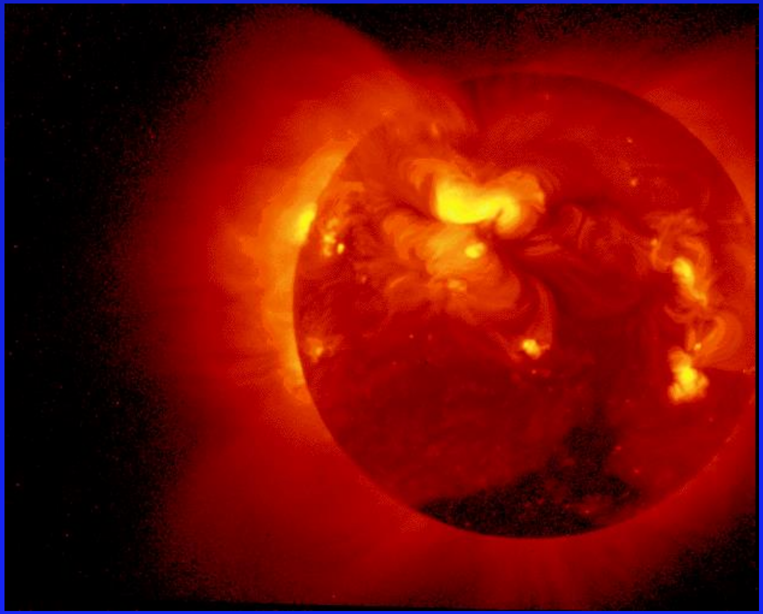
FINAL

Physics 101: Lecture 26
Conduction, Convection, Radiation

Today's lecture will cover Textbook Chapter 14.4-14.9

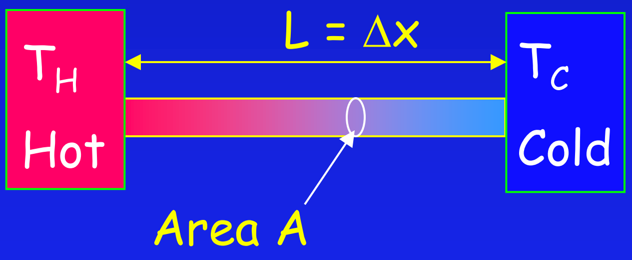


Review

- Heat is FLOW of energy
  - ➔ Flow of energy may increase temperature
- Specific Heat, c
  - ➔ $Q = mc\Delta T$, $\Delta T = Q / (m\ c)$
- Latent Heat, L
  - ➔ heat associated with change in phase
  - ➔ $Q = m\ L$
- Today: Mechanisms of Heat Flow
  - ➔ Conduction
  - ➔ Convection
  - ➔ Radiation

Heat Transfer: Conduction

- Hot molecules have more KE than cold molecules
- High-speed molecules on left collide with low-speed molecules on right *teaspoons*
  - ➔ 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

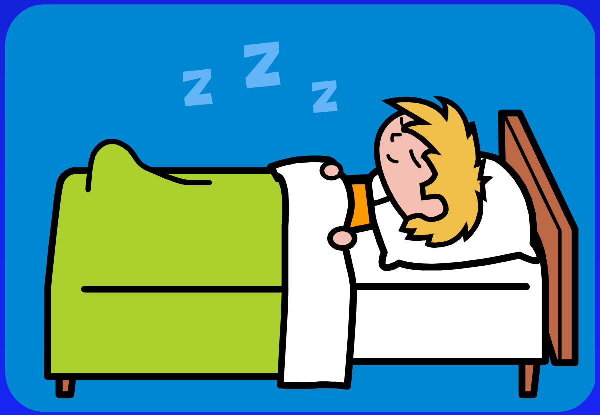
Conduction ACT

- On a cold winter night, which will keep you warmer in bed.

A) A thin cotton sheet

B) A thick wool blanket

C) Either one



Prelecture 1

On a cool night you make your bed with a thin cotton sheet covered by a thick wool blanket. As you lay there all covered up, heat is leaving your body, flowing though the sheet and the blanket and into the air of the room. Compare the amount of heat that flows though the sheet to the amount of heat that flows through the blanket.

1. More heat flows through sheet than through the blanket.
2. More heat flows through blanket than through the sheet.
3. The same amount of heat flows through sheet as the blanket.

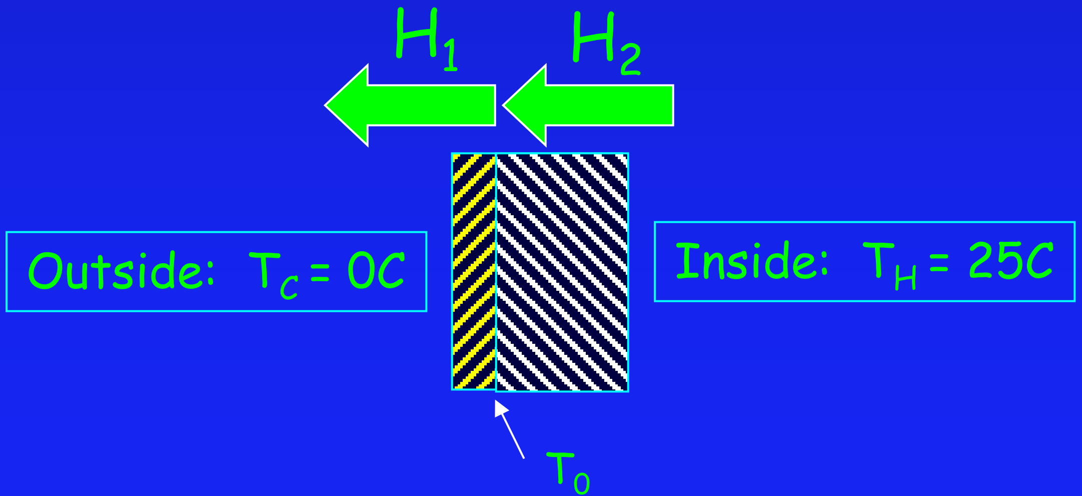
Conduction w/ 2 layers ACT

- Compare the heat flow through material 1 and 2.

  A) $H_1 > H_2$ B) $H_1 = H_2$ C) $H_1 < H_2$

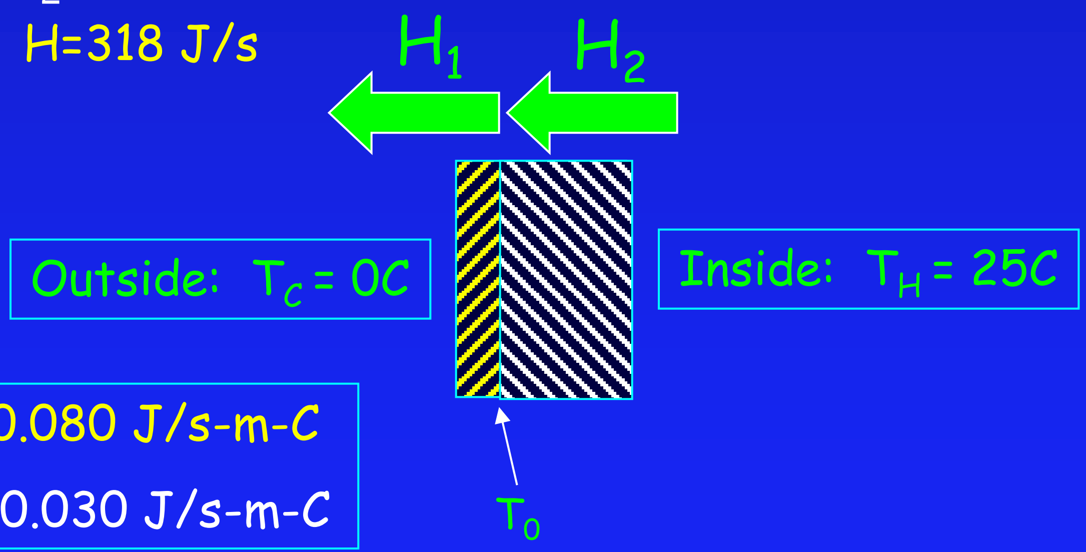
- Estimate T_0, the temperature between the two

  A) 2 C B) 12.5 C C) 20 C



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



$\Delta x_1 = 0.02$ m $A_1 = 35$ m^2 $k_1 = 0.080$ J/s-m-C

$\Delta x_2 = 0.075$ m $A_1 = 35$ m^2 $k_2 = 0.030$ J/s-m-C

Conduction ACT

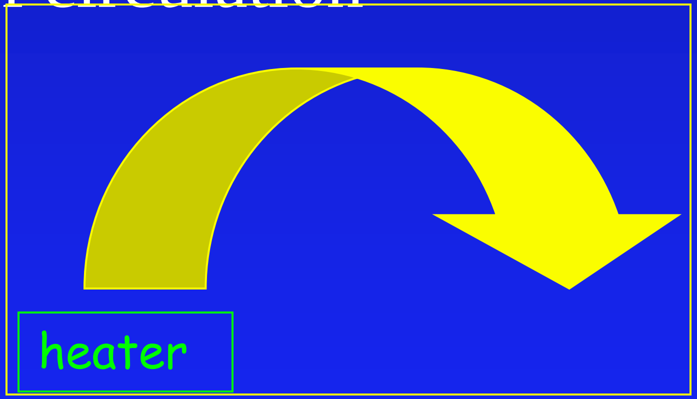
- Which marbles will fall last?

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

DEMO

- All things absorb energy from surroundings
  - ➔ $I_{absorb} = eA\sigma T_0^4$
    - » T_0 is temperature of surroundings in Kelvin
    - » good emitters (e close to 1) are also good absorbers

Heat Transfer: Radiation

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

HW

Earth Homework

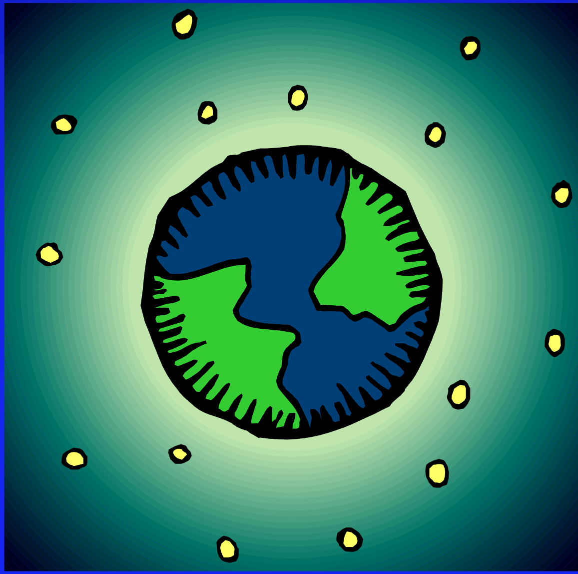
The Earth has a surface temperature around 270 K and an emissivity of 0.8, while space has a temperature of around 2 K. What is the net power radiated by the earth into free space?

(Radii of the Earth and the Sun are $R_e = 6.38 \times 10^6$ m, $R_s = 7 \times 10^8$ m.)

$$I_{net} = I_{emit} - I_{absorb} = eA\sigma(T^4 - T_0^4)$$

$$= \left(5.76\times10^{-8}\right)\left(4\pi R_{earth}^2\right)(0.8)\left(270^4 - 2^4\right)$$

$$= 1.23\times10^{17} \text{ Watts}$$



Prelecture

One day during the winter, the sun has been shining all day. Toward sunset a light snow begins to fall. It collects without melting on a cement playground, but it melts immediately upon contact on a black asphalt road adjacent to the playground. How do you explain this.

Summary

- Conduction - contact
- Convection - fluid motion
- Radiation