Announcements – Tues 5 Nov 2013

1. Exam 3 (median)
   a. Results: average = 64 → $\boxed{\text{10 pt curve!}}$
   b. Exams should be returned Wed afternoon
   c. Solutions will also be posted on Wed afternoon

2. We're on the home stretch! Topics remaining:
   a. Fluid motion (today)
   b. Heat & calorimetry (2 lectures)
   c. Basic thermodynamics & engines (2 lectures)
   --then Exam 4--
   d. Waves & sound (3½ lectures)

3. The power of viscosity:
   http://www.youtube.com/watch?v=W3YZ5veN_Bg

HW due Thurs → last problem hint on Digital Dialog

Archimedes Principle Review

When an object is in a fluid, the fluid itself helps support some of the object's weight. This buoyant force is equal to the weight of the fluid that would otherwise occupy that volume:

$$\boxed{\begin{aligned} F_B &= m_{displaced\ fluid} \times g \\ &= \rho_{fluid} V_{object} g \end{aligned}}$$

Clicker quiz 1: A cannonball is put in a boat. The boat sinks down to displace more water. The amount of new water displaced is

a. a volume of water that weighs **more than** the cannonball
b. a volume of water that weighs **as much as** the cannonball
c. a volume of water that weighs **less than** the cannonball

Clicker quiz 2: If the cannonball now falls from the boat into the water and sits on the bottom of the lake, the amount of water displaced by the cannon ball is

a. a volume of water that weighs **more than** the cannonball
b. a volume of water that weighs **as much as** the cannonball
c. a volume of water that weighs **less than** the cannonball

From last warmup (do as clicker quiz): Therefore…if the cannonball falls from the boat into the water and sits on the bottom of the lake, will the overall water level of the lake rise, fall or stay the same? (compared to when the cannonball was in the boat)

a. rise
b. fall
c. stay the same

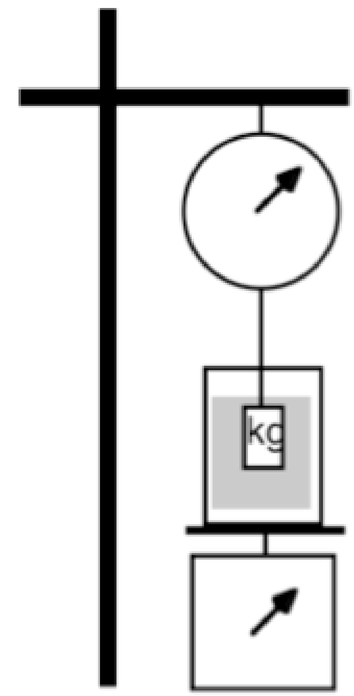
Problem-Solving Tip: Limiting Cases

What happens if the cannonball has a very large density?

What happens if the cannonball has a very small density?

Demo

Hanging mass is submerged



Clicker quiz 1: In the demo, what will happen to the *upper* scale when the mass is submerged

?. a. scale reading increases
b. scale reading decreases
c. nothing changes

Clicker quiz 2: In the demo, what will happen to the *lower* scale when the mass is submerged

?. a. scale reading increases
b. scale reading decreases
?. c. nothing changes

Do the experiment!

Today’s topic: moving fluids

Disclaimer: **viscosity** exists → ***Viscosity***: ***friction*** in fluids

Friction cases a loss in pressure along the tube as fluid flows.

Friction effects depend on radius:
bigger effects if radius is smaller

Friction effects depend on length:
bigger effects if length is longer

The power of viscosity (watch on your own):
http://www.youtube.com/watch?v=W3YZ5veN_Bg

That being said, we’ll now ignore all viscosity effects…
…assume “frictionless fluids” unless otherwise stated

Bernoulli effect

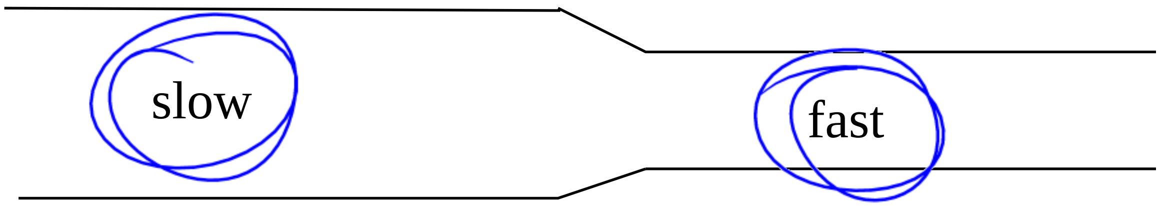
The pressure in a fluid changes with the s~~peed~~ of the fluid.

One way to change speed: change the area

→ think garden hoses

Demo

Bernouilli effect in glass tube with varying diameter



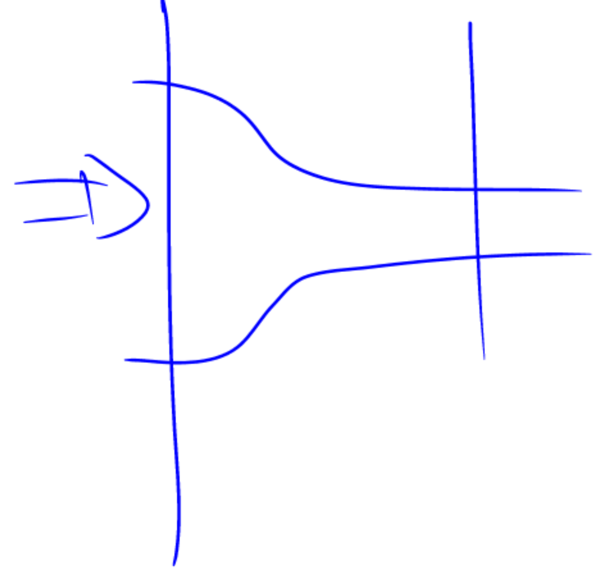
Result of demo: Where is pressure the largest? slow!

Disclaimer 1: This pressure change is **on top** of pressure lost from viscosity effects.

Disclaimer 2: What this *doesn't* mean (i.e. must compare speed in same overall flow)

Detour: fluid speeds

Volume flow rate: m^3/sec past any point



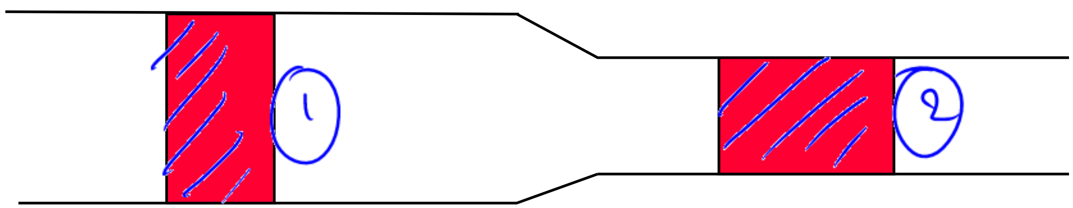
$$VFR = \frac{\Delta Volume}{\Delta t} = \frac{Area\ \Delta x}{\Delta t} = A \cdot v$$

Assume:

- No viscosity (friction)
- Incompressible (constant density) – *not true for gases*
- No turbulence

Then…

Conservation of Mass → Conservation of Volume Flow

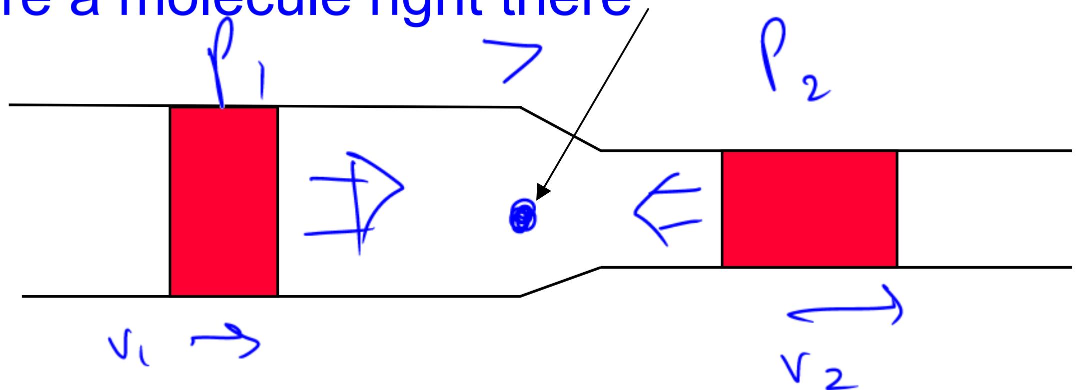


"Garden Hose Equation": $\boxed{A_1 v_1 = A_2 v_2}$ Only if no density change!

Book: "Equation of Continuity"

Why does the pressure depend on speed?

View #1: If you're a molecule right there



in what direction is the net force?

$\longrightarrow$

a

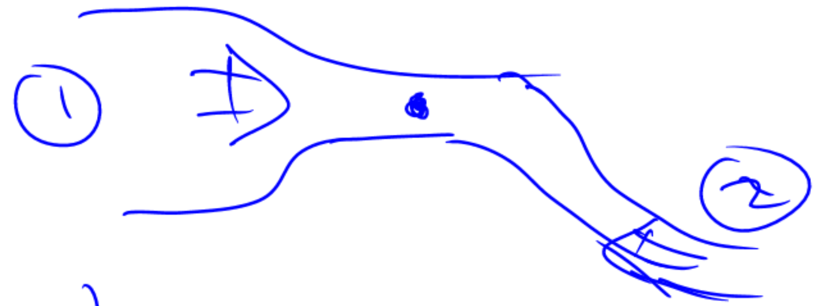
$\longrightarrow$

F

View #2: Energy & work, per volume

$$P = \frac{F}{A}$$

$$F = P \cdot A$$



$$E_1 + W = E_2$$

$$KE_1 + PE_1 + (F_1 - F_2)\cdot x = KE_2 + PE_2$$

$$P_1 A_1 x_1 - P_2 A_2 x_2$$

$$\frac{\frac{1}{2} m v_1^2}{V} + \frac{mgh_1}{V} + (P_1 - P_2)\frac{\cancel{V}}{\cancel{V}} = \frac{\frac{1}{2} m v_2^2}{V} + \frac{mgh_2}{V}$$

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 + P_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2 + P_2$$

if inc.

must dec.

“Bernoulli’s equation”

$$\boxed{P_1 + \frac{1}{2}\rho {v_1}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho {v_2}^2 + \rho g h_2}$$

Another blueprint!

From warmup: In the reading assignment for today, Ralph noticed two different equations labeled "Bernoulli's Equation". One said,

"$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$";

the other said, "$P + \frac{1}{2}\rho v^2 + \rho g h = C$".

He wants to know how they can both be the same equation when they look so different. And what does C stand for, anyway? What can you tell him?

"Pair share"–I am now ready to share my neighbor's answer if called on.

a. Yes

Review

From warmup: Water flows from a pipe with large diameter into a pipe with smaller diameter. The speed of the water in the small tube is:

a. greater than
b. less than
c. equal to

the speed in the large tube

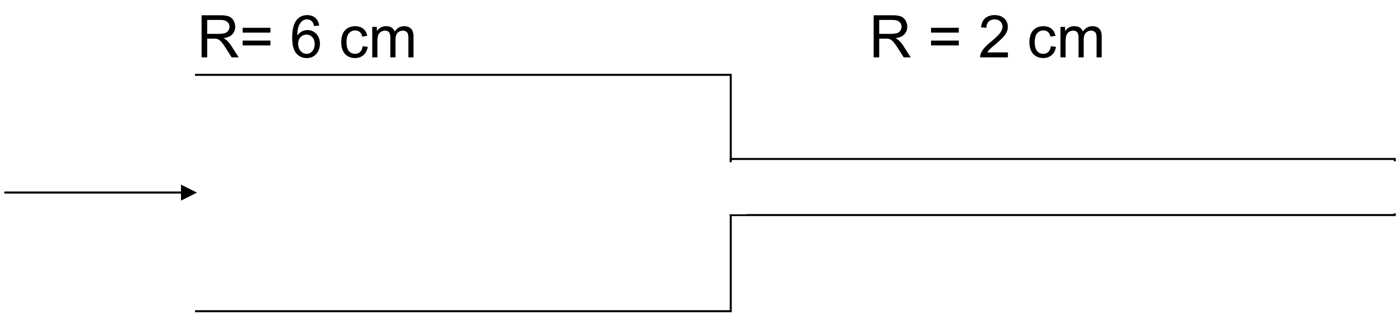
From warmup: Same situation. The pressure in the small tube is

a. greater than
b. less than
c. equal to

the pressure in the large tube

Worked Problem

Water flows from the big pipe into the little pipe. Ignore any friction or height change.



Clicker quiz: The volume flow rate on the right is _______ on the left.

a. greater than
b. same as
c. less than

$$VFR = A \cdot v$$

If the speed on the left is 1 m/s, what's the speed on the right?

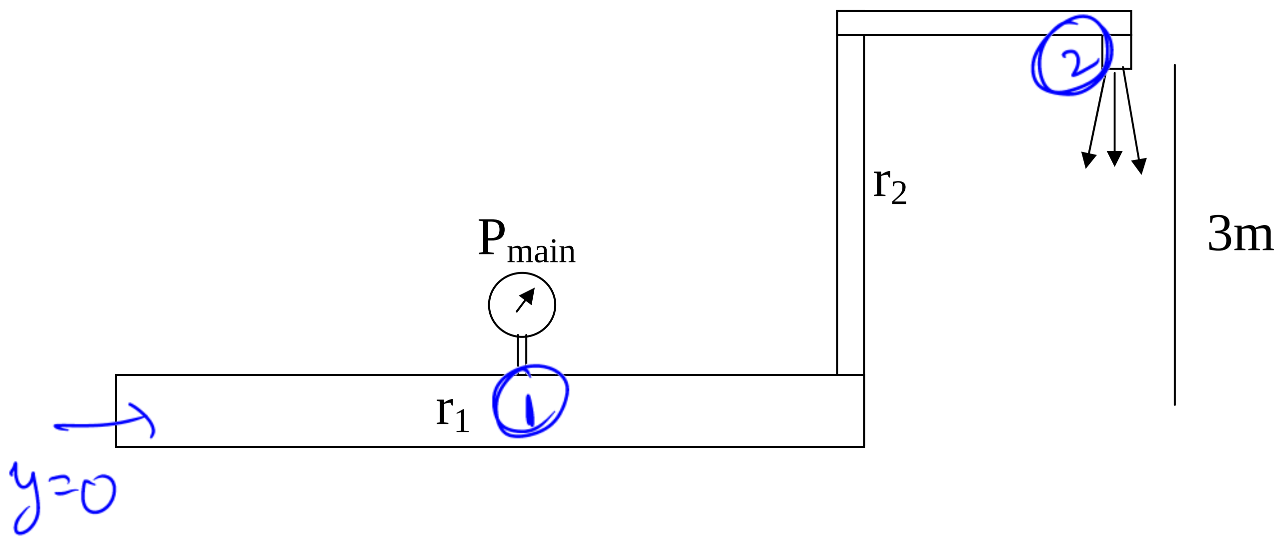
$$A_1 v_1 = A_2 v_2$$

$$v_2 = v_1 \cdot \frac{A_1}{A_2} = \left(1\,\frac{m}{s}\right) \frac{\cancel{\pi}(6\,\cancel{cm})^2}{\cancel{\pi}(2\,\cancel{cm})^2}$$

$$= \boxed{9\,m/s}$$

Answer: $\cancel{1/9}$ m/s

Worked Problem



$VFR = \frac{.015\ m^3}{60\ s}$

The faucet of radius $r_2 = 2$ cm puts water out at 15 liters/minute. The pressure at the opening of the faucet is about 1 atm. The water main ($r_1 = 6$ cm), is 3 meters below the faucet

a. What is the speed of the water in the narrow pipe? Wide pipe?
b. What is the pressure in the water main?

a. $VFR = A \cdot v \longrightarrow$ $v_1 = \frac{.015\ m^3 / 60\ s}{\pi (.06\ m)^2} = \boxed{.022\ m/s}$

$v_2 = \frac{.015\ m^3 / 60\ s}{\pi (.02\ m)^2} = \boxed{.199\ m/s}$

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 + \cancel{(1000)(9.8)(0)} + \frac{1}{2}(1000)(.022)^2 = (1.01\cdot10^5\ \text{Pa}) + (1000)(9.8)(3) + \frac{1}{2}(1000)(.199)^2$$

$$P_1 = \boxed{1.304\cdot10^5\ \text{Pa}}$$

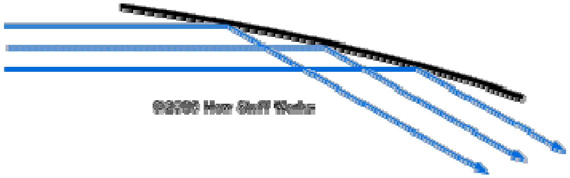
Answers: 0.199 m/s, 1.304×10^5 Pa

The Bernoulli effect – what good is it?

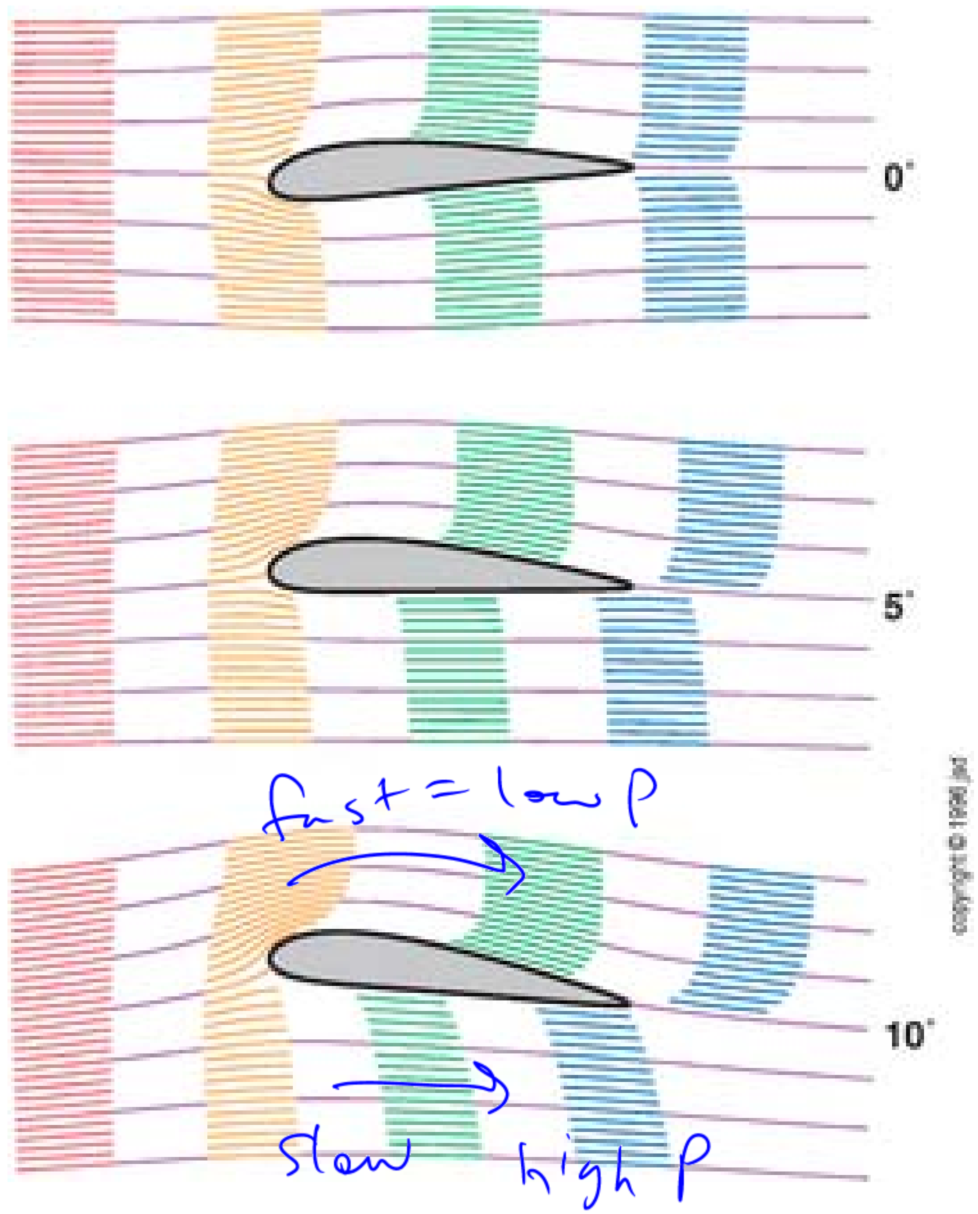
Demos: Blowing on paper, Ball over blower, Venturi blower, funnel, metal plate and wood cylinder
Video: Elder Nelson, April 1997 General Conference (1:58 - 3:45)

Airplane wings, and sails, and other "airfoils" (even racecars!)

Principle 1: air deflection, aka "put hand out the window" effect



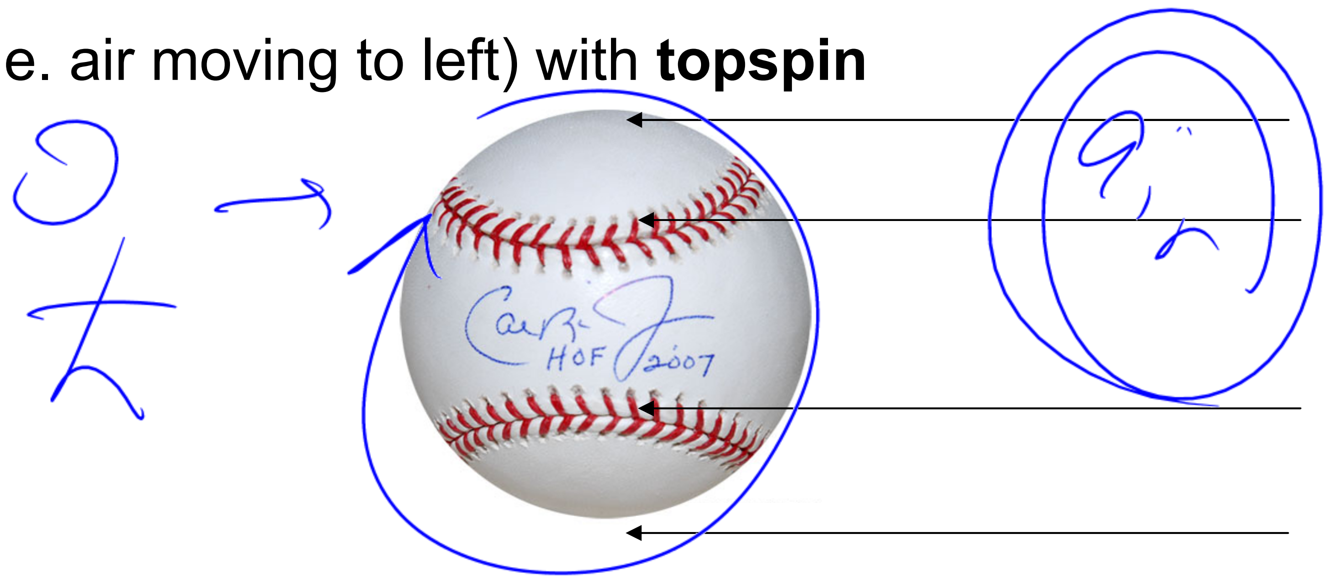
Principle 2: Bernoulli



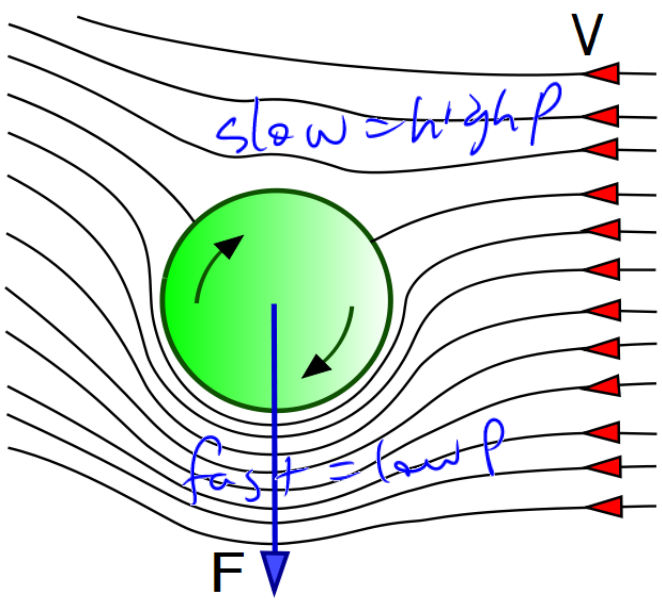
http://www.av8n.com/how/htm/airfoils.html#toc4

Curve balls

ball moving to the right (i.e. air moving to left) with **topspin**



1. Bernoulli



2. Air deflection?

From warmup

A ping pong player puts "topspin" on the ball as he hits it to you by causing it to rotate such that the top of the ball is spinning towards you. Where will the ball strike the table compared to if it were not spinning?

a. closer to you
b. farther from you
c. same distance

Clicker quiz

your right side

A ball is thrown toward you, spinning so that the right side of the ball spins toward you, and the left side away. The ball will

a. “float” more than a nonspinning ball
b. “sink” faster than a nonspinning ball
c. curve to your left
d. curve to your right

Demo

Ping pong!

Worked Problem

A flat roof of area 400 m^2 will rip off if it is subjected to a lift force of 5×10^5 N. (The weight of the roof is included in 5×10^5 N number). What speed of horizontal wind will rip off the roof? $\rho_{air} = 1.29\ kg/m^3$

$$F_{net} = 500{,}000\,N$$

$$P_2 \cdot A - P_1 \cdot A = 500000\,N$$

$$P_1 = \frac{P_2 A - 500{,}000\,N}{A}$$

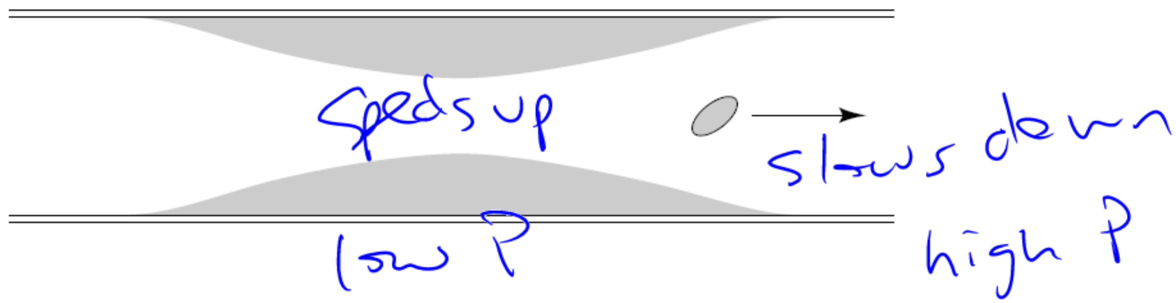
$$= \frac{(101000)(400) - 500000}{400} = \sim$$

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \cancel{\rho g h_1} = P_2 + \tfrac{1}{2}\rho \underbrace{v_2^2}_{=0} + \cancel{\rho g h_2}$$

Solve for v_1

Answer: 44.0 m/s

Clicker quiz (review)



A blood platelet drifts along with the flow of blood through an artery that is partially blocked by deposits. As the platelet moves from the narrow region to the wider region, it experiences…

a. an increase in fluid pressure.
b. a decrease in fluid pressure.
c. no change in fluid pressure.