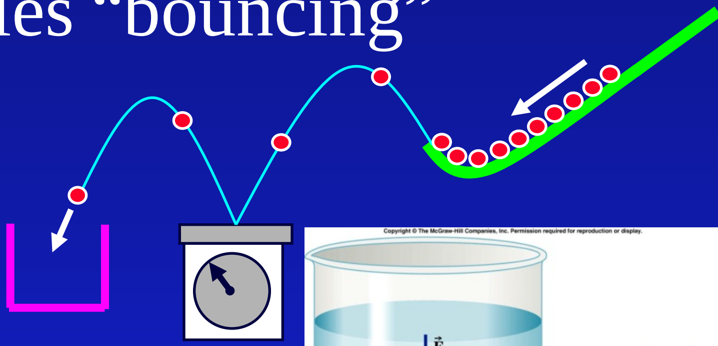
Exam III

Physics 101: Lecture 18
Fluids II

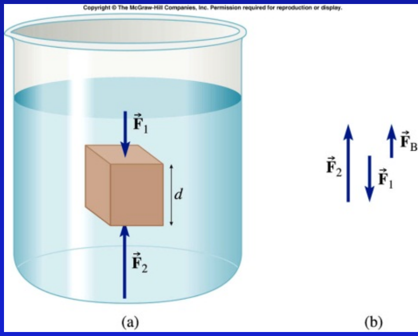
Textbook Sections 9.6 – 9.8

Review Static Fluids

- Pressure is force exerted by molecules "bouncing" off container $P = F/A$



- Gravity/weight effects pressure
  ➔ $P = P_0 + \rho g d$



- Buoyant force is "weight" of displaced fluid.
  ➔ $F = \rho\ g\ V$

Today include moving fluids!

$$A_1 v_1 = A_2\ v_2$$

$$P_1 + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho v_2^2$$

Pressure and Depth

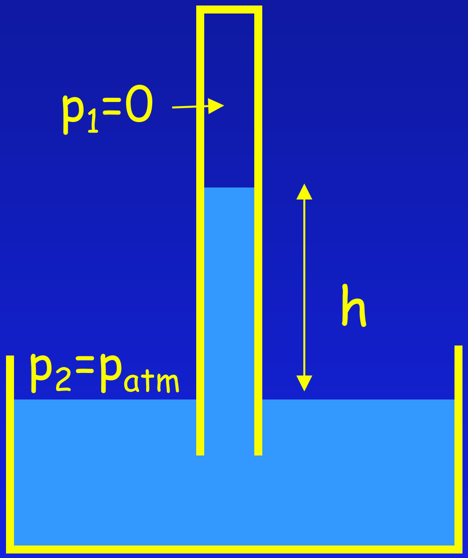
Barometer: a way to measure atmospheric pressure

For **non-moving** fluids, pressure depends only on depth.

$p_2 = p_1 + \rho g h$

$P_{atm} = 0 + \rho g h$

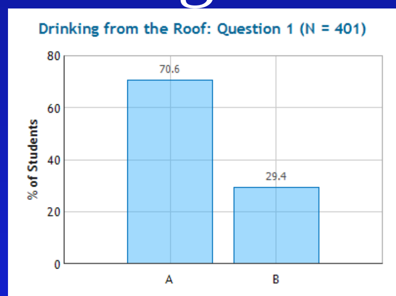
Measure h, determine p_{atm}

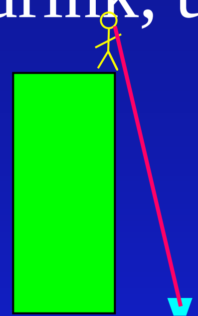


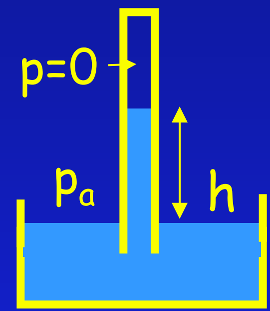
Checkpoint

Is it possible to stand on the roof of a five story (50 foot) tall house and drink, using a straw, from a glass on the ground?

1. No
2. Yes







$P_a = \rho g h$ $\qquad$ $h = \dfrac{P_a}{\rho g}$

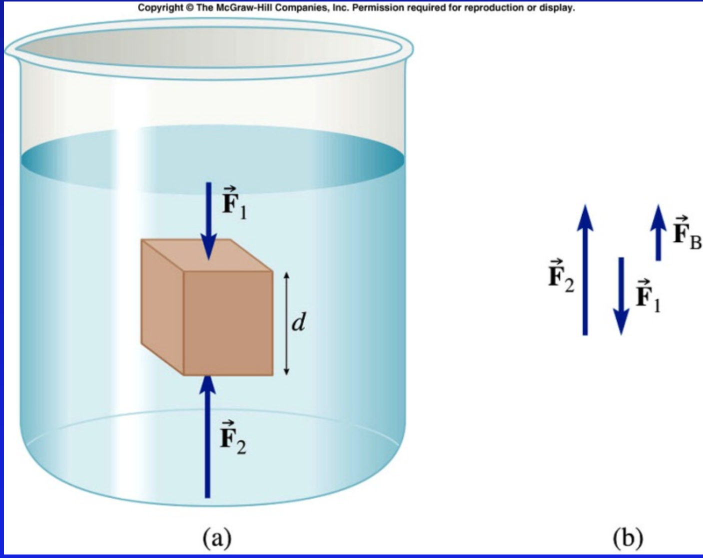
The atmospheric pressure applied to the liquid will only be able to lift the liquid to a limited height no matter how hard you suck on the straw.

Certainly trees have developed some mechanism to transport water from ground level, through their vascular tissues, and to their leaves (which can be higher that 50 feet)

[demo]

Archimedes' Principle

- Determine force of fluid on immersed cube
  - ➔ Draw FBD
    - » $F_B = F_2 - F_1$
    - » $= P_2 A - P_1 A$
    - » $= (P_2 - P_1)A$
    - » $= \rho g d A$
    - » $= \rho g V$
    - » $= (M_{fluid}/V) g V$
    - » $= M_{fluid} g$



- Buoyant force is weight of displaced fluid!

Archimedes' Principle

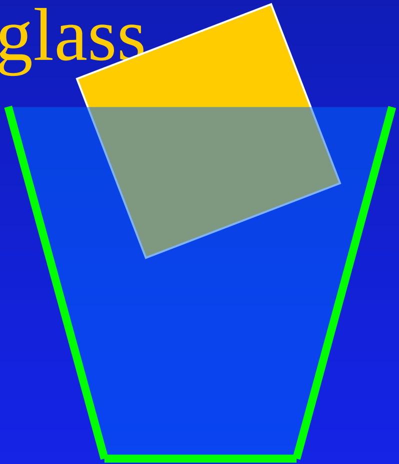
- Buoyant Force (F_B)
  - ➔ weight of fluid displaced
  - ➔ $F_B = \rho_{fluid} V_{displaced}\, g$
  - ➔ $F_g = mg = \rho_{object} V_{object}\, g$
  - ➔ object sinks if $\rho_{object} > \rho_{fluid}$
  - ➔ object floats if $\rho_{object} < \rho_{fluid}$

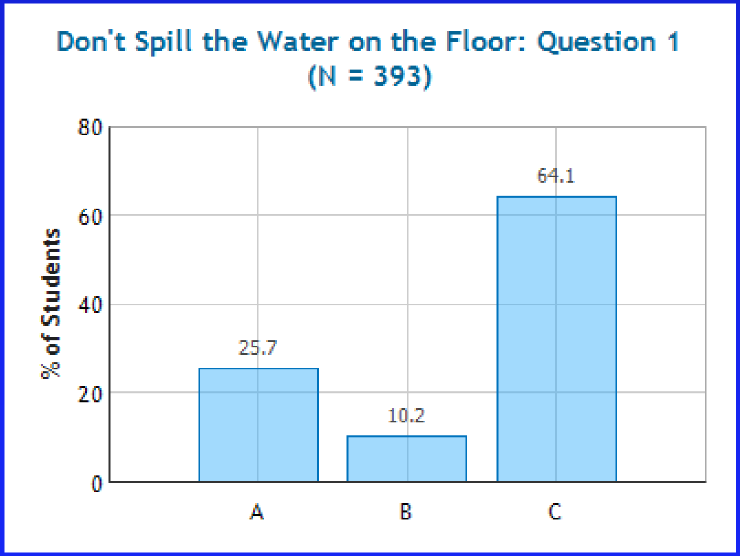
- If object floats…
  - ➔ $F_B = F_g$
  - ➔ Therefore: $\rho_{fluid}\, g\, Vol_{displ.} = \rho_{object}\, g\, Vol_{object}$
  - ➔ Therefore: $Vol_{displ.}/Vol_{object} = \rho_{object} / \rho_{fluid}$

Checkpoint Q1

Suppose you float a large ice-cube in a glass of water, and that after you place the ice in the glass the level of the water is at the very brim. When the ice melts, the level of the water in the glass will:

1. Go up, causing the water to spill out of the glass.
2. Go down.
3. Stay the same. ← CORRECT





$F_B = \rho_W \, g \, Vol_{displaced}$

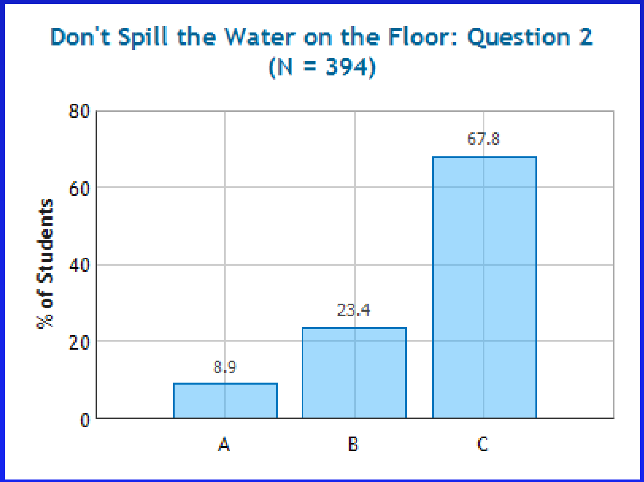
$W = \rho_{ice} \, g \, Vol_{ice} \rightarrow \rho_W \, g \, Vol_{melted\_ice}$

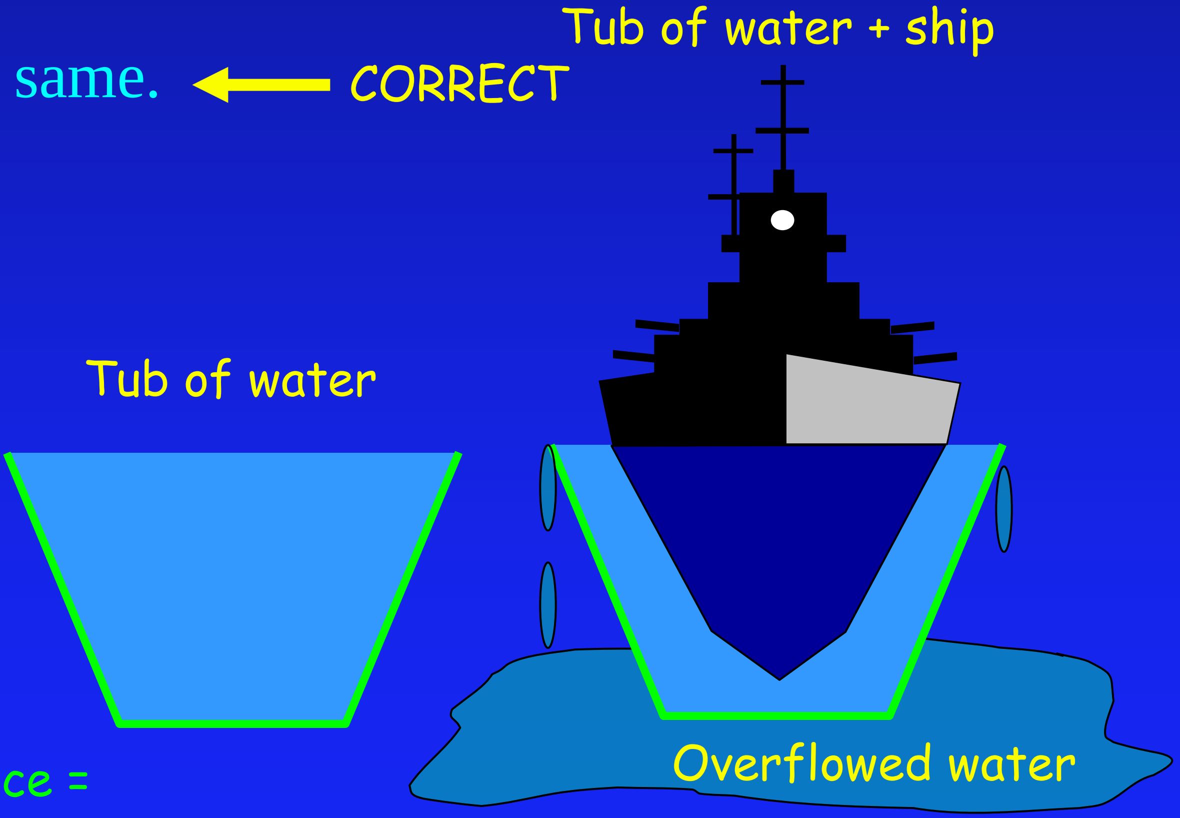
$Vol_{displaced} = Vol_{melted\_ice}$

Checkpoint Q2

Which weighs more:

1. A large bathtub filled to the brim with water.
2. A large bathtub filled to the brim with water with a battle-ship floating in it.
3. They will weigh the same. ← CORRECT

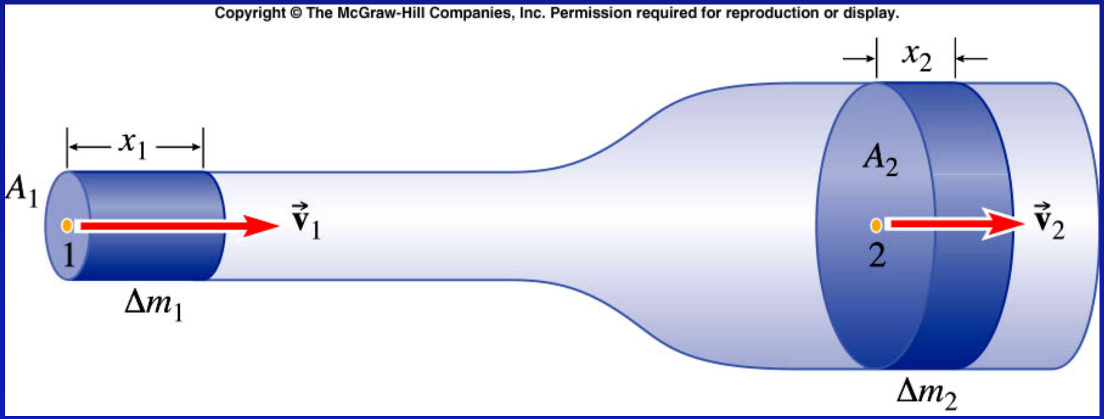




Weight of ship = Buoyant force =

Weight of displaced water

Flowing Fluids and Continuity



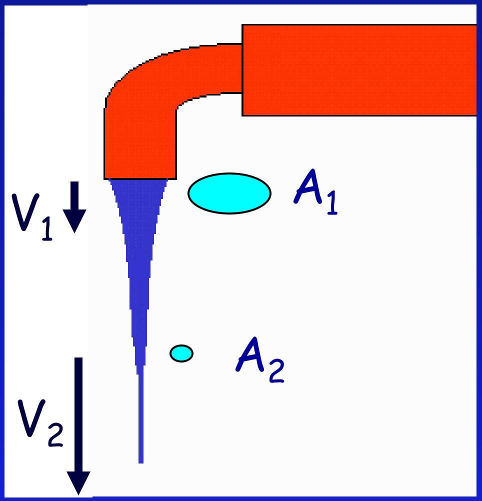
- Watch "plug" of fluid moving through the narrow part of the tube (A_1)
  - Distance fluid moves in time Δt: $x_1 = v_1 \Delta t$
  - Mass of fluid in "plug" $m_1 = \rho V_1 = \rho A_1 x_1$ or $m_1 = \rho A_1 v_1 \Delta t$
- Watch "plug" of fluid moving through the wide part of the tube (A_2)
  - Distance fluid moves in time Δt: $x_2 = v_2 \Delta t$
  - Mass of fluid in "plug" $m_2 = \rho V_2 = \rho A_2 x_2$ or $m_2 = \rho A_2 v_2 \Delta t$
- Continuity Equation says $m_1 = m_2$: "What goes in must come out"

$$\boxed{\bullet A_1 v_1 = A_2 v_2}$$

Faucet Prelecture

A stream of water gets narrower as it falls from a faucet (try it & see).

Explain this phenomenon using the equation of continuity



As the water flows down, gravity makes the velocity of the water go faster so the area of the water decreases.

Because it scared of the dirty dishes in the sink.

wow it does!

My faucet does not act this way

$A_1 v_1 = A_2 v_2$

$A_2 = A_1 (v_1/v_2)$

Pressure, Flow and Work

- Continuity Equation says fluid speeds up going to smaller opening, slows down going to larger opening
  - ➔ $A_1 v_1 = A_2 v_2$
  - ➔ $v_2 = v_1(A_1/A_2)$
- Acceleration due to change in pressure. $P_1 > P_2$

Demo ➔ Smaller tube has faster water and LOWER pressure

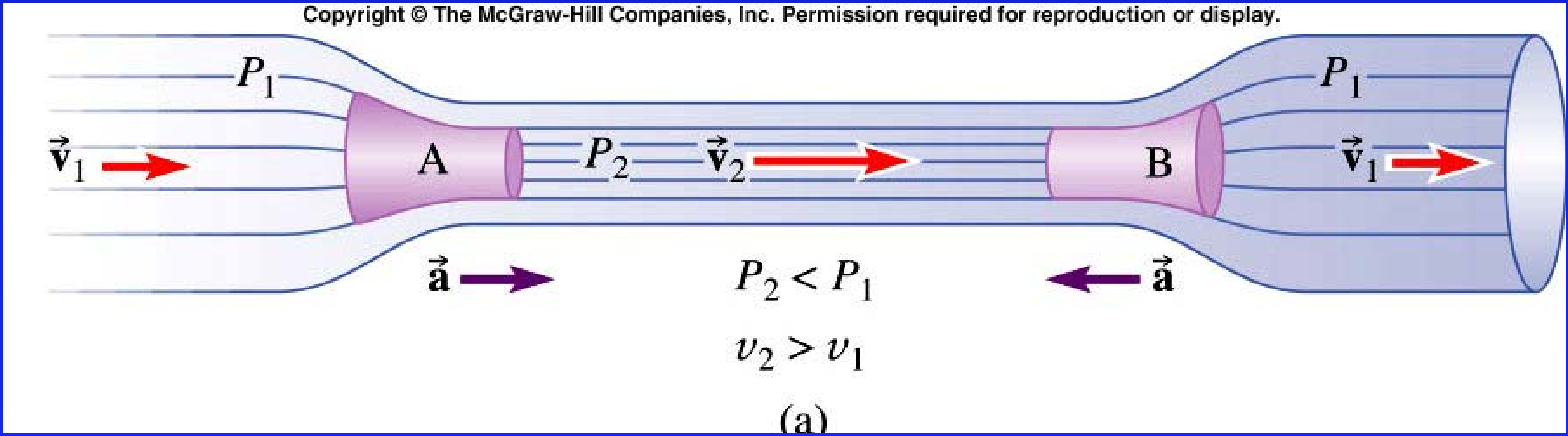
- Change in pressure does work!
  - ➔ $W = (P_1 - P_2)V$

Recall:

$W=F\ d$

$= PA\ d$

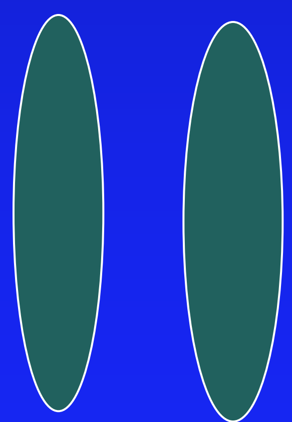
$= P\ V$



Pressure ACT

- What will happen when I "blow" air between the two plates?

A) Move Apart　B) Come Together　C) Nothing



Bernoulli's Eqs. And Work

- Consider tube where both Area, height change.
  - ➔ $W = \Delta K + \Delta U$

$$(P_1 - P_2)\, V = \tfrac{1}{2}\, m\, (v_2^2 - v_1^2) + mg(y_2 - y_1)$$

$$(P_1 - P_2)\, V = \tfrac{1}{2}\, \rho V\, (v_2^2 - v_1^2) + \rho V g(y_2 - y_1)$$

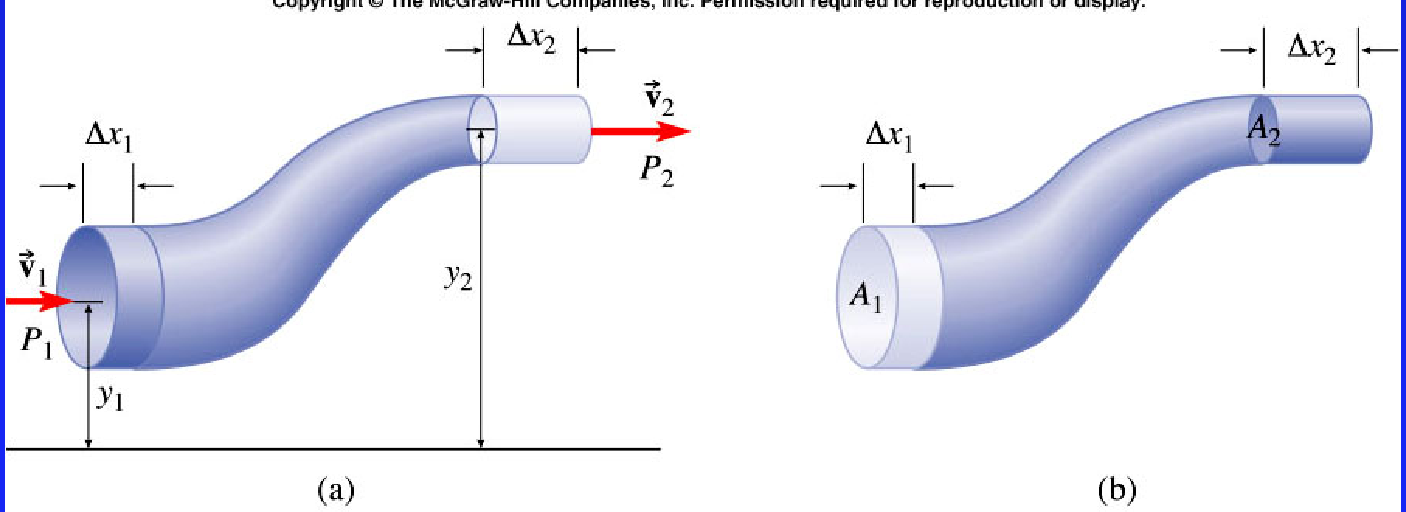
$$\boxed{P_1 + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho v_2^2}$$

Note:

$W = F\, d$

$= PA\, d$

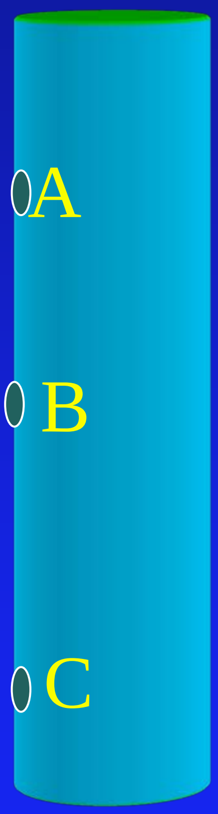
$= P\, V$



Bernoulli ACT

- Through which hole will the water come out fastest?

Compare inside ($P_1 = \rho g h$, $v_1 \sim 0$) and outside ($P_2 = P_{atm}$) tube



INSIDE	OUTSIDE

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

$$\rho g h + \rho g y_1 + 0 = P_{atm} + \rho g y_1 + \frac{1}{2}\rho v_2^2$$

$$\rho g h = P_{atm} + \frac{1}{2}\rho v_2^2$$

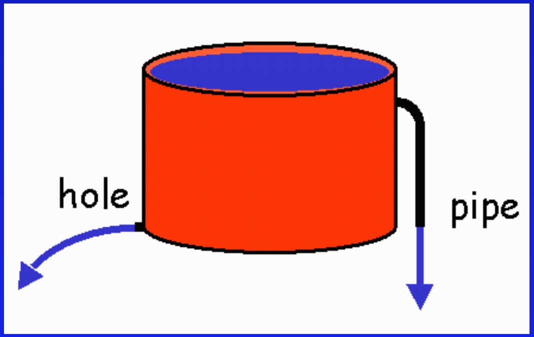
$$\boxed{v_2 = \mathrm{sqrt}[2(gh - P_{atm}/\rho)]}$$

Greater depth h gives larger v. Hole C is fastest!

Act

A large bucket full of water has two drains. One is a hole in the side of the bucket at the bottom, and the other is a pipe coming out of the bucket near the top, which bent is downward such that the bottom of this pipe even with the other hole, like in the picture below:

Though which drain is the water spraying out with the highest speed?



1. The hole
2. The pipe
3. Same ← CORRECT

Both are exiting at the same height!

Lift a House

Calculate the net lift on a 15 m x 15 m house when a 30 m/s wind (1.29 kg/m^3) blows over the top.

$P_1+\rho g y_1 + ½ \rho v_1^2 = P_2+\rho g y_2 + ½\rho v_2^2$

$P_1 - P_2 = ½ \rho (v_2^2 - v_1^2)$

$= ½ \rho (v_2^2 - v_1^2)$

$= ½ (1.29) (30^2) \text{ N / m}^2$

$= 581 \text{ N/ m}^2$

$F = P A$

$= 581 \text{ N/ m}^2 (15 \text{ m})(15 \text{ m}) = 131{,}000 \text{ N}$

= 29,000 pounds! (note roof weighs 15,000 lbs)

Example (like HW)

A garden hose w/ inner diameter 2 cm, carries water at 2.0 m/s. To spray your friend, you place your thumb over the nozzle giving an effective opening diameter of 0.5 cm. What is the speed of the water exiting the hose? What is the pressure difference between inside the hose and outside?

Continuity Equation

$$A_1\, v_1 = A_2\, v_2$$

$$v_2 = v_1\, (A_1/A_2)$$

$$= v_1\, (\pi\, r_1^2 / \pi\, r_2^2)$$

$$= 2 \text{ m/s} \times 16 = 32 \text{ m/s}$$

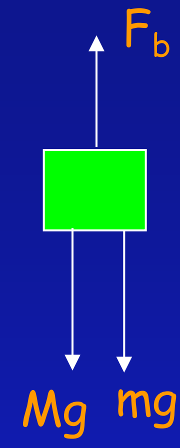
Bernoulli Equation

$$P_1 + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho v_2^2$$

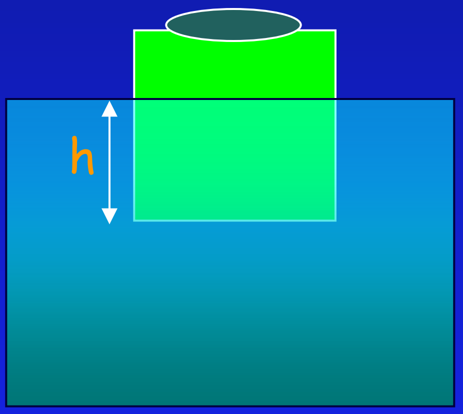
$$P_1 - P_2 = \tfrac{1}{2}\rho\, (v_2^2 - v_1^2)$$

$$= \tfrac{1}{2} \times (1000 \text{ kg/m}^3)\,(1020 \text{ m}^2/\text{s}^2) = 5.1\text{x}10^5 \text{ PA}$$

Archimedes Example



A cube of plastic 4.0 cm on a side with density = 0.8 g/cm^3 is floating in the water. When a 9 gram coin is placed on the block, how much does it sink below the water surface?



$F_{Net} = m\ a$

$F_b - Mg - mg = 0$

$\rho\ g\ V_{disp} = (M+m)\ g$

$V_{disp} = (M+m) / \rho$

$h\ A = (M+m) / \rho$

$h = (M + m)/ (\rho\ A)$

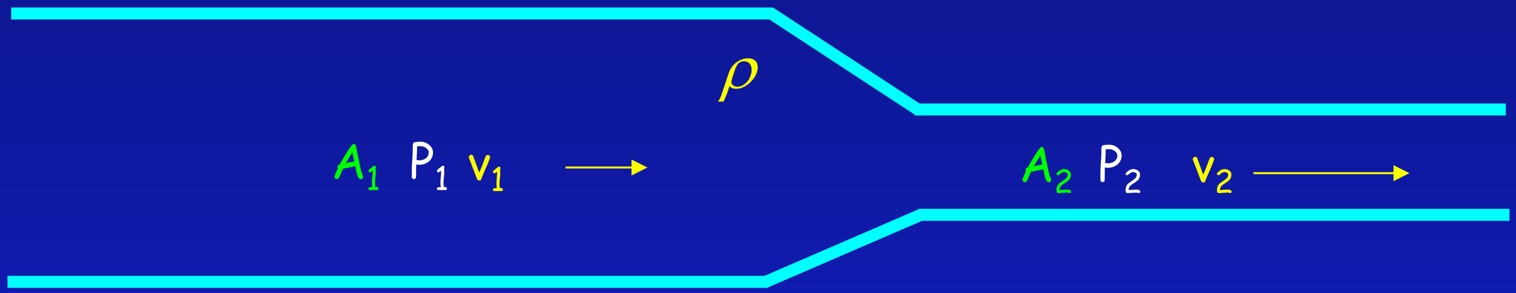
$= (51.2+9)/(1 \times 4 \times 4) = 3.76$ cm

$M = \rho_{plastic}\ V_{cube}$

$= 4 \times 4 \times 4 \times 0.8$

$= 51.2$ g

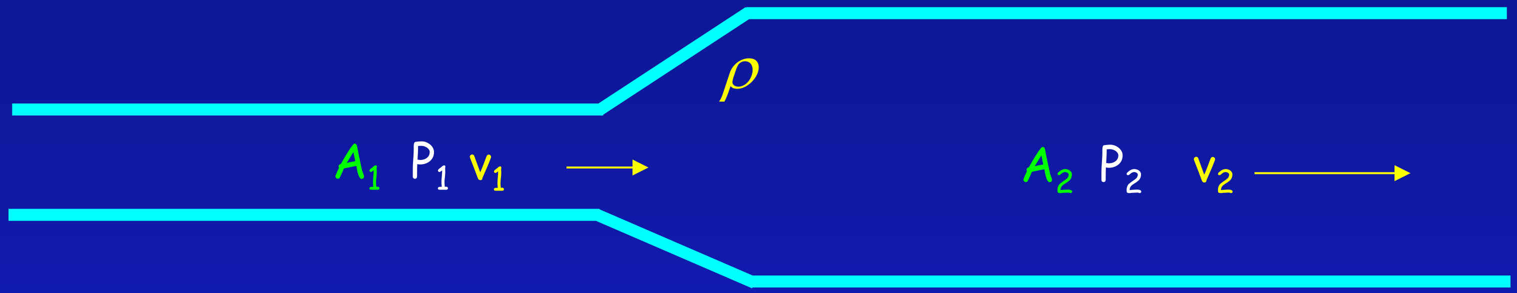
Fluid Flow Summary



- Mass flow rate: ρAv (kg/s)
- Volume flow rate: Av (m^3/s)
- Continuity: $\rho A_1 v_1 = \rho A_2 v_2$
- Bernoulli: $P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$

- Good luck on the exam!

Fluid Flow Concepts



- Mass flow rate: $\rho A v$ (kg/s)
- Volume flow rate: Av (m^3/s)
- Continuity: $\rho A_1 v_1 = \rho A_2 v_2$

  i.e., mass flow rate the same everywhere

  e.g., flow of river