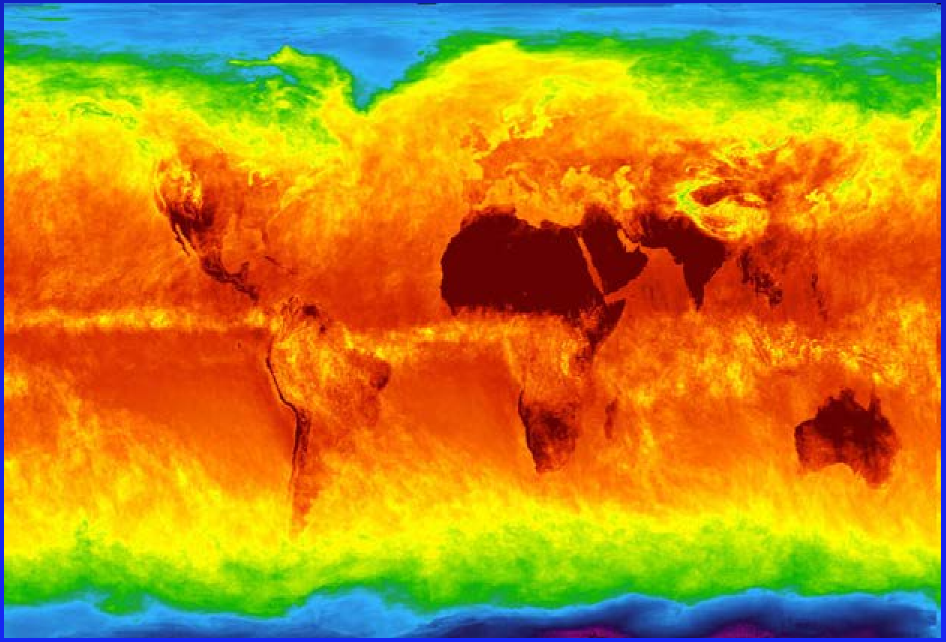
EXAM III

Physics 101: Lecture 23
Temperature and Ideal Gas

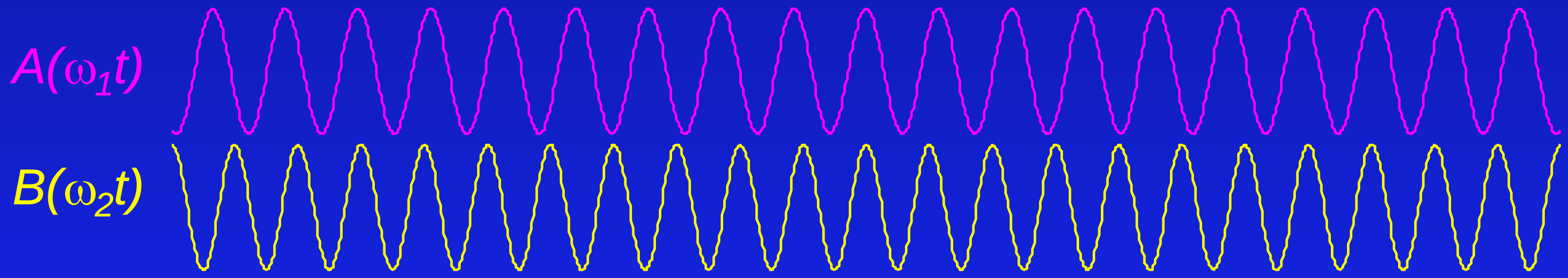
Today's lecture will cover Textbook Chapter 13.1-13.4



Temperature of Earth's surface/clouds from NASA/AIRS satellite

Superposition & Interference

- Consider two harmonic waves *A* and *B* meeting at $x=0$.
  - ➔ Same amplitudes, but $\omega_2 = 1.15 \times \omega_1$.
- The displacement versus time for each is shown below:



What does $C(t) = A(t) + B(t)$ look like??

Superposition & Interference

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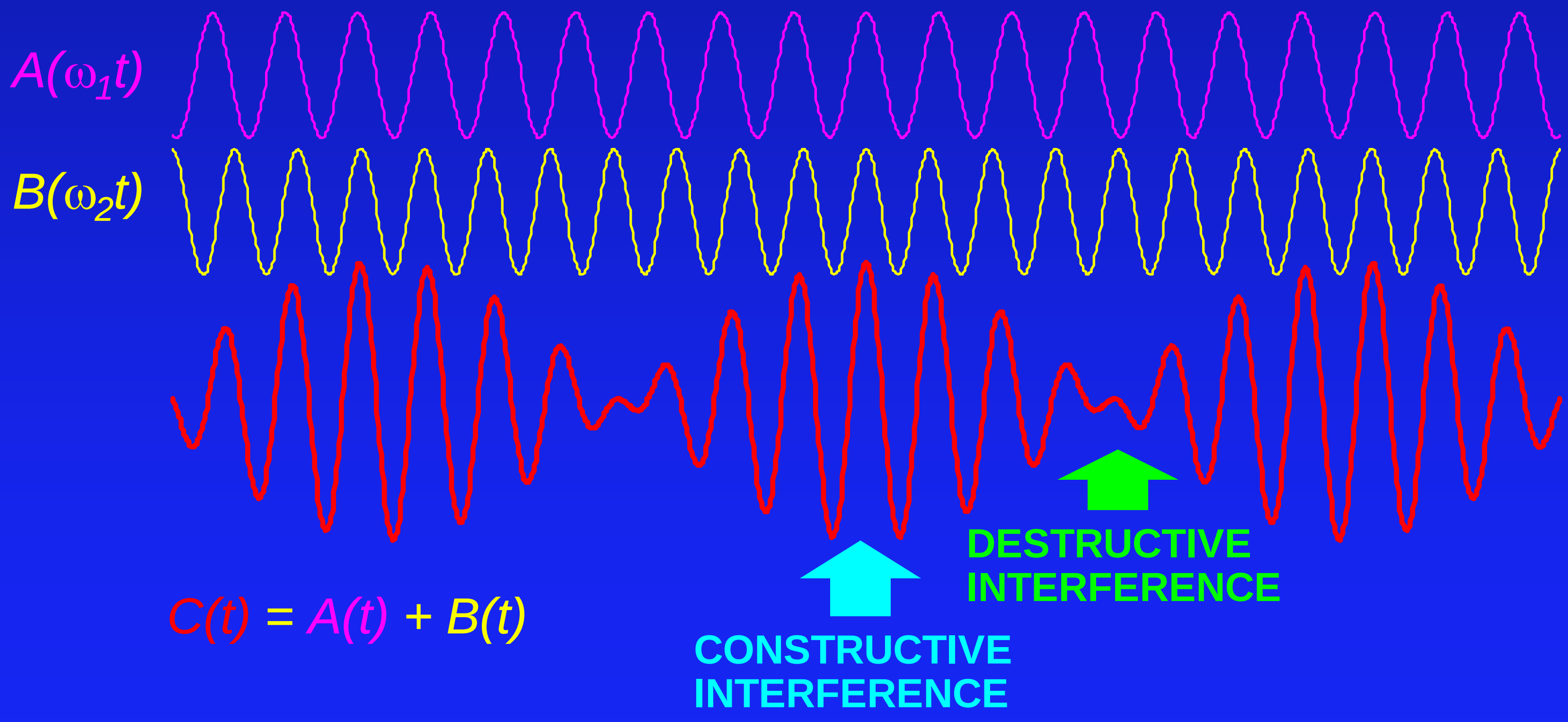


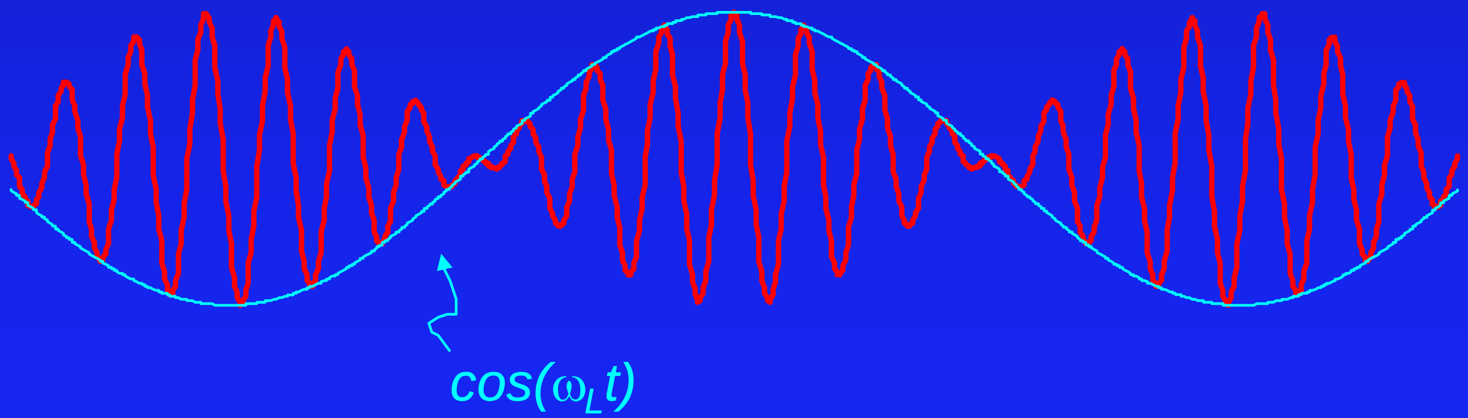
$C(t) = A(t) + B(t)$

Beats

- Can we predict this pattern mathematically?
  - ➔ Of course!
- Just add two cosines and remember the identity:

$$A\cos(\omega_1 t) + A\cos(\omega_2 t) = 2A\cos(\omega_L t)\cos(\omega_H t)$$

where $\omega_L = \frac{1}{2}(\omega_1 - \omega_2)$ and $\omega_H = \frac{1}{2}(\omega_1 + \omega_2)$



Internal Energy and Temperature

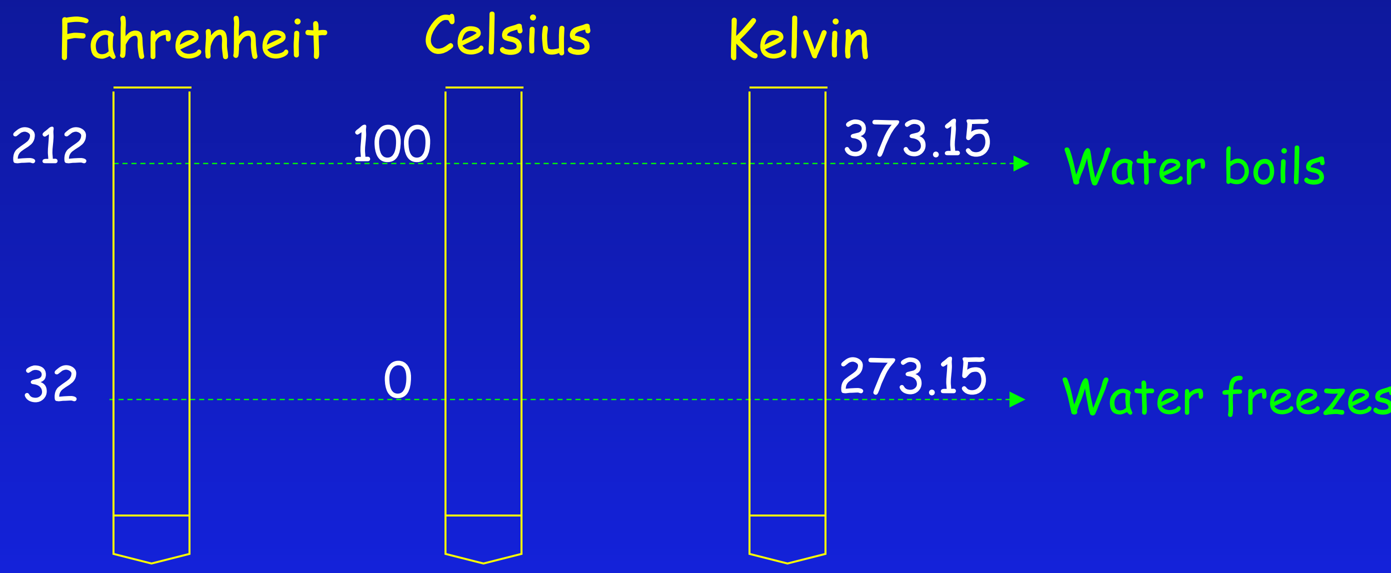
- All objects have "internal energy" (measured in Joules)
  - ➔random motion of molecules
    - » kinetic energy
  - ➔collisions of molecules gives rise to pressure
- Amount of internal energy depends on
  - ➔temperature
    - » related to average kinetic energy per molecule
  - ➔how many molecules
    - » mass
  - ➔"specific heat" – Amount of energy required to change temperture
    - » related to how many different ways a molecule can move
      - translation
      - rotation
      - vibration
    - » the more ways it can move, the higher the specific heat

Zeroth law of Thermodynamics

- If two objects are in thermal equilibrium with a third, then the two are in equilibrium with each other.

- If they are in equilibrium, they are at the same temperature

Temperature Scales



$$F = \frac{9}{5}C + 32 \qquad C = \frac{5}{9}(F - 32)$$

$$K = C + 273 \qquad C = K - 273$$

NOTE: K=0 is "absolute zero", meaning (almost) zero KE/molecule

Sick Act

You measure your body temperature with a thermometer calibrated in Kelvin. What do you hope the reading is (assuming you are not trying to fake some sort of illness) ?

A. 307 K

B. 310 K ← correct

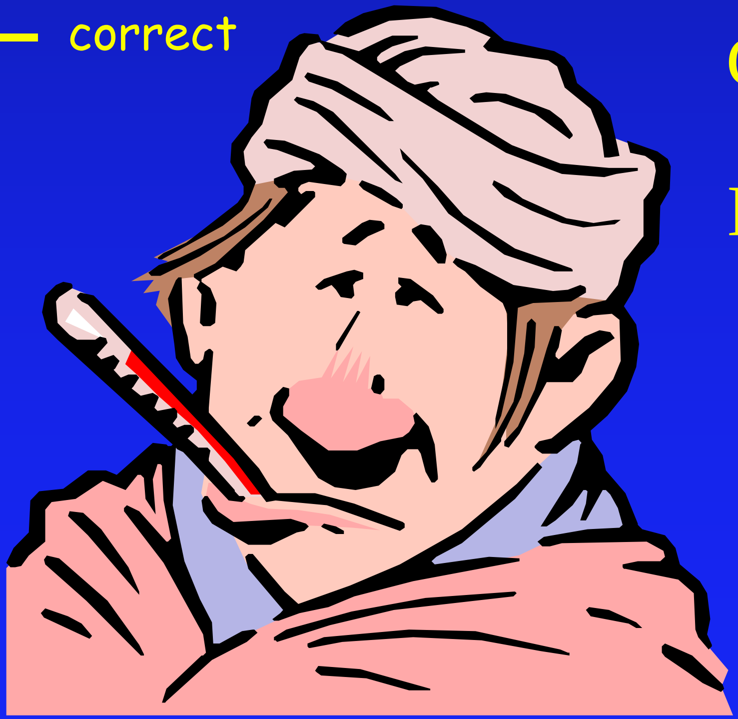
C. 313 K

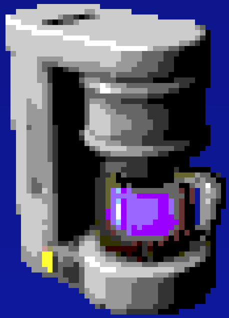
D. 317 K

$$F = 98.6$$

$$C = \frac{5}{9}(F - 32) = 37$$

$$K = C + 273 = 310$$





Temp Scales ACT

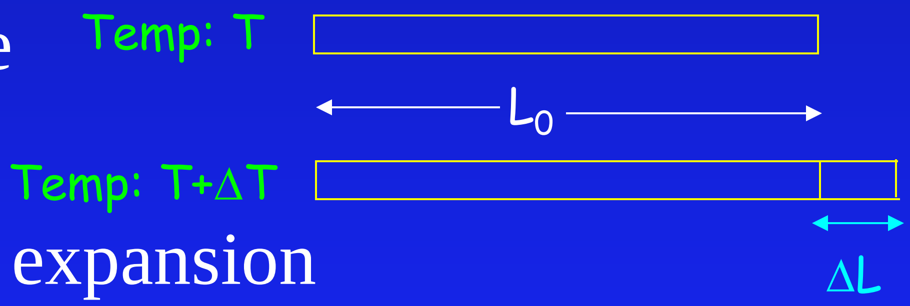
- Two cups of coffee are heated to 100 degrees Fahrenheit. Cup 1 is then heated an additional 20 degrees Centigrade, cup 2 is heated an additional 20 Kelvin. Which cup of coffee is hotter?

A) One B) Two C) Same

$$K = C + 273$$

Thermal Expansion

- When temperature rises
  - ➔ molecules have more kinetic energy
    - » they are moving faster, on the average
  - ➔ consequently, things tend to expand
- amount of expansion depends on…
  - ➔ change in temperature
  - ➔ original length
  - ➔ coefficient of thermal expansion
    - » $\Delta L = \alpha L_0 \Delta T$ (linear expansion)
    - » $\Delta V = \beta V_0 \Delta T$ (volume expansion)



Density ACT

As you heat a block of aluminum from 0 C to 100 C its density

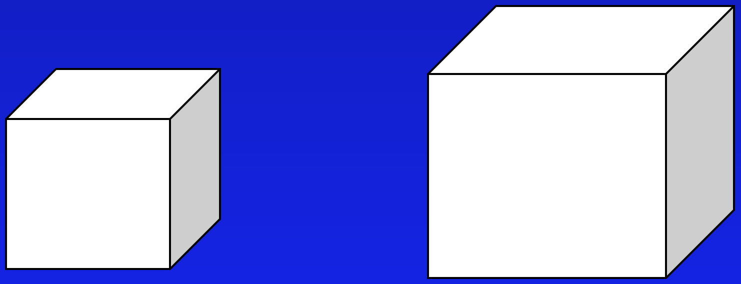
A. Increases

B. Decreases ← CORRECT

C. Stays the same

T = 0 C

T = 100 C



M, V_0

$\rho_0 = M / V_0$

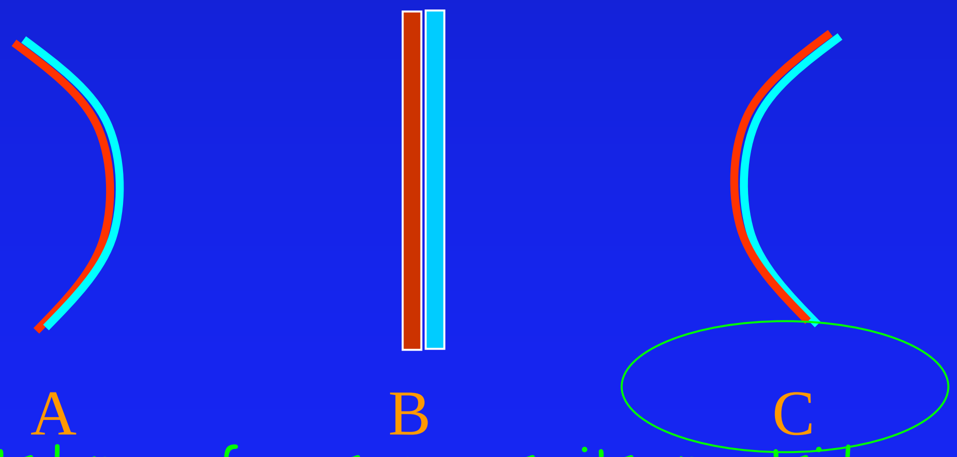
M, V_{100}

$\rho_{100} = M / V_{100}$

$< \rho_0$

Differential Expansion ACT

- A bimetallic strip is made with aluminum $\alpha=16 x 10^{-6}$ /K on the left, and iron $\alpha=12 x 10^{-6}$ /K on the right. At room temperature, the lengths of metal are equal. If you heat the strips up, what will it look like?



Aluminum gets longer, forces curve so its on outside

Swimming Checkpoint

Not being a great athlete, and having lots of money to spend, Gill Bates decides to keep the lake in his back yard at the exact temperature which will maximize the buoyant force on him when he swims. Which of the following would be the best choice?

A. 0 C

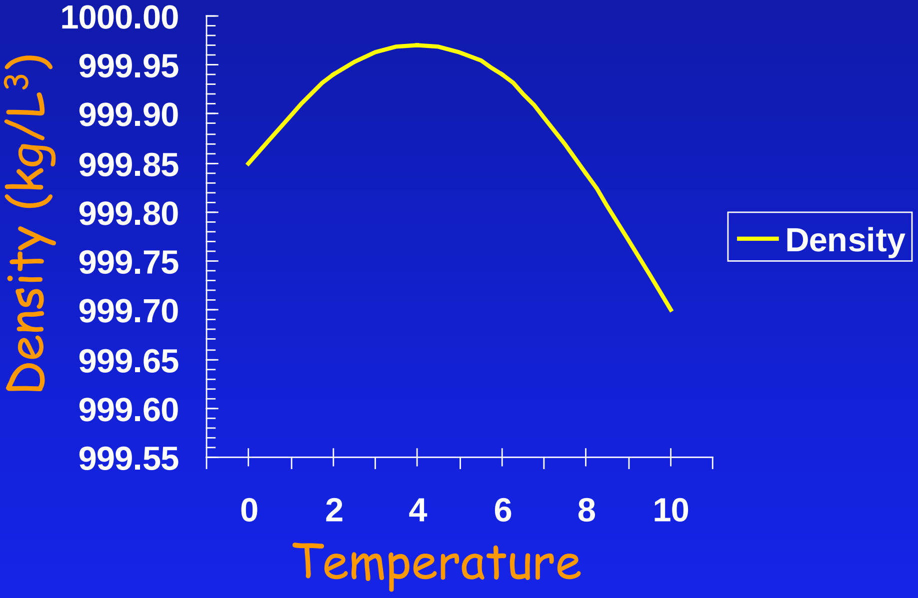
B. 4 C ← CORRECT

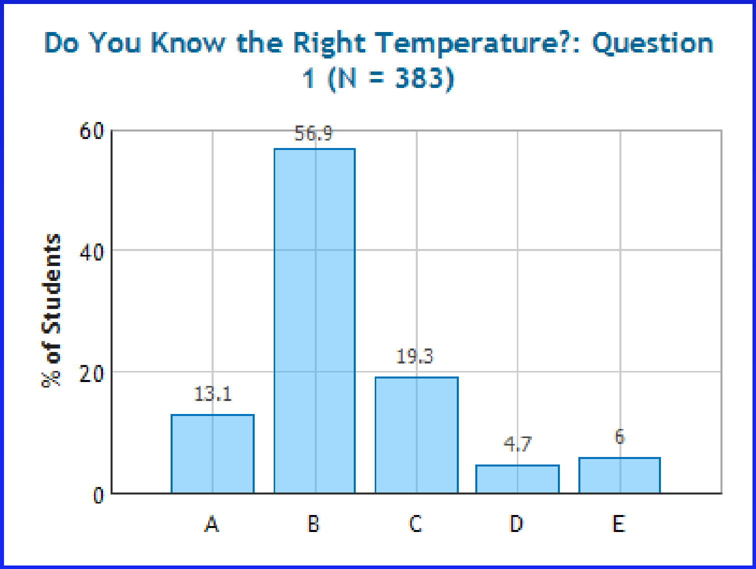
C. 32 C

D. 100 C

E. 212 C

$F_B = \rho_l V g$





water has maximum density at 4C and buoyant force is directly proportional to density

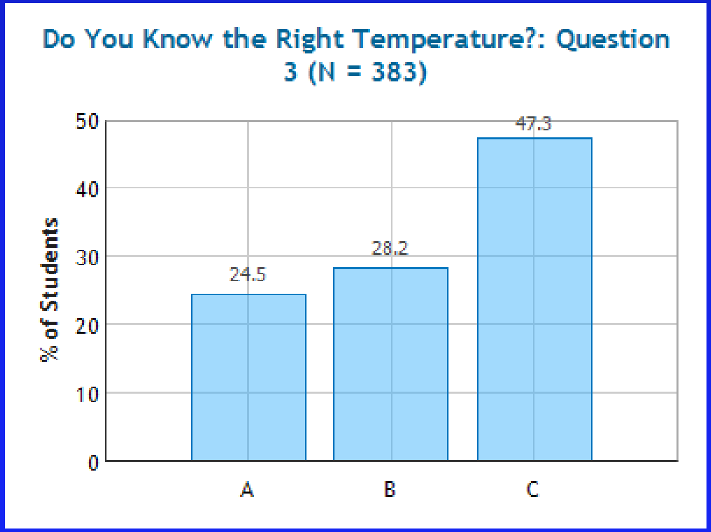
Tight Fit Checkpoint

An aluminum plate has a circular hole cut in it. An aluminum ball (solid sphere) has exactly the same diameter as the hole when both are at room temperature, and hence can just barely be pushed through it. If both the plate and the ball are now heated up to a few hundred degrees Celsius, how will the ball and the hole fit ?

A. The ball won't fit through the hole any more

B. The ball will fit more easily through the hole

C. Same as at room temperature ⟵ CORRECT

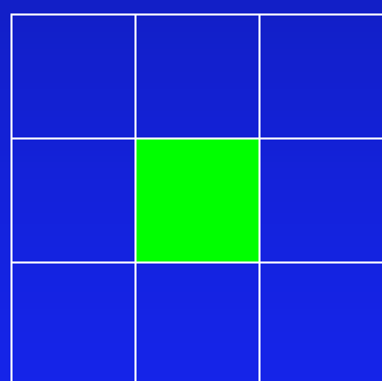


Both are made of the same material so heating it up will mean the objects will expand at the same rate.

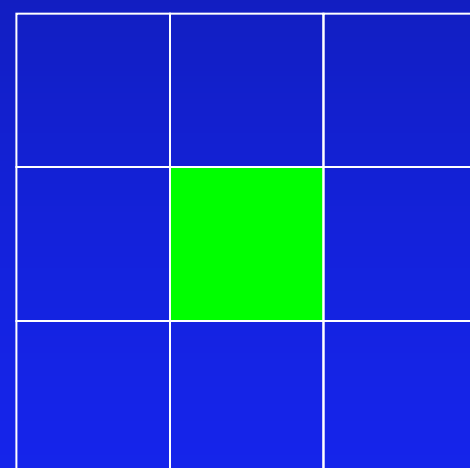
demo

Why does the hole get bigger when the plate expands ???

Imagine a plate made from 9 smaller pieces.
Each piece expands.
If you remove one piece, it will leave an "expanded hole"



Object at temp T



Same object at higher T:

Plate and hole both get larger

Stuck Lid Act

A glass jar ($\alpha = 3x10^{-6}\ K^{-1}$) has a metal lid ($\alpha=16x10^{-6}\ K^{-1}$) which is stuck. If you heat them by placing them in hot water, the lid will be

A. Easier to open ⟵ CORRECT

B. Harder to open

C. Same

Metal lid expands more, making a looser fit, and easier to open!

Jar Act

A cylindrical glass container ($\beta = 28 \times 10^{-6}$ K^{-1}) is filled to the brim with water ($\beta = 208 \times 10^{-6}$ K^{-1}) . If the cup and water are heated 50C what will happen

A) Some water overflows

B) Same

C) Water below rim

Water expands more than container, so it overflows.

See example 13.3 in book

Molecular Picture of Gas

- Gas is made up of many individual molecules
- Number density is number of molecules/volume $N/V = \rho/m$
  - ➔ ρ is the mass density
  - ➔ m is the mass for one molecule
- Number of moles $n = N / N_A$
  - ➔ N_A = Avogadro's number 6.022×10^{23} mole^{-1}

Number Density ACT

- Two gas cylinders are filled such that they have the same mass of gas (in the same volume). One cylinder is filled with Helium, the other with Oxygen. Which container has the larger number density?

A) Helium B) Oxygen C) Same

Helium atom is "lighter" than Oxygen molecule. If you have the same mass, you must have many more Helium molecules than Oxygen. So the Helium number density is larger.

Summary

- Temperature measure of average Kinetic Energy of molecules

- Thermal Expansion
  - ➔ $\Delta L = \alpha L_0 \Delta T$ (linear expansion)
  - ➔ $\Delta V = \beta L_0 \Delta T$ (volume expansion)

- Gas made up of molecules