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

# Doppler Effect Clicker Q

- **After** a police car passes you with its siren on, the frequency of the sound you hear from its siren

Doppler Example Audio

Doppler Example Visual

1) Increases 2) Decreases 3) Same

Hint: higher frequency means higher pitch sound, and lower frequency means lower pitch sound

# Doppler Effect
## (s=source, ℓ=listener)

- If either a source of sound (i.e., a siren), or a listener, is moving toward or away from each other (or if both are moving), a different frequency (pitch) is heard by the listener.
- The frequency heard by the listener is given by the following equation:

$$f_{listener} = \left[ \frac{v_{sound} \pm v_{listener}}{v_{sound} \mp v_{source}} \right] f_{source}$$

- Numerator: Use + if listener moves toward source and – if listener moves away from source.
- Denominator: Use – if source moves toward listener and + if source moves away from listener.

# Example

- A police siren emits a frequency of $f_{source}$=700 Hz. The police car is behind you and moving toward you at 60 mph and you are moving in the same direction as the police car at 45 mph. What frequency do you hear?

$$f_{listener} = \left[ \frac{v_{sound} \pm v_{listener}}{v_{sound} \mp v_{source}} \right] f_{source}$$

$$f_{listener} = \left[ \frac{761 \text{ mph} - 45 \text{ mph}}{761 \text{ mph} - 60 \text{ mph}} \right] 700 \text{ Hz} = 715 \text{ Hz}$$

- If the police car and you are moving toward each other it would be:

$$f_{listener} = \left[ \frac{761 \text{ mph} + 45 \text{ mph}}{761 \text{ mph} - 60 \text{ mph}} \right] 700 \text{ Hz} = 805 \text{ Hz}$$

# Doppler Clicker Q

A: You are driving along the highway at 65 mph, and behind you a police car, also traveling at 65 mph, has its siren turned on.

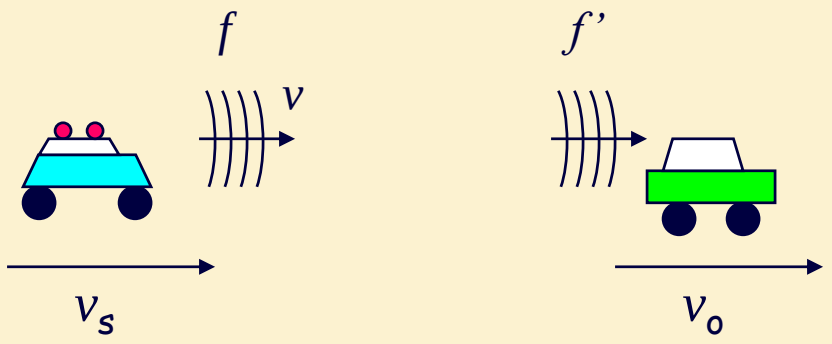
B: You and the police car have both pulled over to the side of the road, but the siren is still turned on.

In which case does the frequency of the siren seem higher to you?

A. Case A

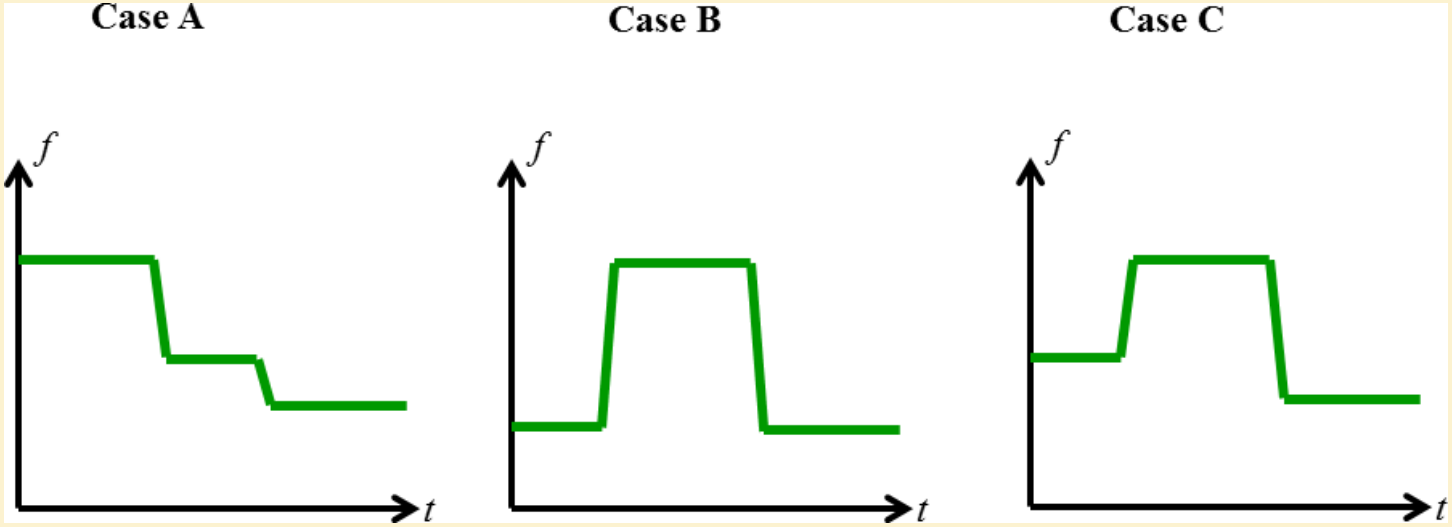
B. Case B

C. Same



# Checkpoint: Doppler

On a quiet day while standing on a sidewalk you hear a friend holding a tuning fork produce a pure 440 Hz sound tone. When she sees you, she begins to ride her bike toward you. When she passes by you, she does not stop; instead, she continues biking away from you. Which of the following plots best represents qualitatively the frequency you hear of the wave emitted by the tuning fork?



# Internal Energy and Temperature

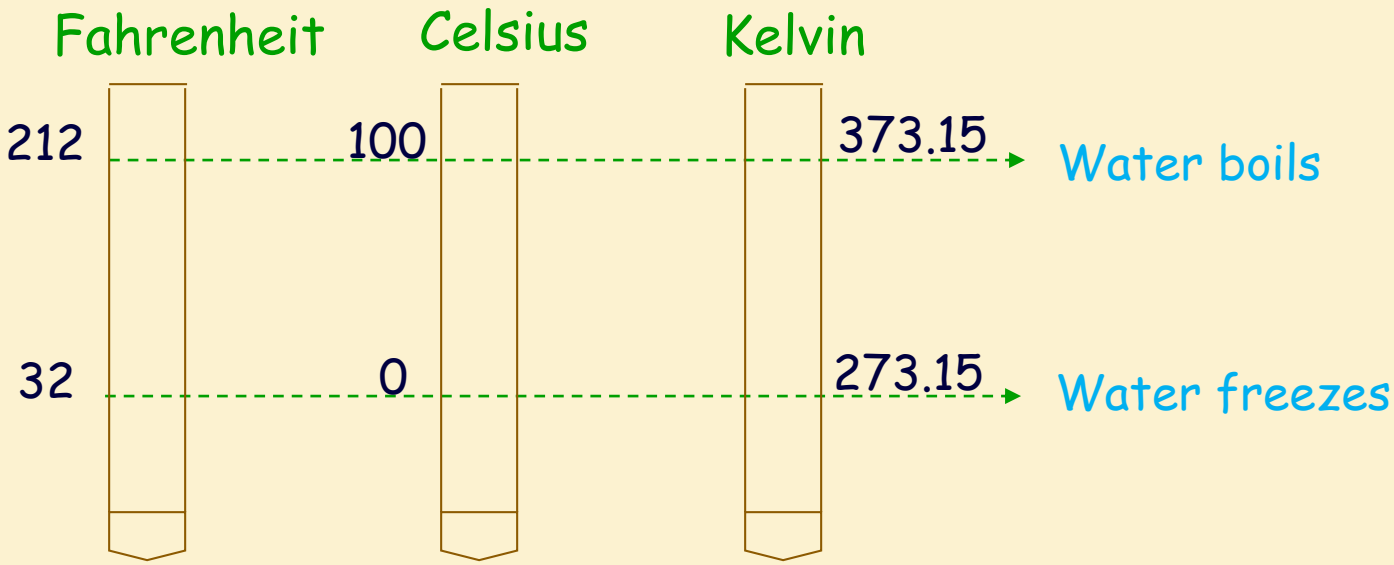
- All objects have “internal energy” (measured in Joules)
  - ➔random motion of molecules
    - » kinetic energy
  - ➔collisions of molecules gives rise to pressure
- Amount of internal energy depends on
  - ➔temperature
    - » related to average kinetic energy per molecule
  - ➔how many molecules
    - » 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

# Sick Clicker Q

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

C. 313 K

D. 317 K

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

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

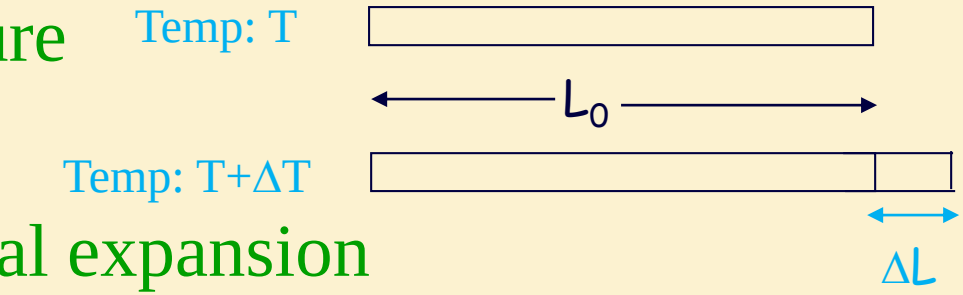
# Temp Scales Clicker Q

- 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

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



# Density Clicker Q

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

A. Increases

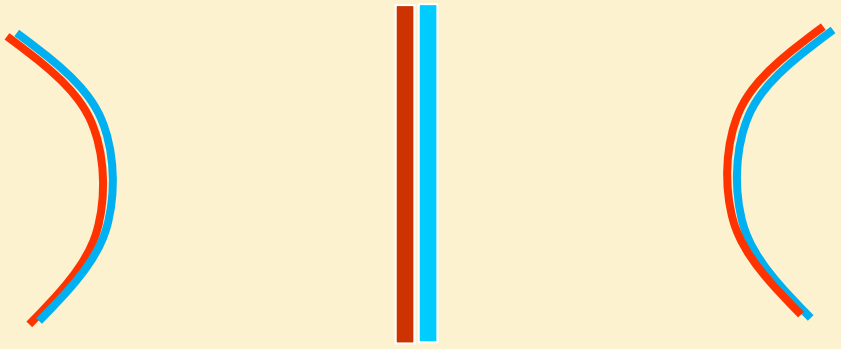
B. Decreases

C. Stays the same

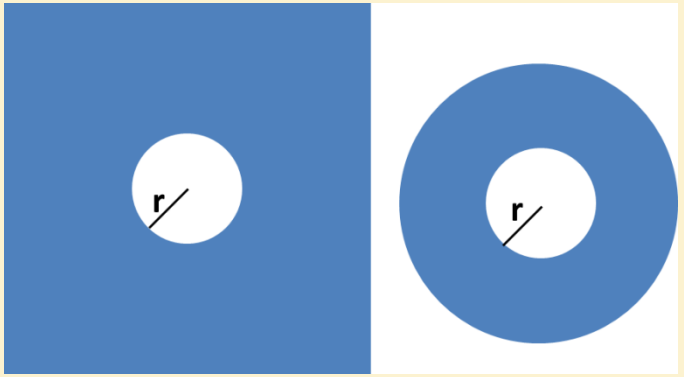
Reminder: density=M/V

# Differential Expansion Clicker Q

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



# Checkpoint 3




A circular hole, with a radius of 10 cm, is cut in the center of two aluminum plates. The aluminum plates have different shapes, as shown in the figure. The coefficient of linear expansion of aluminum is $2.4\times10^{-5}\ ^{\circ}C^{-1}$. If the temperature of each plate is increased by 20°C (an increase of about 36°F) above the starting temperature, then:

A. The area of the hole in the square plate will increase more than the area of the hole in the circular plate.

B. The area of the hole in the circular plate will increase more than the area of the hole in the square plate.

C. The area of the hole in each plate will increase by the same amount.

D. The area of the hole in each plate does not change.

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

To be discussed in class

# Stuck Lid Clicker Q

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

B. Harder to open

C. Same

# Jar Clicker Q

A cylindrical glass container ($\beta = 28x10^{-6}\ K^{-1}$) is filled to the brim with water ($\beta=208x10^{-6}\ K^{-1}$). If the cup and water are heated 50C what will happen?

A) Some water overflows

B) Same

C) Water below rim

# Summary

- Doppler Effect

$$f_{listener} = \left[ \frac{v_{sound} \pm v_{listener}}{v_{sound} \mp v_{source}} \right] f_{source}$$

- 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)