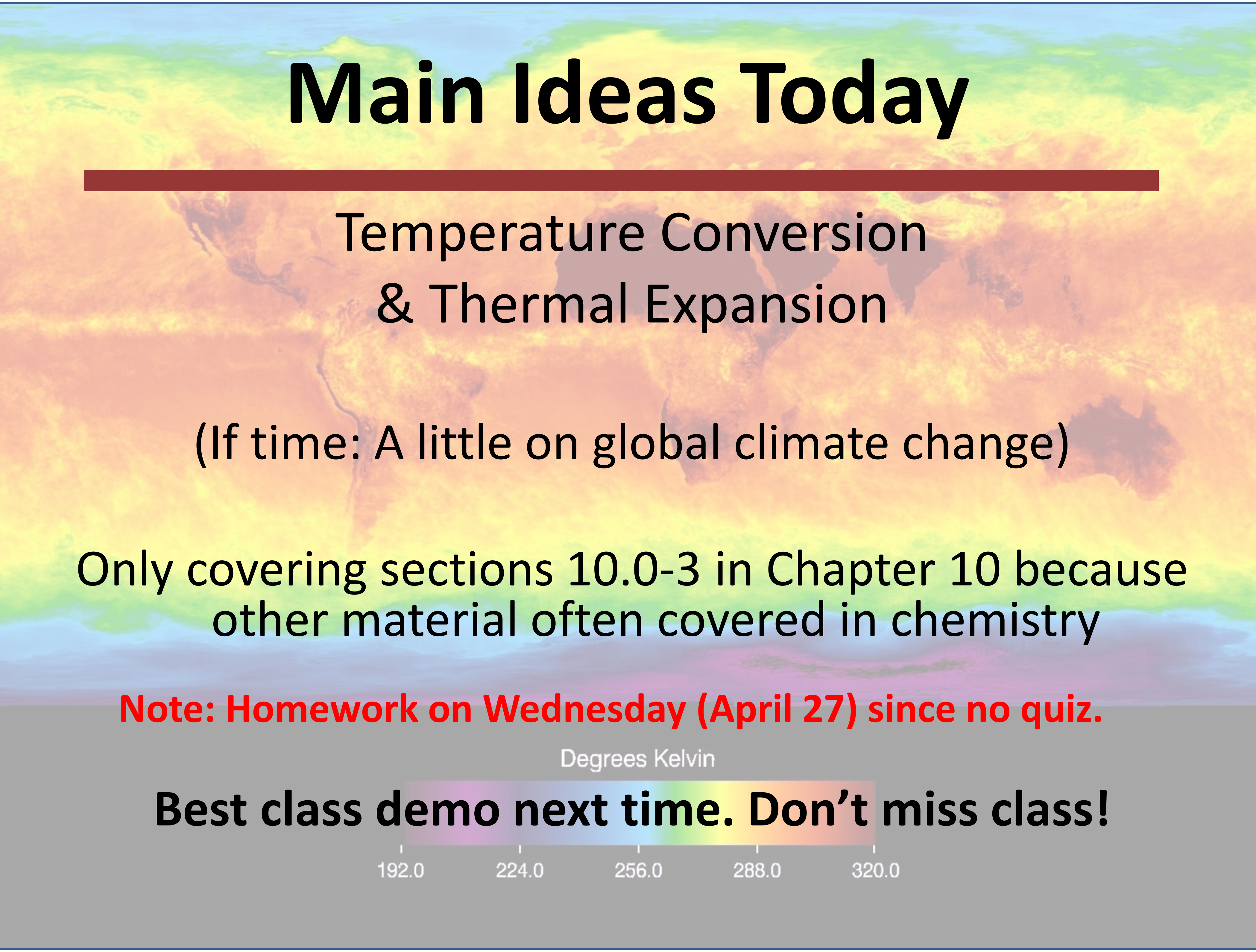
Main Ideas Today

Temperature Conversion
& Thermal Expansion

(If time: A little on global climate change)

Only covering sections 10.0-3 in Chapter 10 because other material often covered in chemistry

Note: Homework on Wednesday (April 27) since no quiz.



Best class demo next time. Don’t miss class!

Thermal Equilibrium

Two objects of different temperature when placed in contact will eventually reach the same temperature

Hot black coffee

+

Cold milk

=

Warm white coffee

In Thermal Equilibrium?

- This is why when you crowd a bunch of people into a room, it gets hotter.
- But not up to 98.6°F. Why don't we come into equilibrium with the air in the room?

- Air conditioning, thankfully
- Our body, the furnace
- What else is the room in contact with?

Body A has a higher temperature than body B (not necessarily the same size, maybe drastically different). Which of the following statements must be true?

Grading this one for participation only

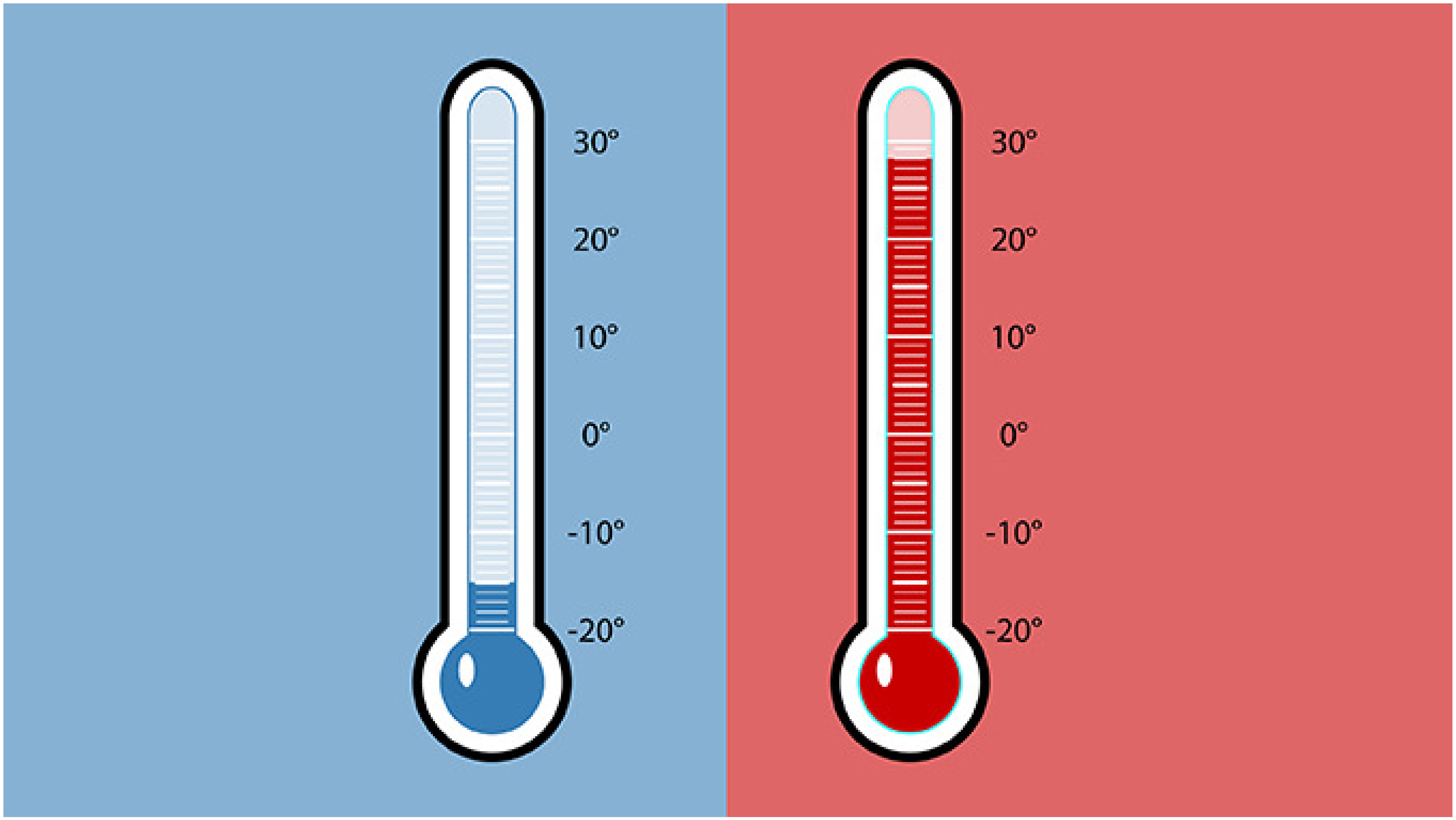
A. Body A will feel hotter than B.
B. Body A contains more energy than B.
C. If placed in contact with each other, energy will flow from body A to body B.
D. More than one statement is true.

Q157

Body A has a higher temperature than body B. Which of the following is true?

1. Body A will feel hotter. (How "hot" an object feels depends on the object's temperature AND how quickly heat can flow through the object to your hand or vice versa. A metal ice tray feels colder than a package of frozen vegetables even if it's the same temperature)
2. Body A contains more energy. (Thermal energy depends on the material and volume. For example, 1 cm^3 of lead holds much more thermal energy than 1 cm^3 of plastic at the same temperature, and 1 m^3 of lead holds much more heat than 1 cm^3 of lead.)
3. **If placed in contact with each other, energy will flow from body A to body B.** (Heat always flows from a higher-temperature object to a lower-temperature one. This is the **zeroth law of thermodynamics**.)

How do we measure temperature?



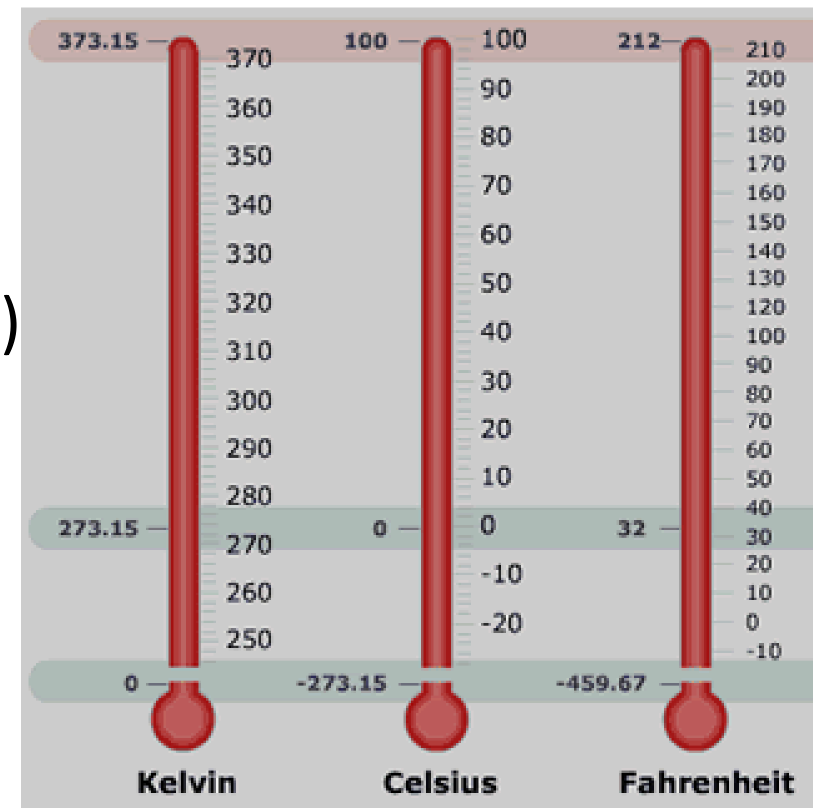
Temperature and scales

Temperature scales (melting point MP & boiling point BP of water)

–Degrees Celsius (MP 0°C, BP 100°C)

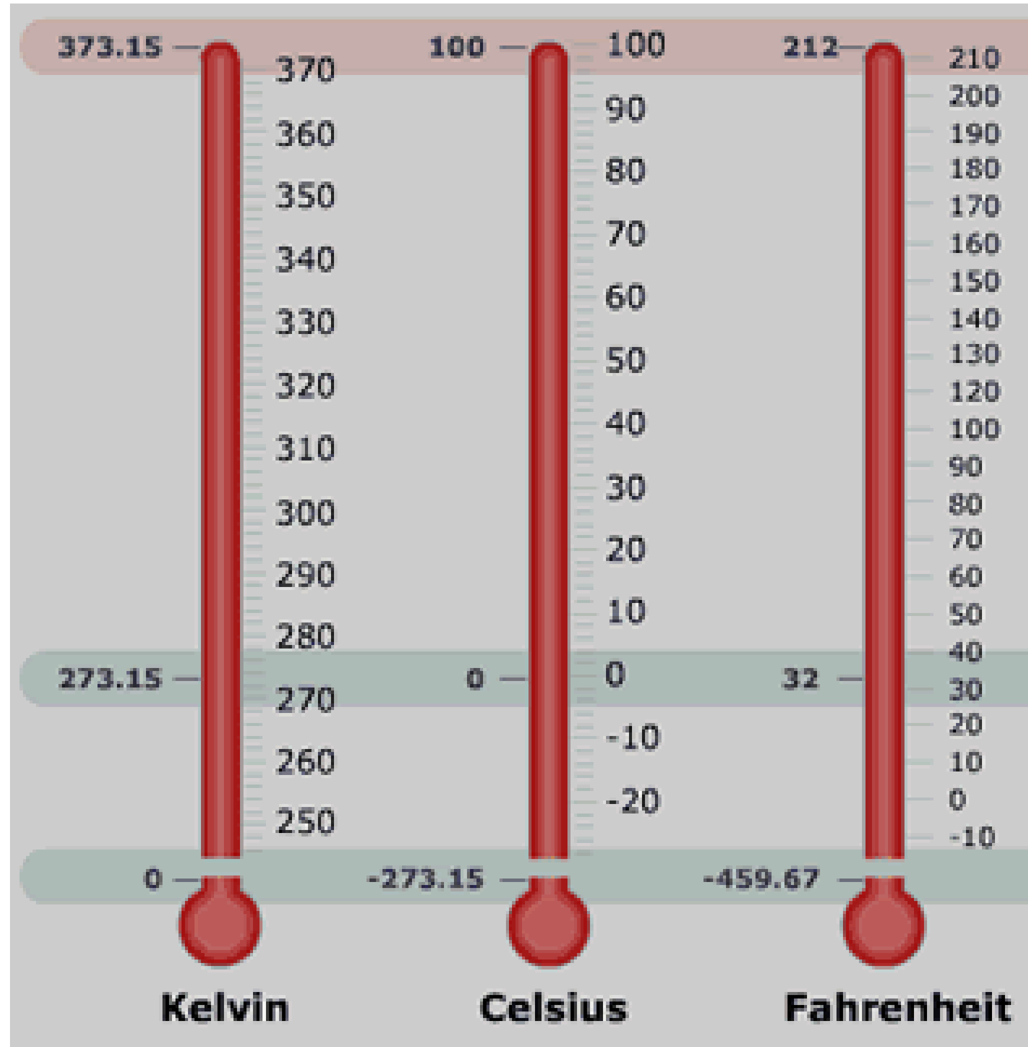
–Degree Fahrenheit (MP 32° F, BP 212°F)

–Degrees Kelvin (MP 273.15 K, BP 373.15 K)



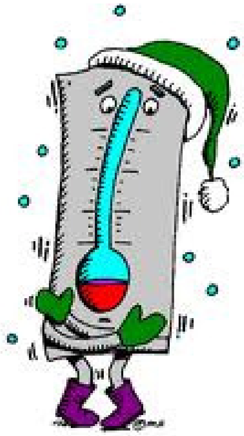
Converting between scales

- Fahrenheit to Celsius
  - $T_F = T_C \times (9/5) + 32$
  - $T_C = (T_F - 32) \times (5/9)$
- Kelvin to Celsius
  - $T_K = T_C + 273.15$
  - $T_C = T_K - 273.15$



Not a simple factor conversion

Do conversion example



Converting Temperature

The **temperature difference** between the inside and outside of a home on a cold winter day is 57.0°F. Express this difference on the Celsius scale.

What if I asked the question for the Kelvin scale?

A. 13.9°C

B. 31.7°C

C. 45.0°C

D. 57°C

E. 134.6°C

Q158

Fahrenheit to Celsius

$$T_F = T_C \times (9/5) + 32$$

$$T_C = (T_F - 32) \times (5/9)$$

Kelvin to Celsius

$$T_K = T_C + 273.15$$

$$T_C = T_K - 273.15$$

If you would like, you can pick outside and inside temperatures to compare.

Changes with temperature

Properties of materials change with temperature

- Length
- Volume
- Resistance
- Ability to store heat (next time)

Joints such as this one are used in bridges to accommodate thermal expansion.

Hotter things become longer

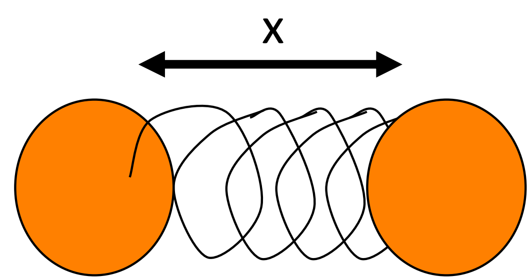
- Most solids get bigger when they get hot
  - A 1 meter long bar heated by 1 degree gets bigger by
    - Steel ≈0.01 mm
    - Glass ≈ 0.001 mm
    - Zerodur ≈ 0.0001mm

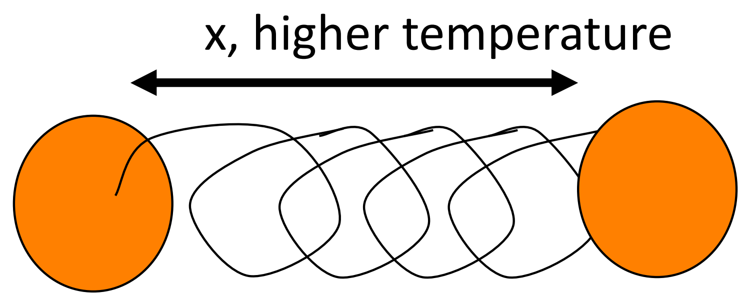
Rails expand and may buckle on a hot summer day

e.g. fire alarms and thermometers

Thermal expansion, why?

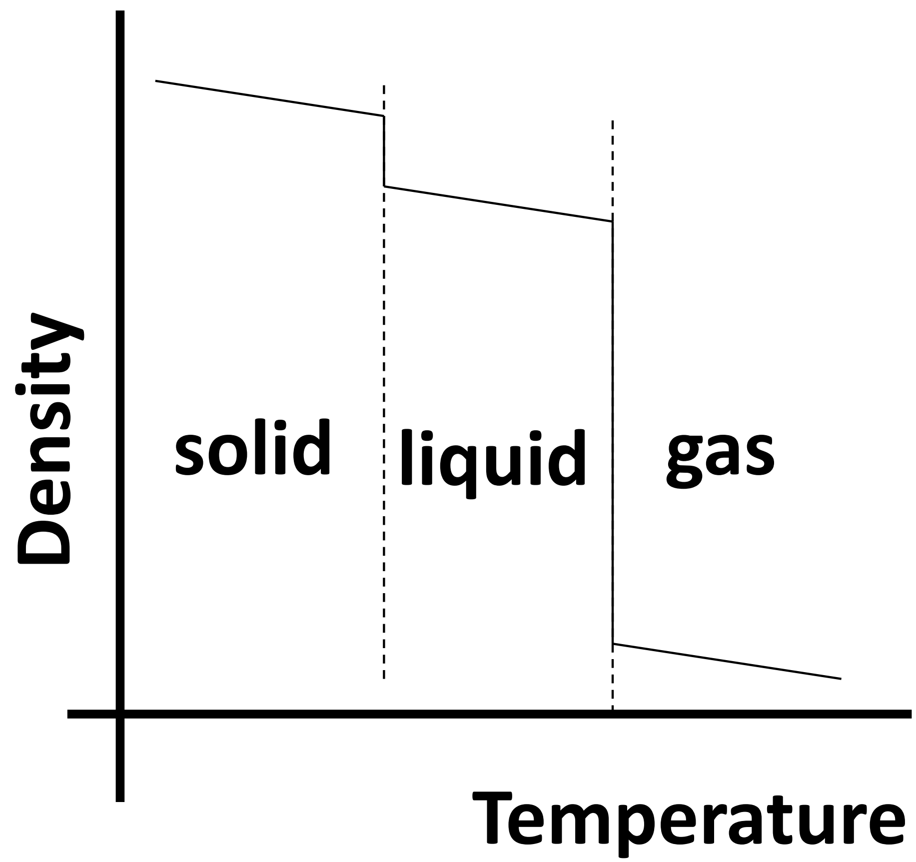
- Every microscopic object moves due to thermal energy
- Atoms vibrate with respect to each other as if attached by springs
- Hotter atoms vibrate more (more energy)





Changes between states of matter

- We discussed that density (ρ) changes with temperature.
- A significant change is often observed at a phase transition



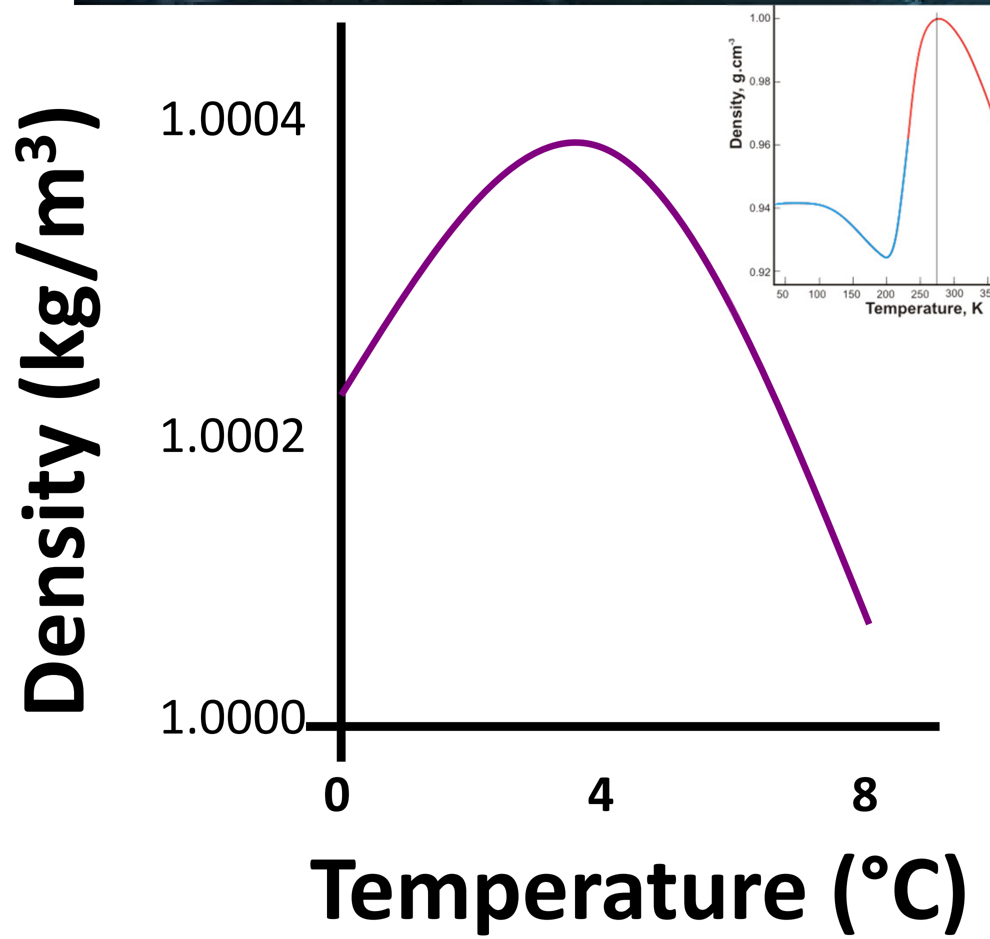
Water: A Rare and Important Exception

- Density of ice is less than water!!!
  - Why Icebergs float
- Density of water maximum at 4°C
  - Nearly frozen water floats to the top of the lake and hence freezes

If ice were more dense than water (meaning it would not float), life on Earth may not have been possible!

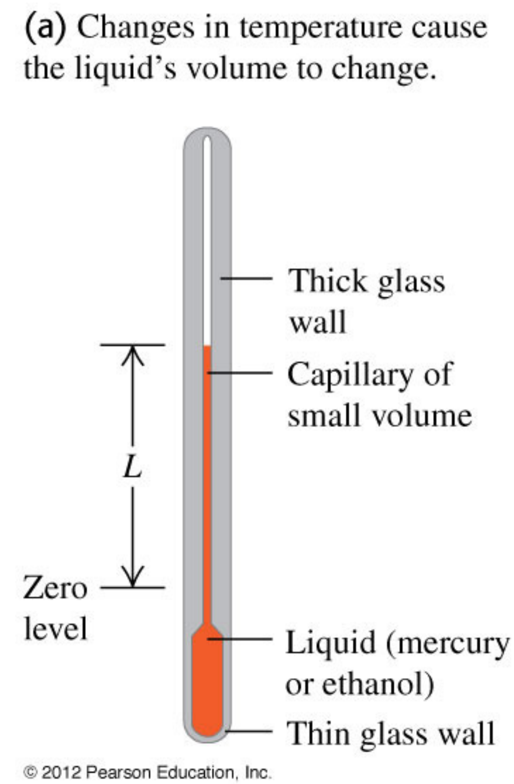
Ice would sink to the bottom of the ocean and build up over time.

Over time, this would have turned the Earth to ice similar to Hoth in Star Wars.



Three ways things expand

- Length expansion (thermometer) $\Delta L = \alpha L_o \Delta T$
- Area expansion (ring) $\Delta A = \gamma A_o \Delta T$
- Volume expansion (basketball) $\Delta V = \beta V \Delta T$
- Note: ΔT is in °C (or K)
- Note: $\gamma = 2\alpha$, $\beta = 3\alpha$
- Thermometers rely on a thermal expansion of a liquid (e.g. mercury)



Thin tube
(Gives big length change for small increase in volume)

Fahrenheit to Celsius

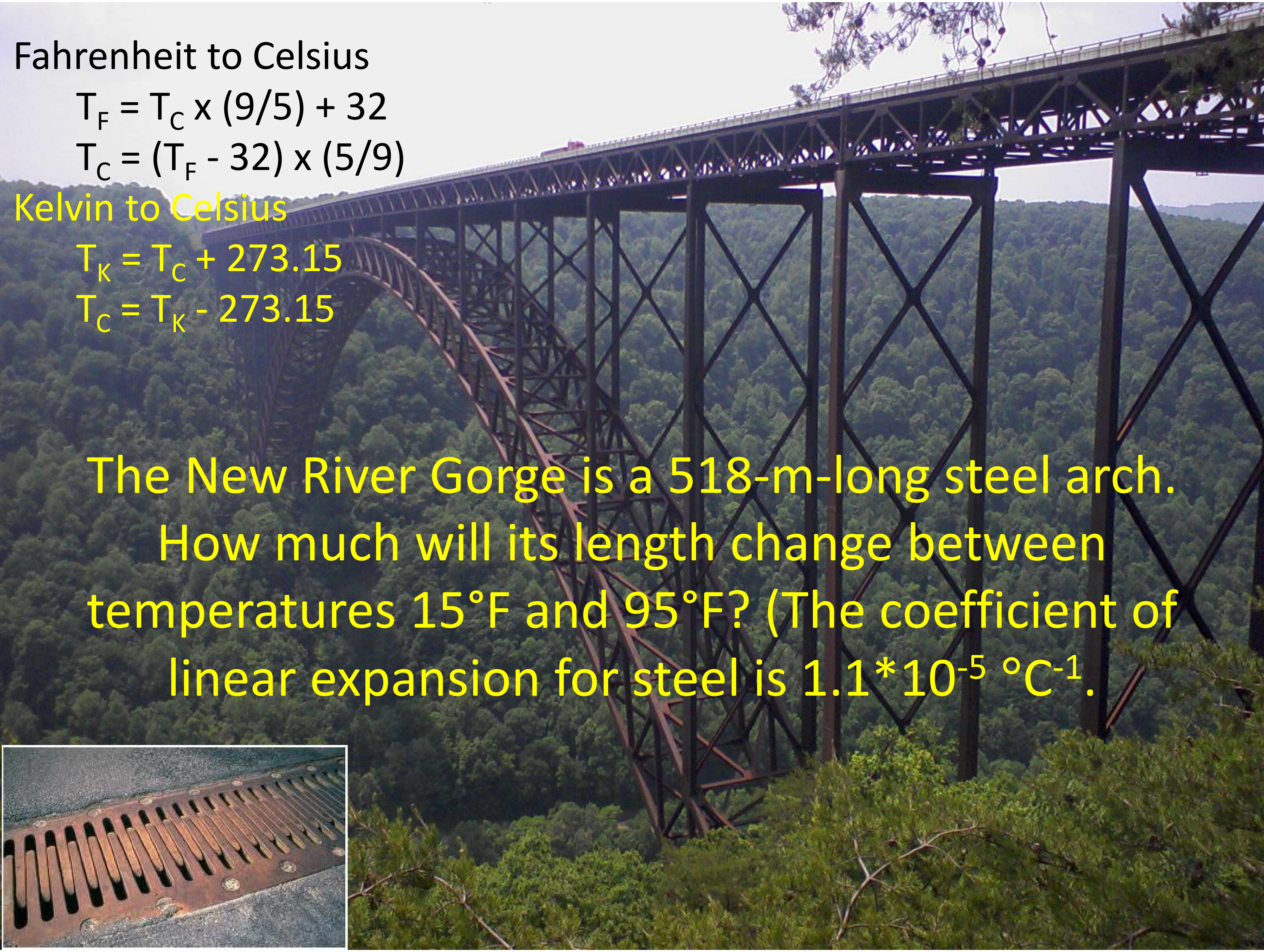
$T_F = T_C \times (9/5) + 32$

$T_C = (T_F - 32) \times (5/9)$

Kelvin to Celsius

$T_K = T_C + 273.15$

$T_C = T_K - 273.15$



The New River Gorge is a 518-m-long steel arch. How much will its length change between temperatures 15°F and 95°F? (The coefficient of linear expansion for steel is 1.1×10^{-5} °C^{-1}.

Global Warming: Ocean Expansion

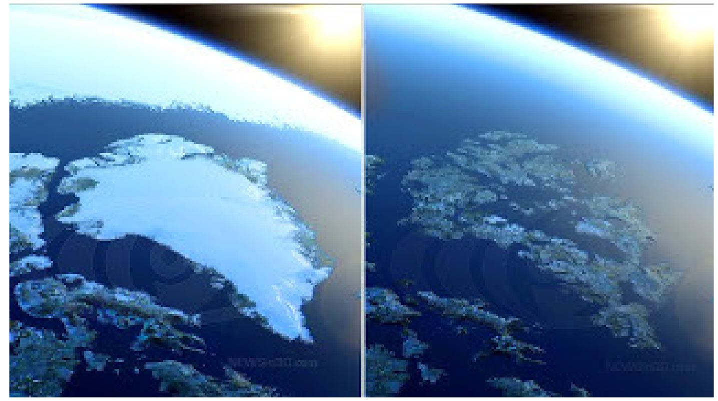
Neglects melting of ice caps with may be more significant

Let's consider a modest temperature change of 1°C.

Use the fact that the average depth of the ocean is 4000 m to estimate the change in depth due to this global warming.

Note that $\alpha_{water} = 6.9 \times 10^{-5}\ (°C)^{-1}$.

Hurricane Sandy



May not seem like much, but consider the effect of flooding.

I normally try to avoid politics but this one really affects our survival.

Disclaimer

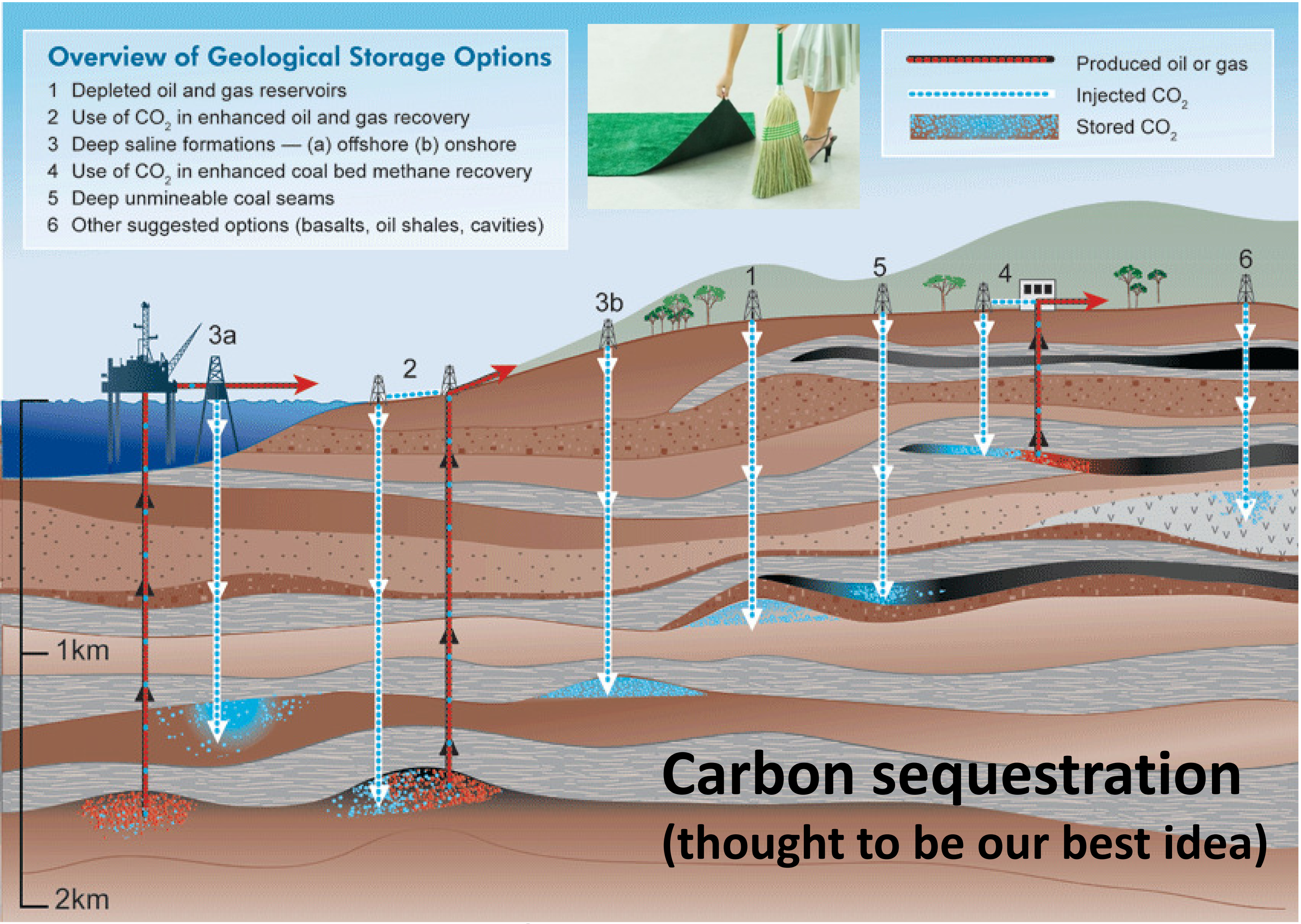
I don’t care what you believe, but I do care that you think about why you believe it.


CLIMATE
SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• etc. etc.

Regardless of the cause of Global Warming

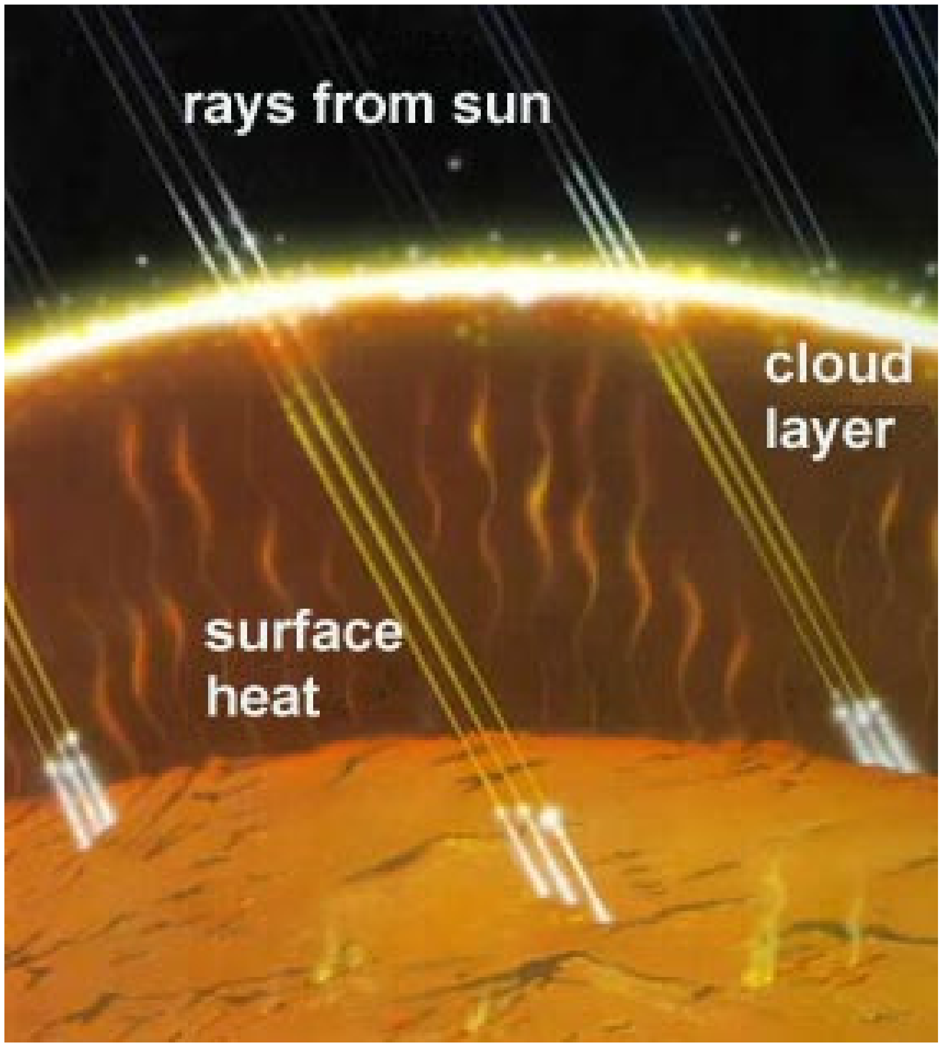
- Warmer air can make and hold more water vapor, which means more **frequent and longer droughts**, as well as more **severe floods**.
- Leads to less reliable food supply and higher food prices
- Hotter temperatures means increased intensity of storms (hurricanes, tornadoes, snow)

- Also hurts our ability to produce energy. Coal, hydroelectric and nuclear power plants all require water (e.g. cooling).



How do we stop it?

Venus is a runaway greenhouse



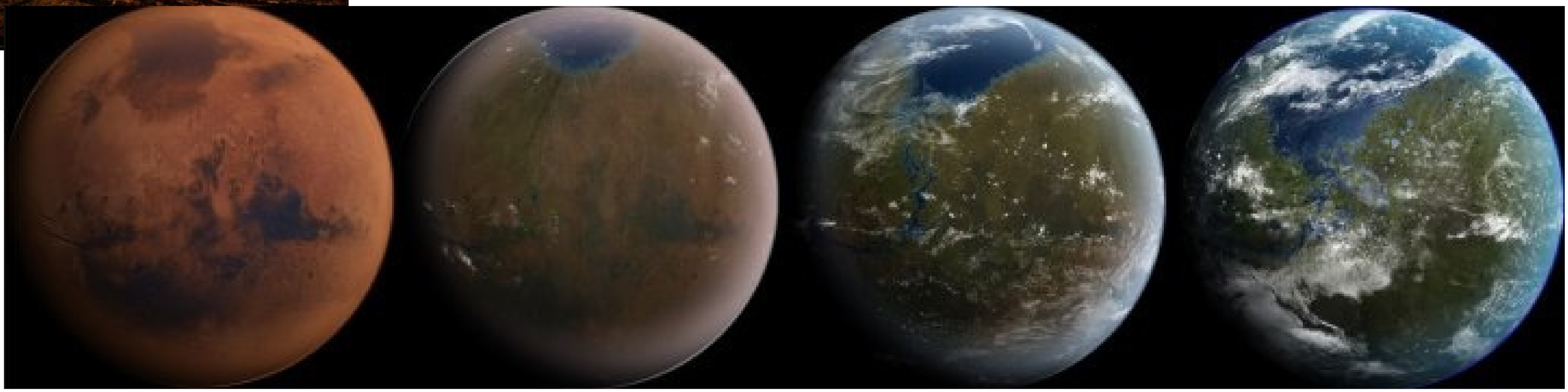
Venus' atmosphere is 96.5% CO_2

Any water originally on Venus is now gone. (boiled into space)

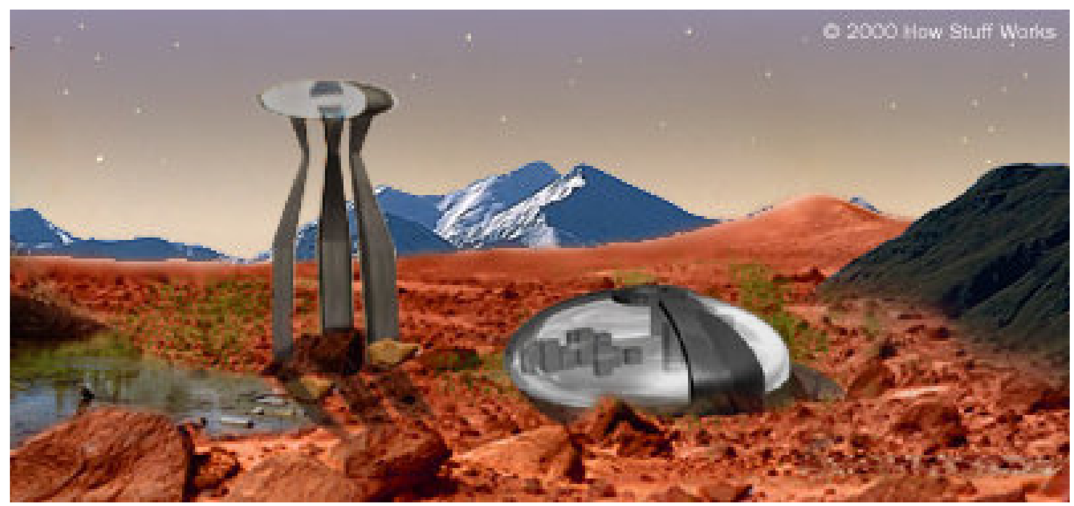
Water is key in controlling the greenhouse effect on Earth:

(1) the oceans absorb a lot of CO_2
(2) water and CO_2 react with silicate rock to lock the CO_2 up in carbonaceous rock; and (3) water nourishes plants, which remove CO_2 from the atmosphere.

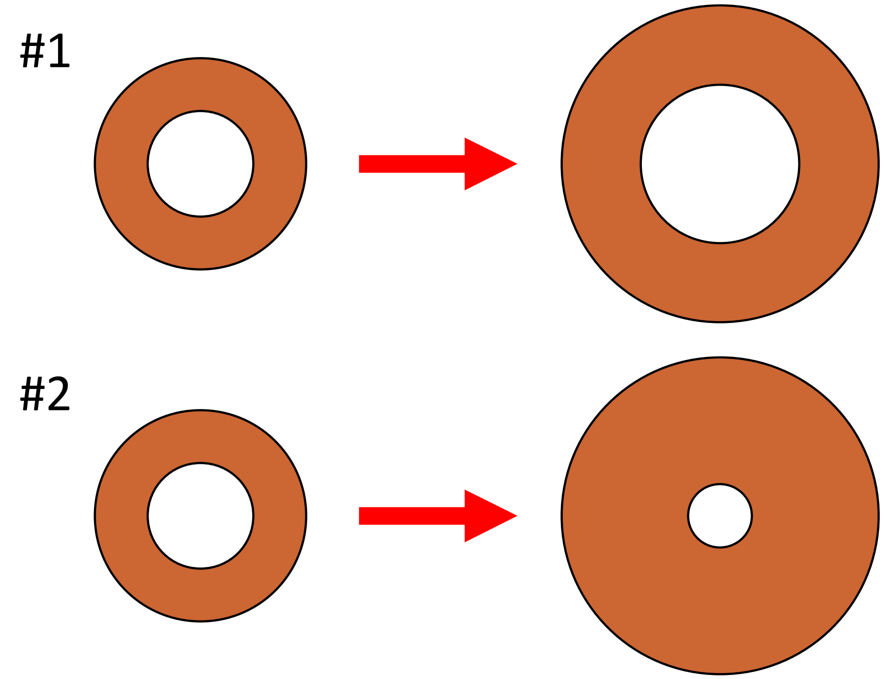
We could do the same thing on Mars to make it ideal for life!



No atmosphere on Mars now, but we could build one by polluting it some.



A solid object has a hole in it. Which of these illustrations more correctly shows how the size of the object and the hole change as the temperature increases?



A. illustration #1 (hole radius increases)

B. illustration #2 (hole radius decreases)

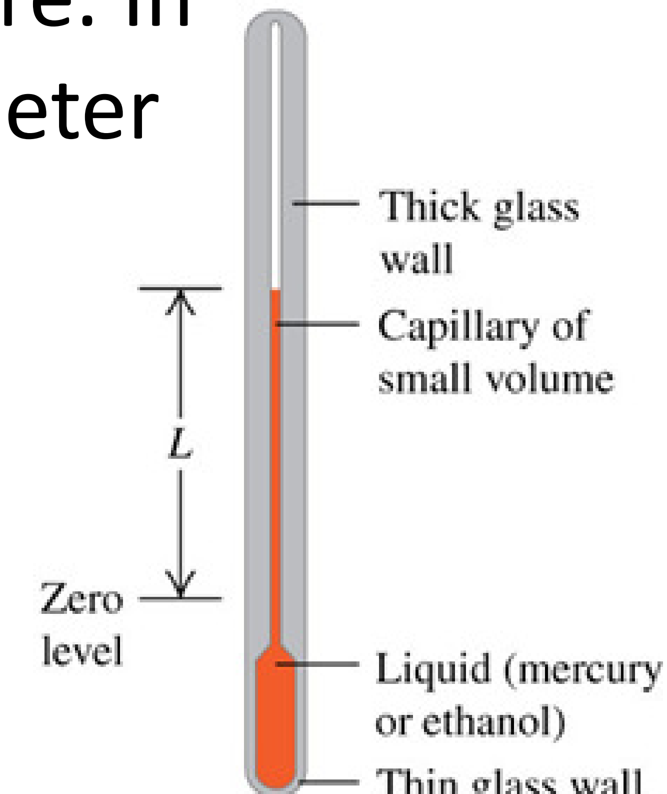
C. Hole radius stays the same

C. The answer depends on the material of which the object is made.

D. The answer depends on how much the temperature increases.

Q159

The illustration shows a thermometer that uses a column of liquid (usually mercury or ethanol) to measure air temperature. In thermal equilibrium, this thermometer measures the temperature of



A. the column of liquid.

B. the glass that encloses the liquid.

C. the air outside the thermometer.

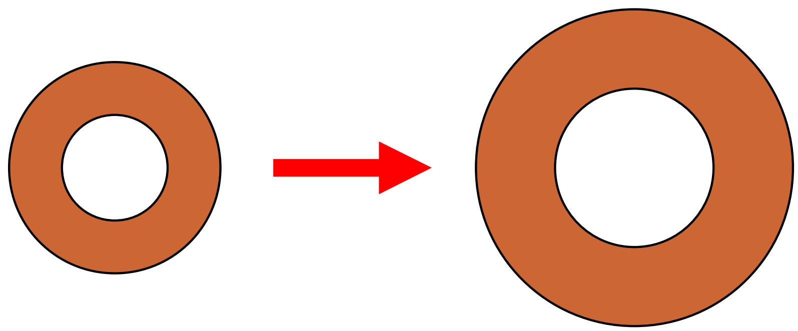
D. both A. and B.

E. all of A., B., and C.

Q160

Clicker Answers for Today: C,B,A,E

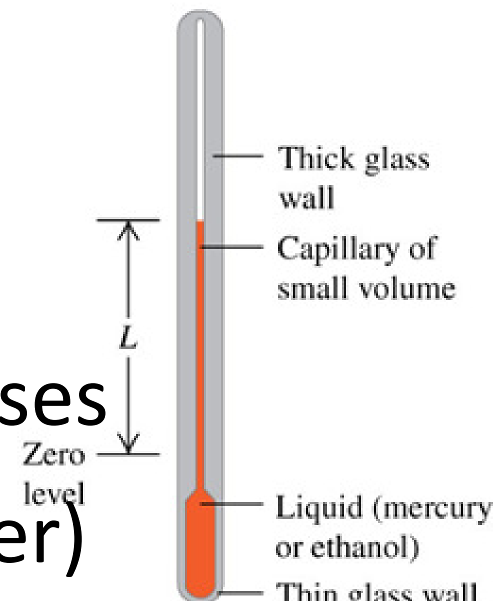
- If Body A has a higher temperature than body B, then when placed in contact with each other, energy will flow from body A to body B.
- Temperature difference equals 31.7°C.
- When heated:



- This thermometer measures the temperature of all of the above

(the column of liquid, the glass that encloses

the liquid, the air outside the thermometer)



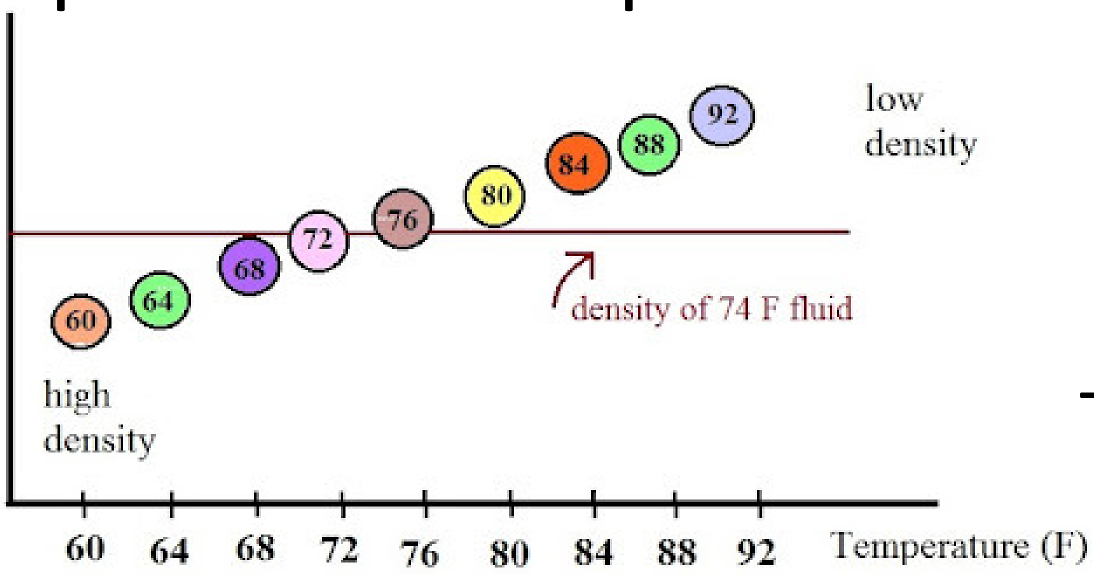
The first thermometer

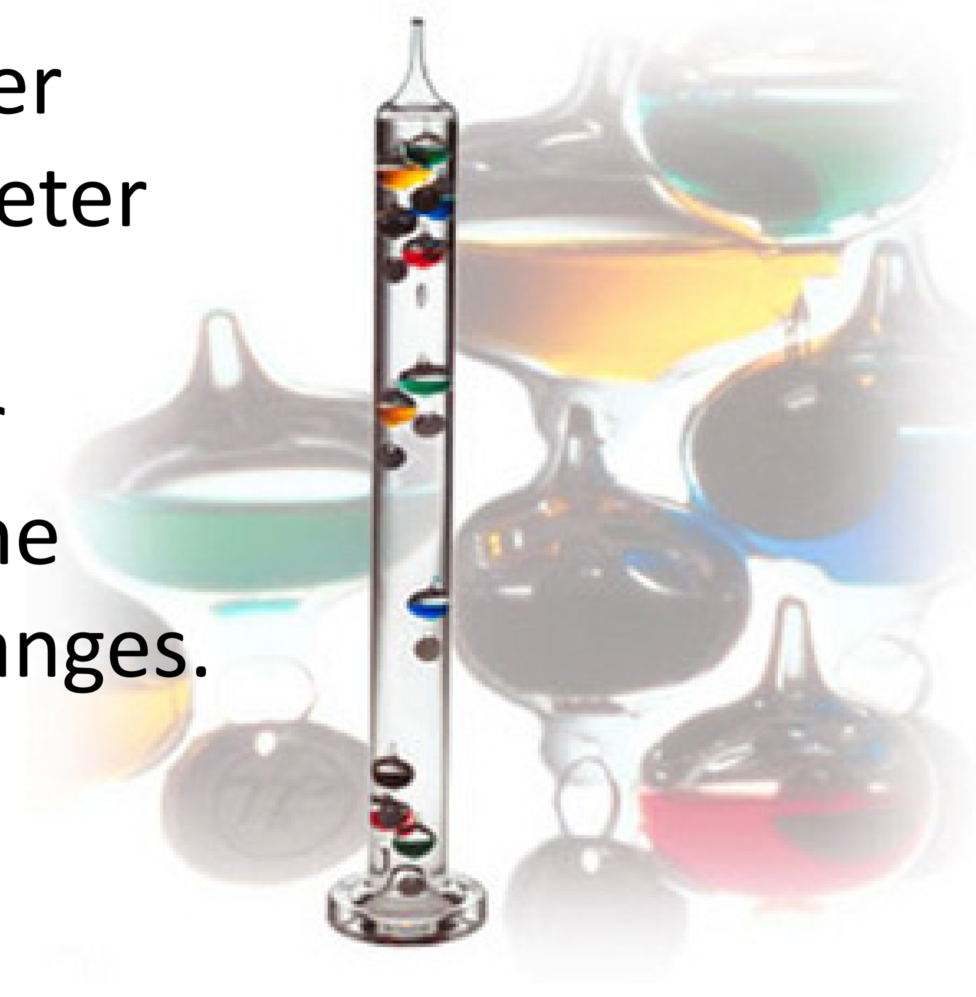
Any guesses why this works?

The bulb floating in the gap tells the temperature. If no bulb in the gap then the average of the values of the bulb above and below gives the temperature.

Galileo realized density changed with temperature

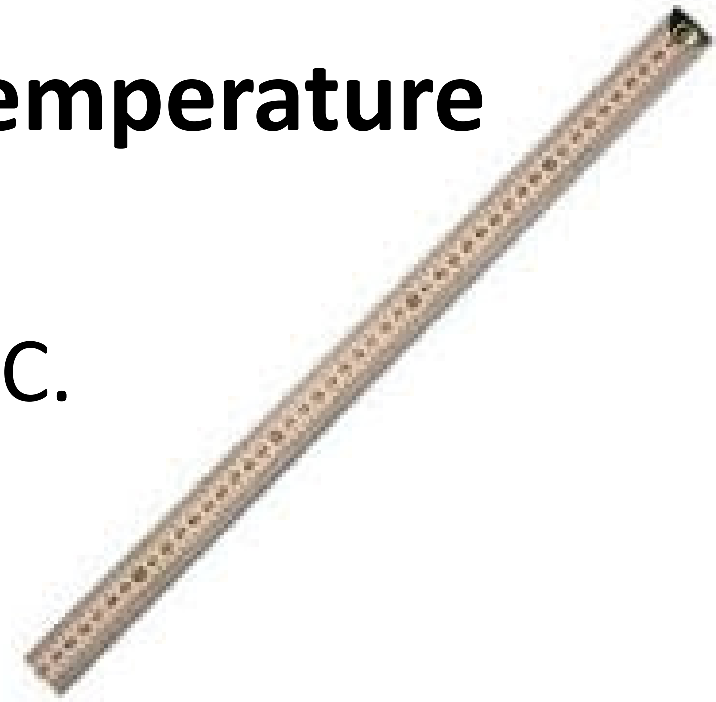
A **Galilean thermometer** (after Galileo Galilei), is a thermometer containing a series of objects whose densities get bigger or smaller than the density of the liquid as the temperature changes.





The bulb floating in the gap tells the temperature.

Measurement Error due to Temperature



Metersticks are calibrated at 20°C.

What is the error in a measurement of 500mm if made at 45°C?

α_{steel}= 1.2x10^{-5} K^{-1}

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

$\Delta L = 0.5 \text{ m} \times 1.2\times10^{-5} \times 25$

$\Delta L = 0.00015\text{m} = 0.15 \text{ mm}$

Main Ideas in Class Today

You should be able to:

- Apply Thermal Equilibrium
- Be able to convert between Kelvin, Celsius and Fah. temperature scales
- Calculate the amount of thermal expansion

Practice: C10.3, C10.11, 10.1, 10.3, 10.5, 10.7, 10.11, 10.13, 10.17, 10.19 (harder), 10.21