Announcements – 4 Nov 2014

1. Prayer

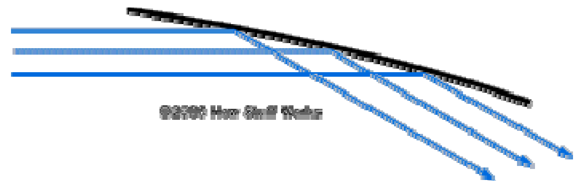
2. Exam 2
   a. Deadline: today, 2 pm
   b. Curve: I'll decide on curve tomorrow morning
   c. Handed back: will likely be handed back tomorrow afternoon or Thursday morning

“Which of the problems from last night's HW assignment would you most like me to discuss in class today?”

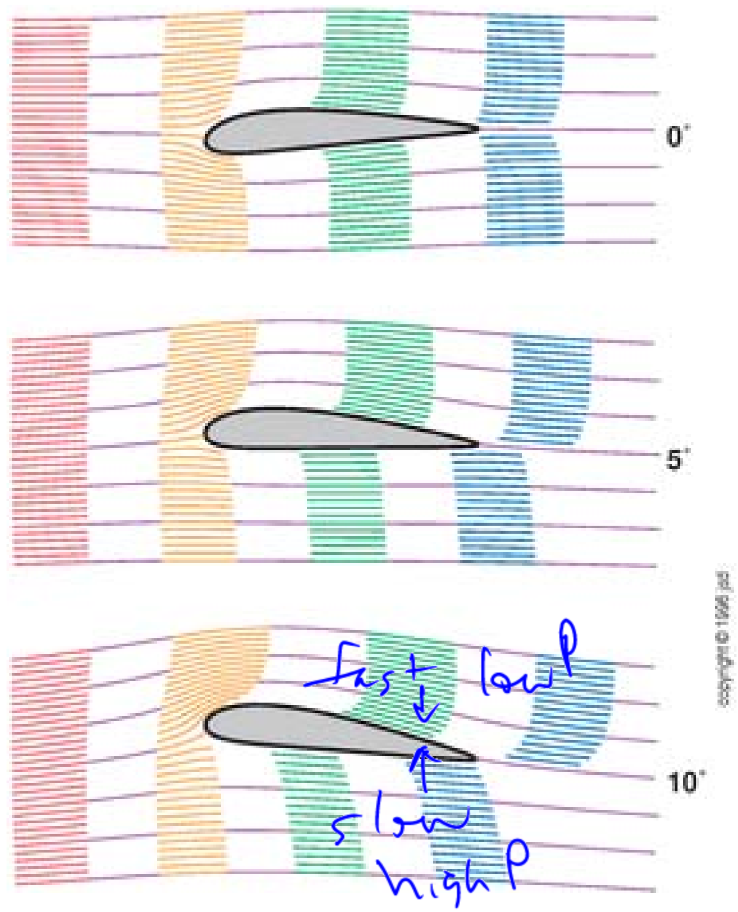
Airfoils

Airplane wings, and sails, and racecars

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



Principle 2: Bernoulli



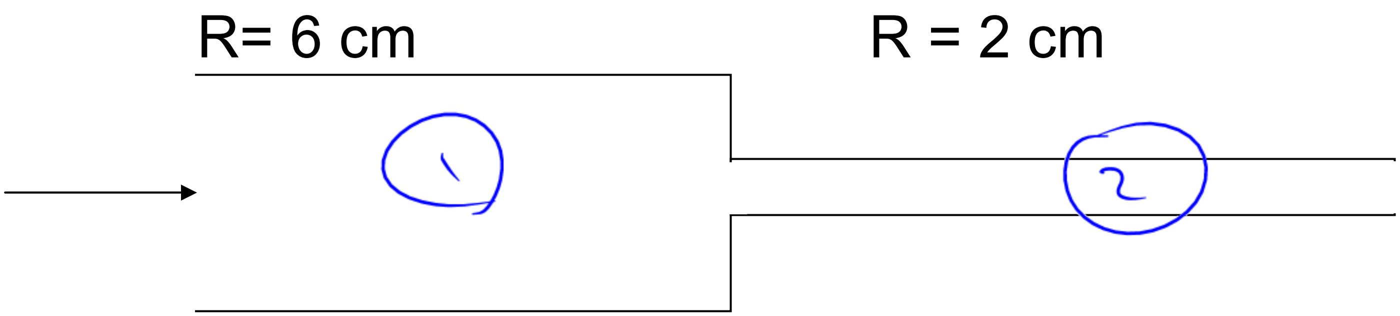
$VFR = A_1 v_1 = A_2 v_2$ $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

Worked Problem

$VFR = A_1 v_1$

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

$VFR = A_2 v_2$



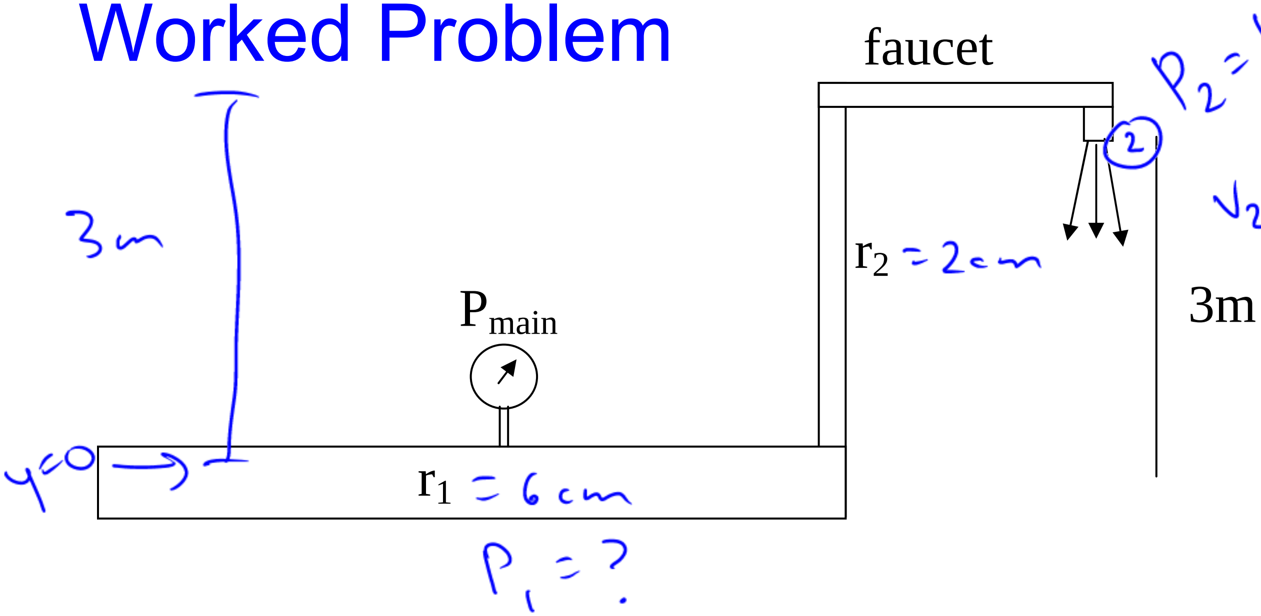
If the speed on the left is 1 m/s, what's the speed on the right?

$$A_1 v_1 = A_2 v_2$$

$$v_2 = v_1 \frac{A_1}{A_2} = (1\ m/s)\frac{\pi\, 6^2\ cm^2}{\pi\, 2^2\ cm^2} = 9\ m/s$$

~~Answer: 0.111 m/s~~

Worked Problem



$P_2 = 1\text{ atm} = 1.01\cdot10^5\text{ Pa}$

$v_2 = ?$

$VFR = 15\ \frac{\text{liters}}{\text{min}} \times \frac{1\text{ m}^3}{1000\text{ L}} \times \frac{1\text{ min}}{60\text{ s}} = 2.5\cdot10^{-4}\ \frac{\text{m}^3}{\text{s}}$

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?
b. What is the pressure in the water main?

(a) $VFR = Av$

$\left(2.5\cdot10^{-4}\ \frac{\text{m}^3}{\text{s}}\right) = \pi(.02\text{ m})^2\, v_2$

$v_2 = .199\text{ m/s}$

$A_1 v_1 = A_2 v_2$

$v_1 = v_2 \frac{A_2}{A_1}$

$= \left(.199\ \frac{\text{m}}{\text{s}}\right)\frac{\pi(2\text{ cm})^2}{\pi(6\text{ cm})^2}$

$= \frac{.199}{9}\ \frac{\text{m}}{\text{s}} = .0221\ \frac{\text{m}}{\text{s}}$

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

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

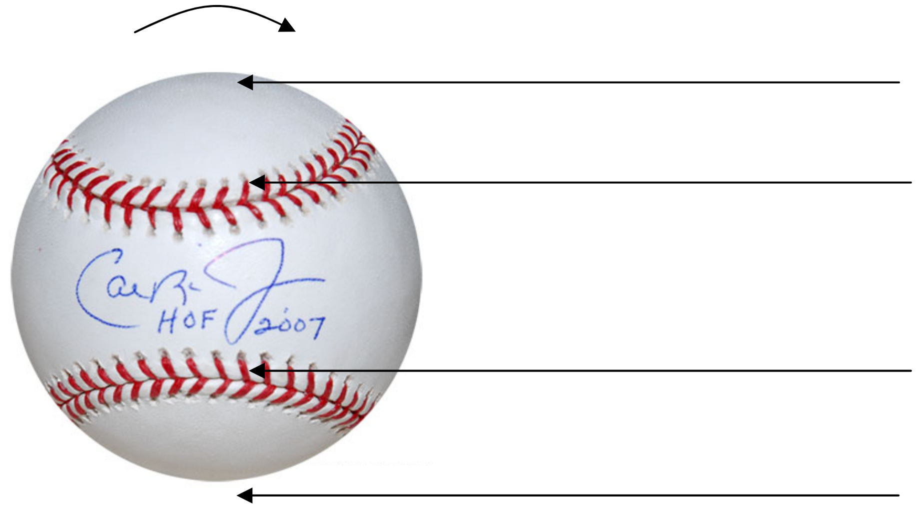
$$= (1.01\cdot 10^5\ \text{Pa}) + \frac{1}{2}\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(.199\ \frac{\text{m}}{\text{s}}\right)^2 - \frac{1}{2}\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(.0221\ \frac{\text{m}}{\text{s}}\right)^2 + \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(3\ \text{m})$$

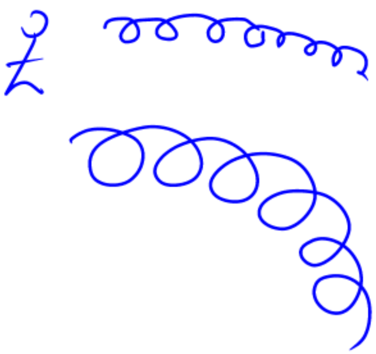
$$= \boxed{1.304\cdot 10^5\ \text{Pa}}$$

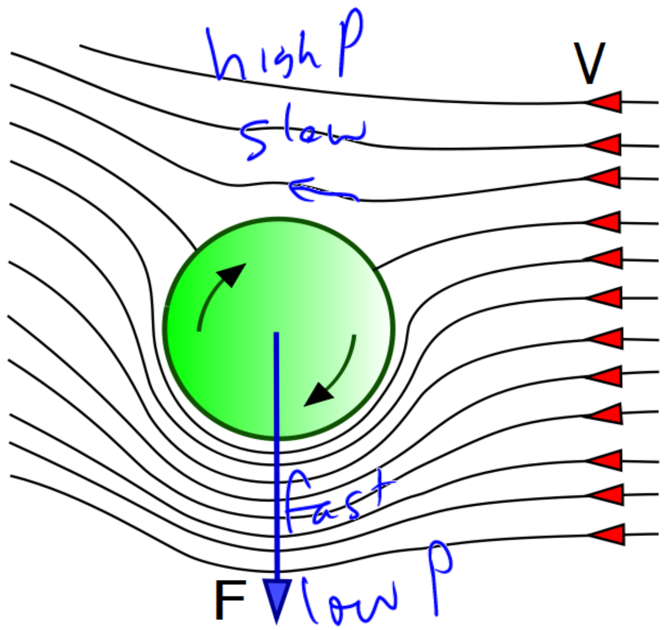
Answers: 0.199 m/s, 1.304×10^5 Pa

Curve balls

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



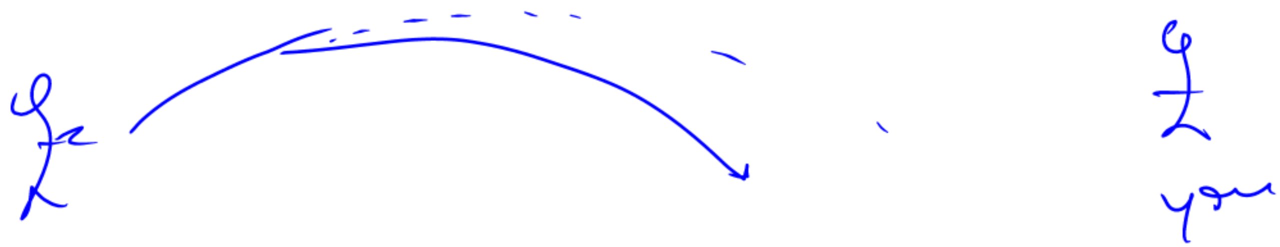




From warmup

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?

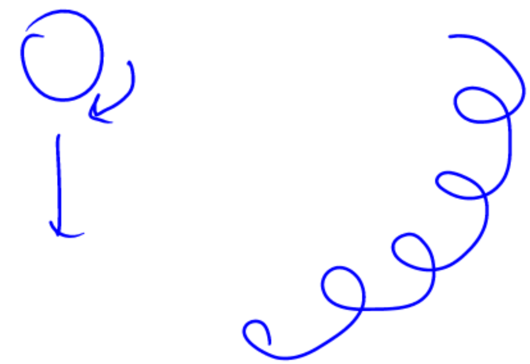
a. closer to you
b. farther from you
c. same distance



Clicker quiz

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. curve to your left
b. curve to your right

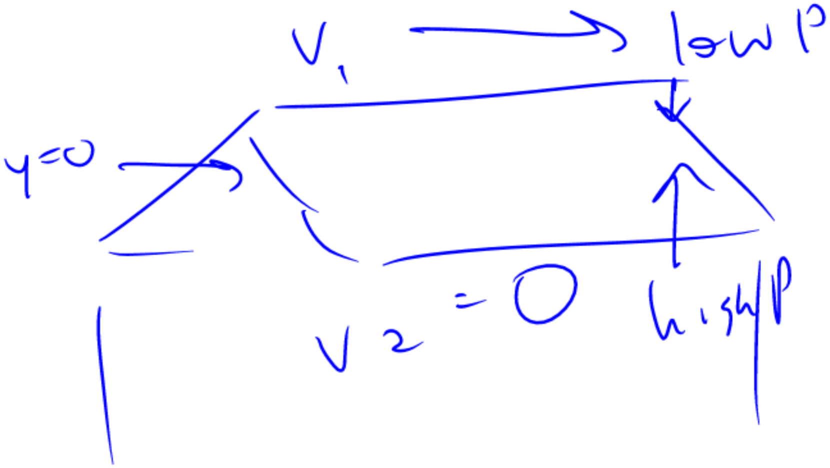


Demo: Ping pong!

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? ρ_{air} = 1.29 kg/m^3

$F = P \cdot A \qquad F_{net} = 5\cdot10^5\ \text{N}$



$P_2 A - P_1 A = 5\cdot10^5\ \text{N}$

$(P_2 - P_1)\cdot A = 5\cdot10^5\ \text{N}$

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

$P_2 - P_1 = \frac{1}{2}\rho v_1^2$

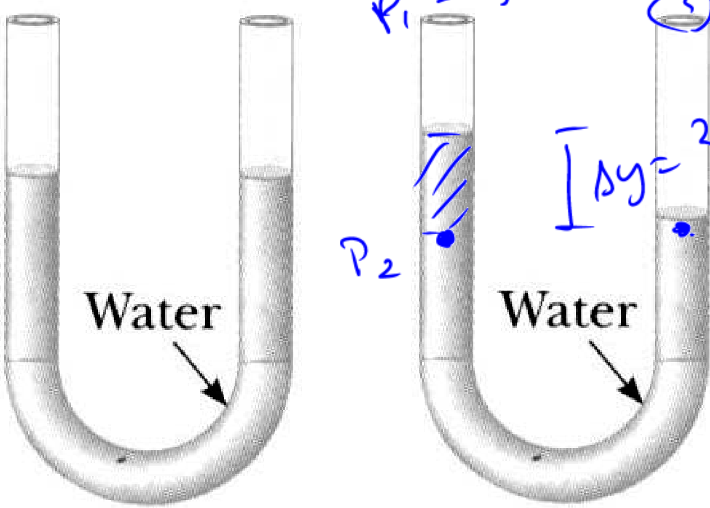
$\frac{1}{2}\rho v_1^2 \cdot A = 5\cdot10^5\ \text{N}$

$v_1 = \sqrt{\frac{2\cdot5\cdot10^5\ \text{N}}{\rho\cdot A}} = \sqrt{\frac{2\cdot5\cdot10^5\ \text{N}}{1.29\ \text{kg/m}^3\cdot400\ \text{m}^2}} = 44\ \text{m/s}$

Answer: 44.0 m/s

Worked Problem

Water is put in a "U-tube" as shown. Air is then blown across the left side at the top at 20 m/s, reducing the pressure. This causes the water to be "sucked" up on that side. What is the difference in heights of the left and right sides? The density of air is 1.29 kg/m^3; the density of water is 1000 kg/m^3.



$P_2 = P_3 = 1\text{ atm}$

Also $P_2 = P_1 + \rho_w g \Delta y$

$1\text{ atm} = P_1 + \rho_w g \Delta y$

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_3 + \frac{1}{2}\rho v_3^2 + \rho g h_3$

$P_1 = 1\text{ atm} - \frac{1}{2}\rho_a v_1^2$

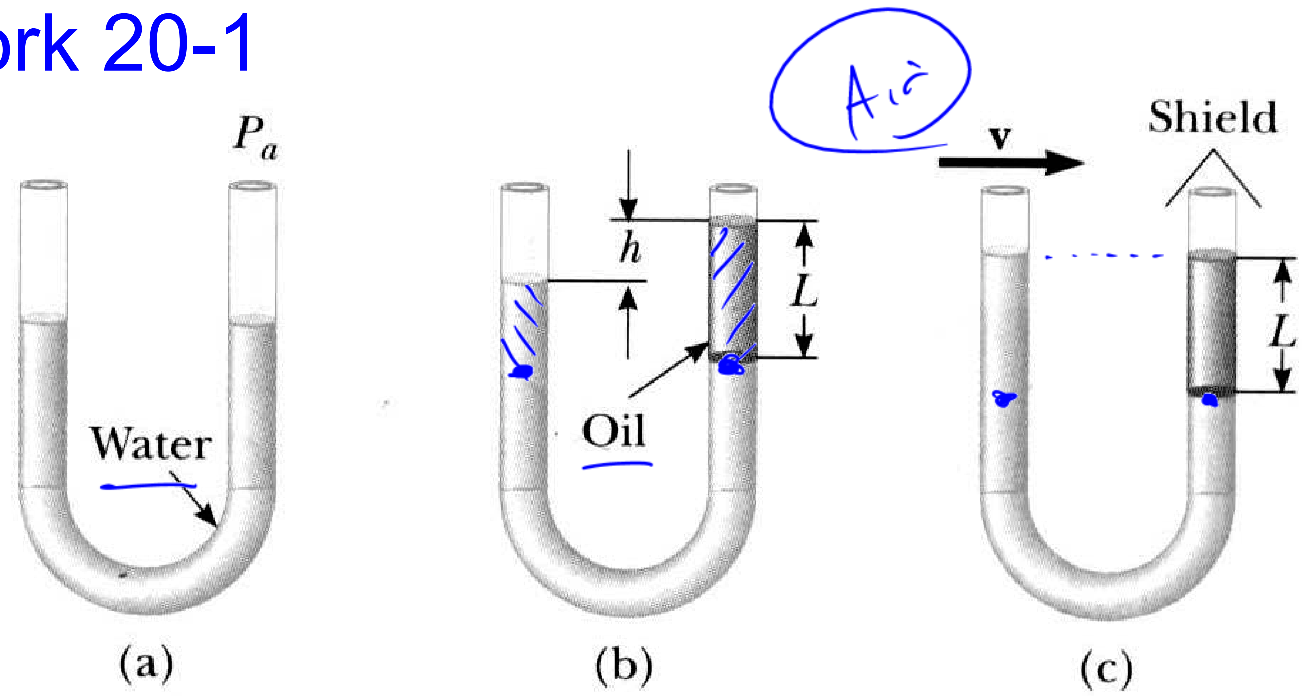
$1\text{ atm} = \left(1\text{ atm} - \frac{1}{2}\rho_a v_1^2\right) + \rho_w g \Delta y$

$\frac{\frac{1}{2}\rho_a v_1^2}{g \rho_w} = \Delta y$

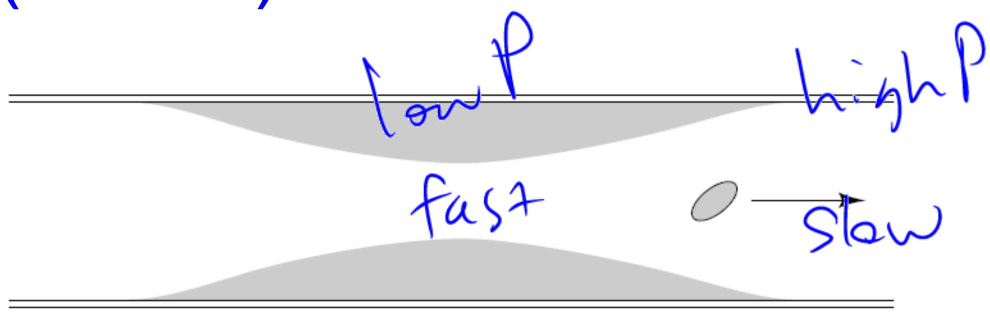
$= .026\text{ m}$

Answer: 2.6 cm

Homework 20-1



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.

Temperature scales

<u>Celsius</u>

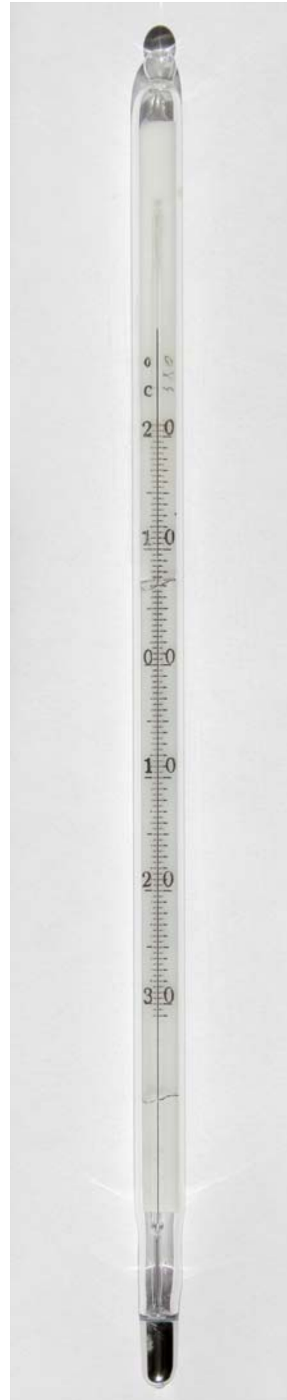
<u>Kelvin</u> $T_K = T_C + 273.15°$

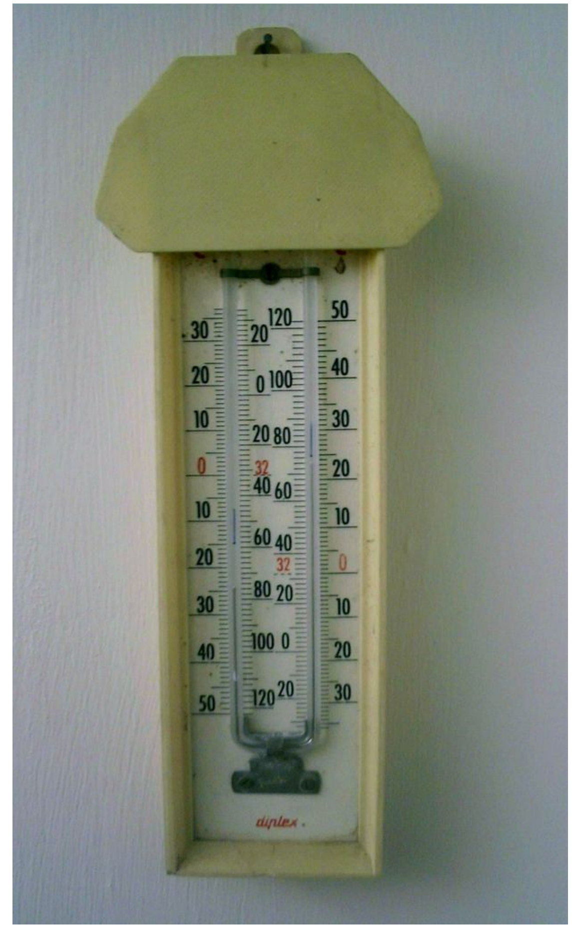
<u>Fahrenheit</u>

$T_F = \frac{9}{5} T_C + 32°$

From warmup: Which is coldest?

a. 0 degrees Celsius
b. 0 degrees Kelvin
c. 0 degrees Fahrenheit





What is a **thermometer**?

Expansion
Thermocouples
Resistors
→ Semiconductors

→ Just find some property you can measure that changes consistently with temperature

Demo: Two thermometers

What is **temperature**?

→ The property that governs heat flow

Two objects in thermal contact will exchange heat energy until they come to thermal equilibrium: they then have the "same temperature"

What is heat? transfer of random kinetic energy

Temperature, cont.

Is there a maximum temperature? Not really

Is there a minimum temperature? Yes

Thermal expansion:

For a given material, a temperature change will cause length to change by some fraction

thermal expansion coefficient

$$\Delta L = \alpha L_o \Delta T$$

$$\Delta A = \gamma A_o \Delta T$$

$$\Delta V = \beta V_o \Delta T$$

For solids:
$\gamma = 2\alpha$
$\beta = 3\alpha$

What went wrong here?

For reference: $\alpha_{steel} \approx 11\times10^{-6}$ /°C

You heat up a 1 meter steel rod by 1 degree C. How long is it now?

$$\Delta L = (11\cdot10^{-6}/°C)(1\,m)(1\,°C) = 11\cdot10^{-6}\,m$$

$$L_{new} = 1.000011\,m$$

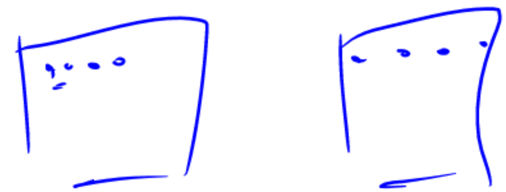
Demo

Bimetallic strip

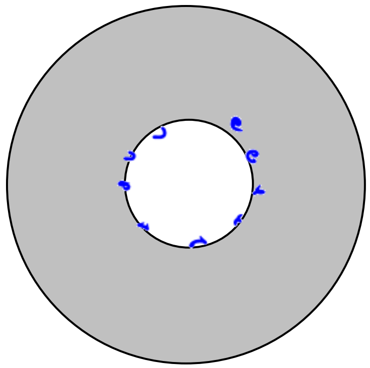
(including cooling with liquid nitrogen)

Microscopic View

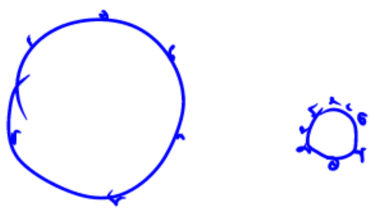
Why do most materials expand when heated?



From warmup: You heat a disc with a hole in it. Will the radius of the hole get larger, smaller, or stay the same?



a. Larger
b. Smaller
c. Stay the same



Demo

Ring and ball

Liquid Nitrogen

Rubber nail
Lead bell