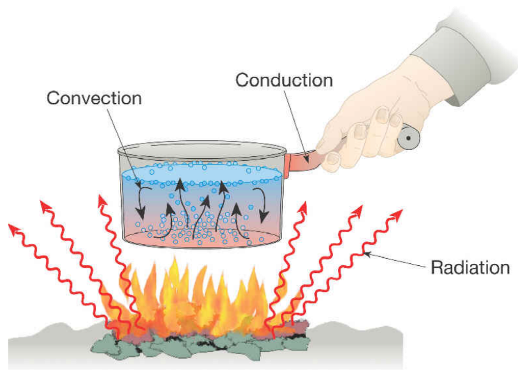
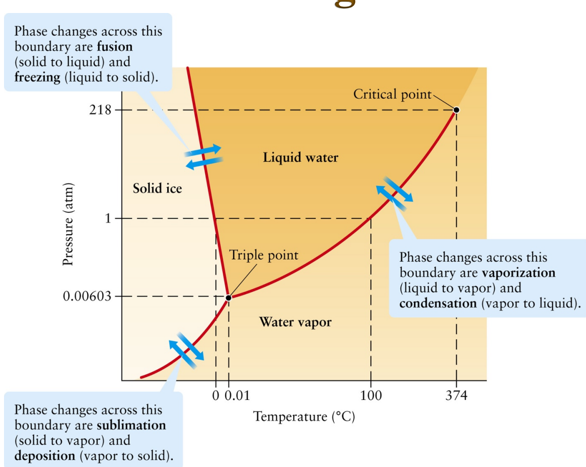
Physics 101: Lecture 27
Phase Diagrams, Heat Transfer by Conduction, Convection, & Radiation

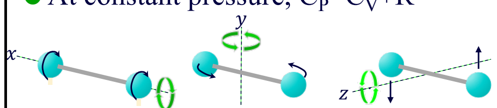


Phase Diagrams



Specific Heat for Ideal Gas

- Monatomic Gas (single atom)
  - All energy is translational Kinetic
  - At constant Volume work = 0
  - $Q = \Delta K_{tr} = 3/2\ nR\Delta T = C_V\ n\ \Delta T$
  - $C_V = 3/2\ R = 12.5$ J/(K mole) (molar heat capacity at cst vol)
- Diatomic Gas (two atoms)
  - Can also rotate
  - $C_V = 5/2\ R = 20.8$ J/(K mole)
- At constant pressure, $C_P = C_V + R$



	Gas	$C_V\left(\frac{J/K}{mol}\right)$
Monatomic	He	12.5
	Ne	12.7
	Ar	12.5
Diatomic	H_2	20.4
	N_2	20.8
	O_2	21.0
Polyatomic	CO_2	28.2
	N_2O	28.4

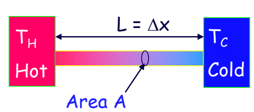
Review

- Heat is FLOW of energy
  - Flow of energy may increase temperature
- Specific Heat, c
  - $Q = mc\Delta T$, (Solids & liquids)
  - $Q = nC\Delta T$, (gases, where C is at constant V or P)
- Latent Heat, L
  - heat associated with change in phase
  - $Q = m L$
- Today: Mechanisms of Heat Flow
  - Conduction
  - Convection
  - Radiation

07

Heat Transfer: Conduction

- Hot molecules have more KE than cold molecules
- High-speed molecules on left collide with low-speed molecules on right *teaspoons get hot in hot coffee*
  - energy transferred to lower-speed molecules
  - heat transfers from hot to cold
- H = rate of heat transfer = Q/t [J/s]
  - $H = \kappa A (T_H - T_C)/L$
    - » $Q/t = \kappa A \Delta T/\Delta x$
  - κ = "thermal conductivity"
    - » Units: J/s-m-C
    - » good thermal conductors…high κ
    - » good thermal insulators … low κ

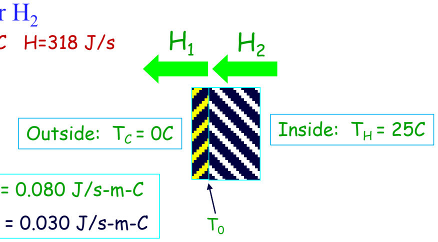


demos

13

Conduction w/ 2 layers

- Find H=Q/t in J/s
  - Key Point: Continuity (just like fluid flow)
    - » $H_1 = H_2$
    - » $\kappa_1 A(T_0 - T_C)/\Delta x_1 = \kappa_2 A(T_H - T_0)/\Delta x_2$
    - » solve for T_0 = temp. at junction
    - » then solve for H_1 or H_2
      - answers: T_0=2.27 C H=318 J/s



Δx_1 = 0.02 m A_1 = 35 m^2 κ_1 = 0.080 J/s-m-C

Δx_2 = 0.075 m A_1 = 35 m^2 κ_2 = 0.030 J/s-m-C

Conduction Clicker Q

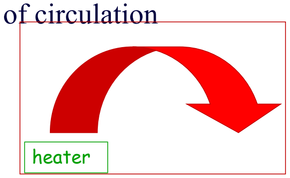
- Which marbles will fall **last**?

1) Copper 2) Steel 3) Aluminum

Material	$\kappa\left(\frac{W}{m \cdot K}\right)$
Air	0.023
Rock wool	0.038
Cork	0.046
Wood	0.13
Soil (dry)	0.14
Asbestos	0.17
Snow	0.25
Sand	0.39
Water	0.6
Glass	0.63
Concrete	1.7
Ice	1.7
Stainless steel	14
Lead	35
Steel	46
Nickel	60
Tin	66.8
Platinum	71.6
Iron	72.8
Brass	122
Zinc	116
Tungsten	173
Aluminum	237
Gold	318
Copper	401
Silver	429

Heat Transfer Convection

- Air heats at bottom
- Thermal expansion…density gets smaller
- Lower density air rises
  - Archimedes: low density floats on high density
- Cooler air pushed down
- Cycle continues with net result of circulation of air
- Practical aspects
  - heater ducts on floor
  - A/C ducts on ceiling
  - stove heats water from bottom
  - "riding the thermals"



demos

Heat Transfer: Radiation

- All things radiate electromagnetic energy
  - $H_{emit} = Q/t = eA\sigma T^4$
    - » e = emissivity (between 0 and 1)
      - perfect "black body" has e=1
    - » T is temperature of object in Kelvin
    - » σ = Stefan-Boltzmann constant = 5.67×10^{-8} J/s-m^2-K^4
  - No "medium" required
- All things absorb energy from surroundings
  - $H_{absorb} = eA\sigma T_0^4$
    - » T_0 is temperature of surroundings in Kelvin
    - » good emitters (e close to 1) are also good absorbers

Surroundings at T_0

T ← Hot stove

DEMO

Heat Transfer: Radiation

- All things radiate and absorb electromagnetic energy
  - $H_{emit} = eA\sigma T^4$
  - $H_{absorb} = eA\sigma T_0^4$
  - $H_{net} = H_{emit} - H_{absorb} = eA\sigma(T^4 - T_0^4)$
    - » if $T > T_0$, object cools down
    - » if $T < T_0$, object heats up

Surroundings at T_0

T ← Hot stove

Summary

- Conduction - contact
- Convection - fluid motion
- Radiation