The pressure at a certain depth depends on the density of the liquid.

b. Pressure has the units N/m^2

c. At a certain point in a fluid, the pressure depends on what direction you measure it in (up, down, left, right, etc.)

d. As you go deeper in a liquid, the pressure increases.

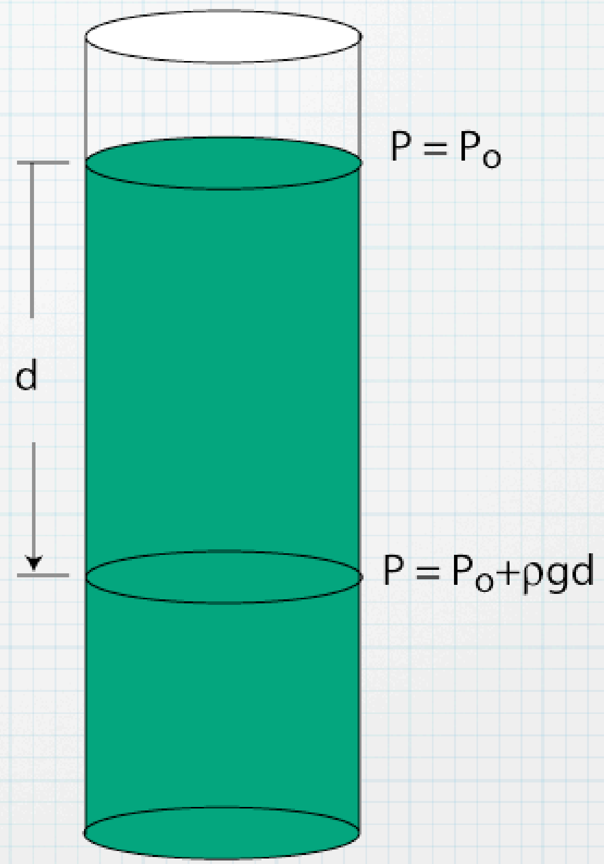
e. Pressure cannot be negative.

Pressure vs. Depth

- for a static column of fluid we can see that Bernoulii's equation works:

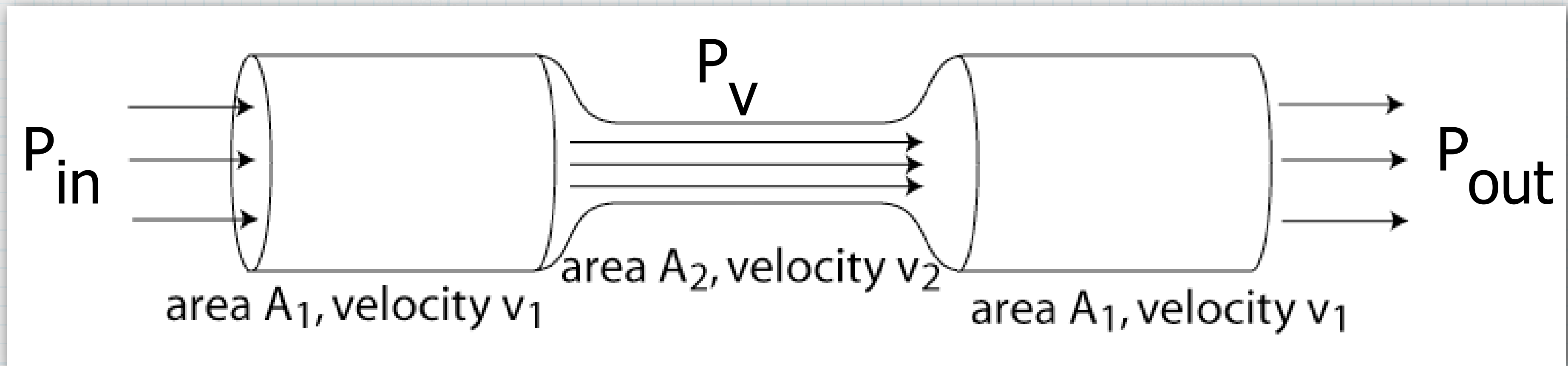
$$\Delta P + \Delta(\rho g h) = 0$$

$$\Rightarrow P - P_o = \rho g d$$



Venturi Tube

- what is the pressure in the venturi tube restriction?



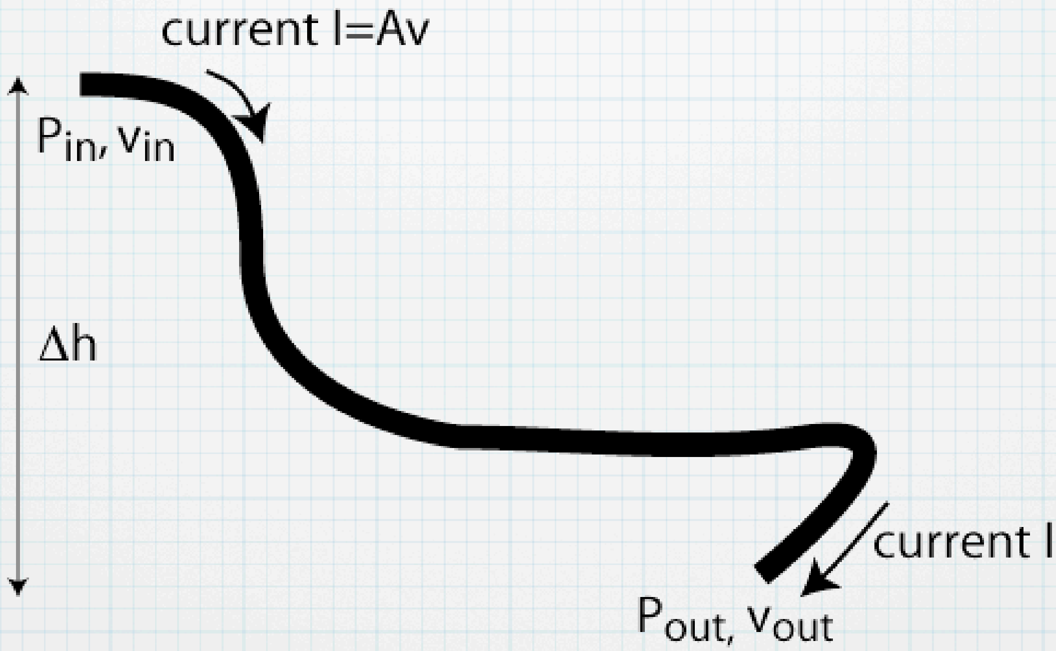
- $P_{out} = P_{in}$ by Bernoulli equation; $P_v < P_{in}$:

$$P_v - P_{in} = -\Delta(\rho g h) - \Delta(\frac{1}{2}\rho v^2)$$

$$P_v - P_{in} = -\frac{1}{2}[v_2^2 - v_1^2]$$

Pressure in Fluid "Circuit"

- consider portion of a fluid circuit; where is pressure the greatest?

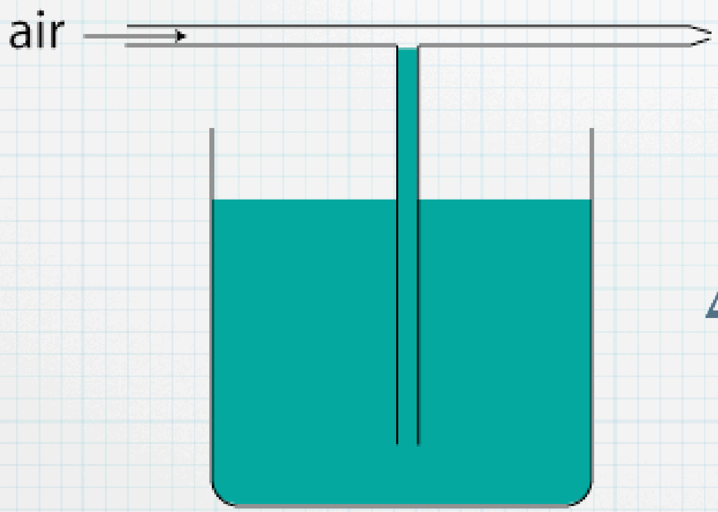


$$\text{out} - \text{in}: \quad \Delta P - \rho g \Delta h = 0$$

$$\Rightarrow P_{out} > P_{in}$$

Atomizer

- atomizer works because high velocity air has lower pressure than atmospheric:

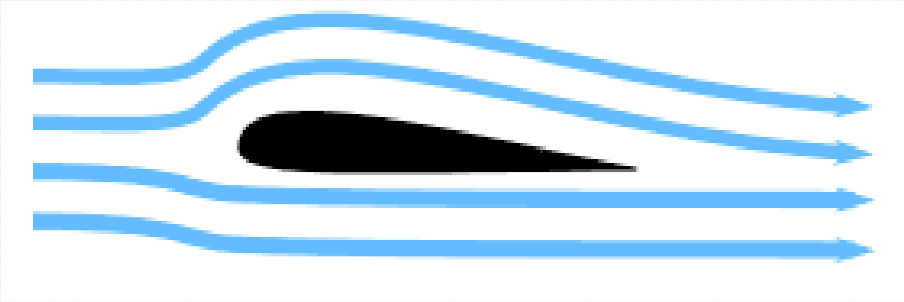


$$\Delta P + \Delta(\frac{1}{2}\rho v^2) = 0$$

(Here we approximate air as incompressible...)

Airfoil?

- How can airplanes fly? Usually Bernoulli is invoked:



- "Air pressure less on top where flow is faster"
- False! Detailed analysis reveals this airfoil has no lift.

Airfoil?

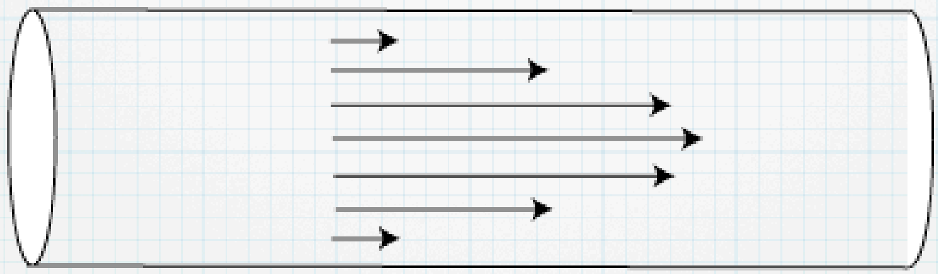
- A better depiction of a real airfoil in action:

Not always easy to understand Bernoulli effect...still want to get in an airplane?

(It's the angle of attack that matters.)

Fluid Resistance

- in real pipes, fluid flows more slowly next to walls:



- there is a resistance R leading to energy loss in pipe wall
- energy lost ΔE_{th} is proportional to current I:

$\Delta E_{th}/vol = IR$

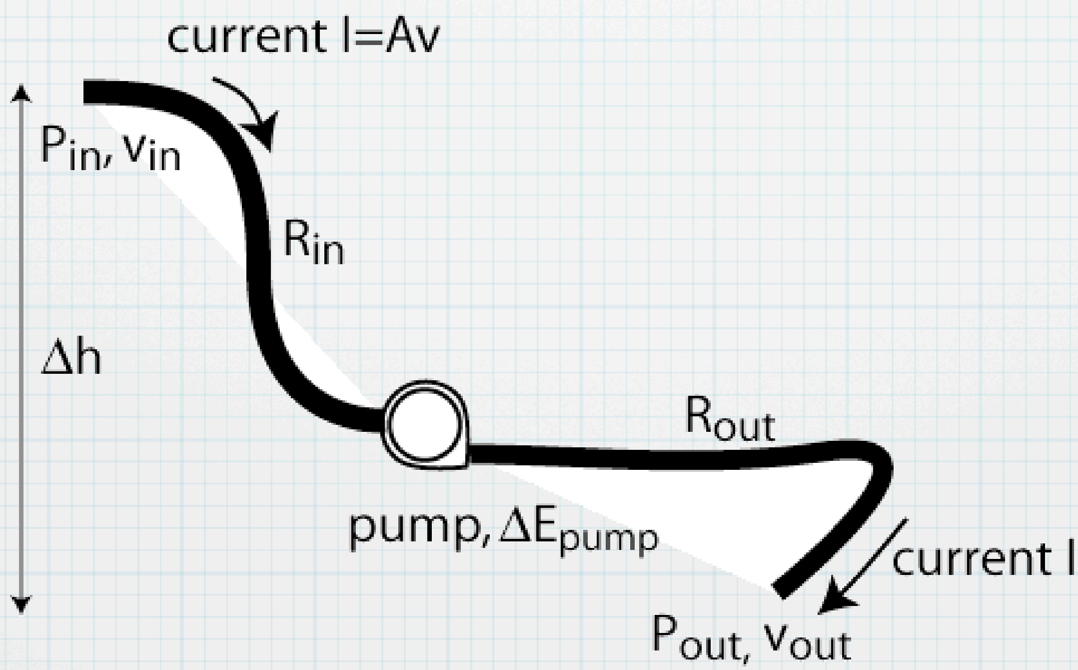
Pumps

- placing a pump in a fluid circuit can change pressure
- flow rate into pump = flow rate out of pump!
- it takes a certain amount of energy per unit volume to do this: ΔE_{pump}
- need to have extra term in Bernoulli's equation

"Extended" Bernoulli Eqn.

- adding the dissipative terms and pumps we have

$$\Delta P + \Delta(\rho g h) + \Delta(\frac{1}{2}\rho v^2) = \frac{\Delta E_{pump}}{vol} - IR$$



Bernoulli - PRS

For P_{out} to equal P_{in} we must have that

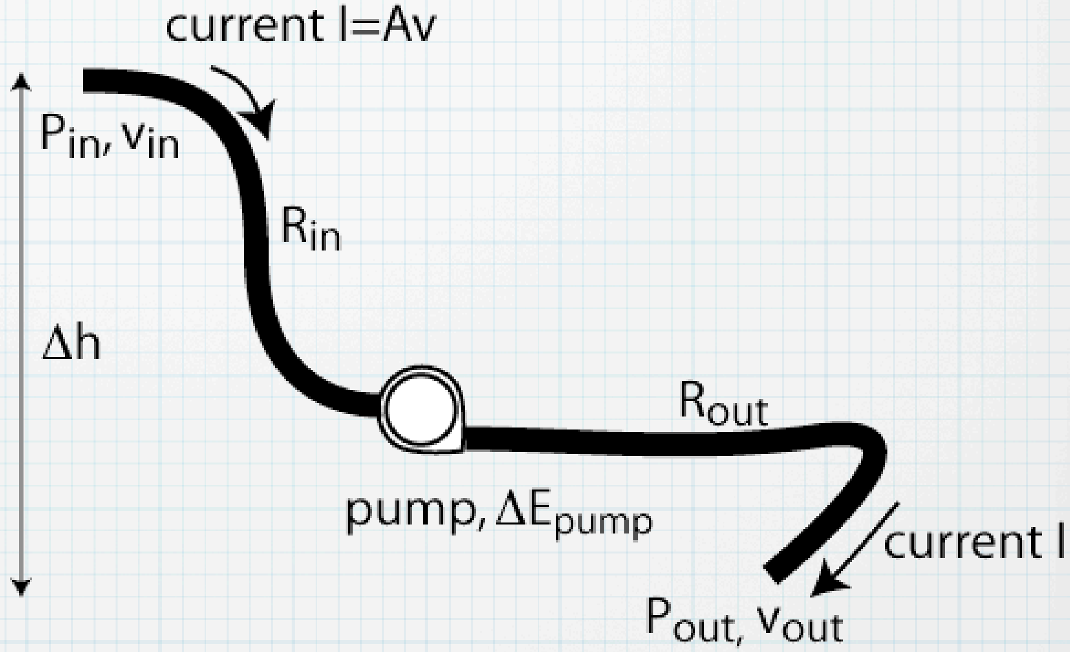
A. the total resistance is greater than the effect of the pump

B. the pump is off

C. must have no resistance

D. the pump plus the change in height balances the resistance

E. can't have $P_{out} = P_{in}$



For Next Week...

- study those block notes!
- go back over this lecture
- get ready for applying these ideas to electric circuits!