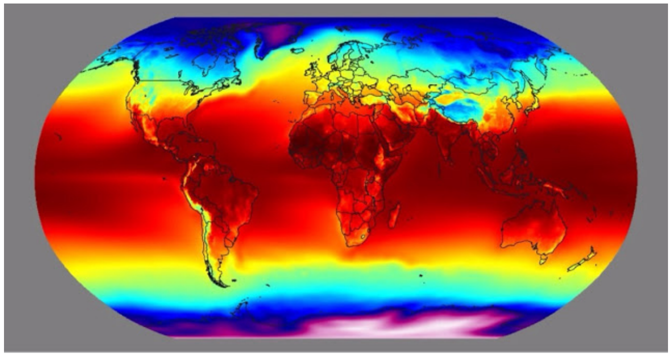
Physics 101: Lecture 24
Doppler Effect, Temperature and Ideal Gas



Doppler Effect
moving source v_s (s=source. o=observer)

How to determine if V_o and V_s are negative or positive.

- When source is coming toward you ($v_s > 0$)
  - ➡Distance between waves decreases (wavelength)
  - ➡Frequency is higher
- When source is going away from you ($v_s < 0$)
  - ➡Distance between waves increases (wavelength)
  - ➡Frequency is lower
- $f_o = f_s / (1 - v_s/v)$ (v is *speed of sound* in air)

Doppler Effect
moving observer (v_o)

- When moving toward source ($v_o < 0$)
  - Time between waves peaks decreases (wavelenth decreases)
  - Frequency is higher
- When away from source ($v_o > 0$)
  - Time between waves peaks increases (wavelength increases)
  - Frequency is lower
- $f_o = f_s\ (1 - v_o/v)$

Combine: $f_o = f_s\ (1 - v_o/v) / (1 - v_s/v)$

Doppler sign convention

Doppler shift: $f_o = f_s\ (1 - v_o/v) / (1 - v_s/v)$

$v_s = v(\text{source})$

$v_o = v(\text{observer})$

$v = v(\text{wave})$

Summary: Doppler sign convention

Doppler shift: $f_o = f_s\ (1 - v_o/v) / (1 - v_s/v)$

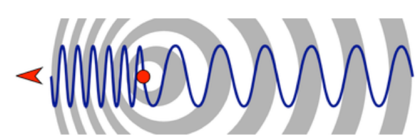
$v_s = v(\text{source})$

$v_o = v(\text{observer})$

$v = v(\text{wave})$

\+ If ***same*** direction as sound wave

\- If ***opposite*** direction to sound wave



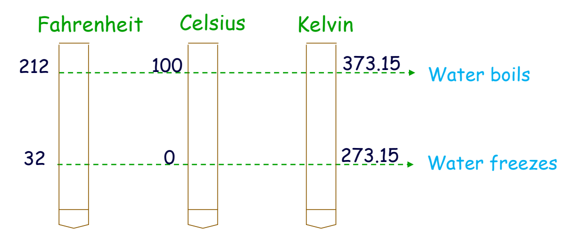
Internal Energy and Temperature

- 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”
    - » 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, they are at the same temperature
- If two objects are in thermal equilibrium with a third, then the two are in equilibrium with each other.

Temperature Scales



$$F = \frac{9}{5}C + 32$$

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

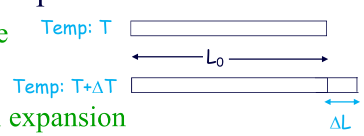
$$C = K - 273$$

$$K = C + 273$$

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

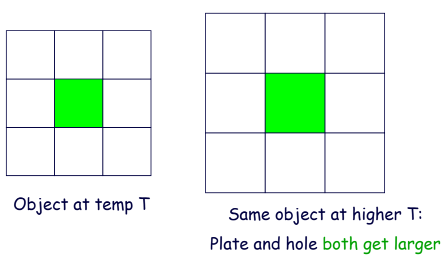
Thermal Expansion

- 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) ($\beta = 3\alpha$)



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"



Summary

- Doppler Effect $f_o = f_s (v-v_o) / (v-v_s)$
- 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)