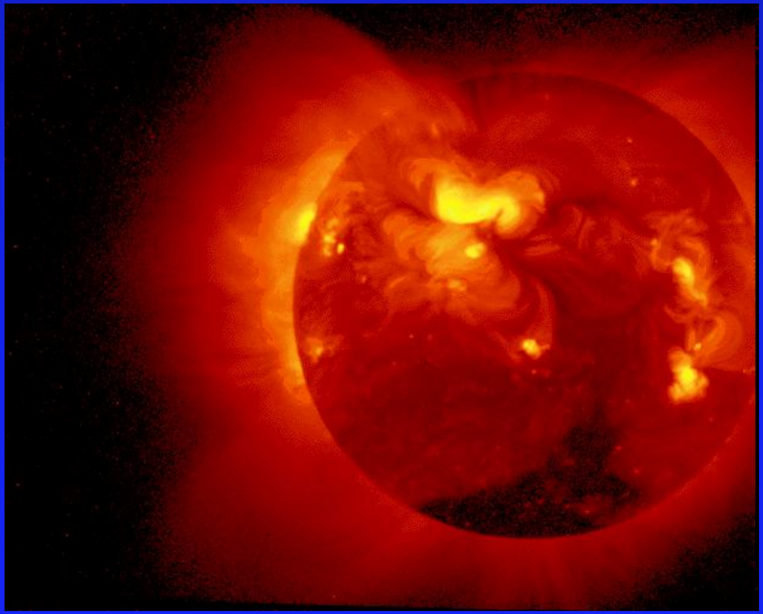
FINAL

Physics 101: Lecture 26
Conduction, Convection, Radiation

Today's lecture will cover Textbook Chapter 14.4-14.9



Calendar

Today: HE 3 at 7pm, conflict at 5:15pm

There is quiz 11 this week.

Wed April 25 lecture: Thermodynamics I
Mon April 30 lecture: Thermodynamics II (Last lecture)
Wed May 2: No lecture.

Check your grades in grade book!

Finals: Wed May 9: 7 pm – 10 pm
Fri May 11: 7 pm – 10 pm

Finals practice exam (key) will be posted on Google group tomorrow.

You can sign up for either: Deadline for signup is 10 pm, Monday April 30.

Decibels/Log problems

$$\beta_2 - \beta_1 = (10\ \text{dB})\ \text{lo}_{10}(I_2/I_1)$$

$$I = P / A = P/(4\pi R^2)$$

Thermal expansion in 1D, 2D, 3D

- » $\Delta L = \alpha L_0 \Delta T$ (linear expansion)
- » $\Delta A = 2\alpha A_0 \Delta T$ (area expansion)
- » $\Delta V = \boxed{3\alpha} V_0 \Delta T$ (volume expansion)

$=\beta$

Review

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

How much heat goes through a window per second?

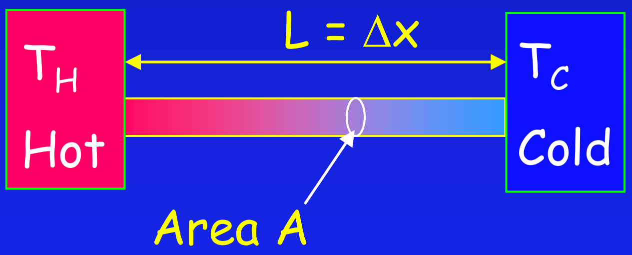
-This depends on the thickness, area, and materials of window as well as on the temperature difference inside/outside.

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

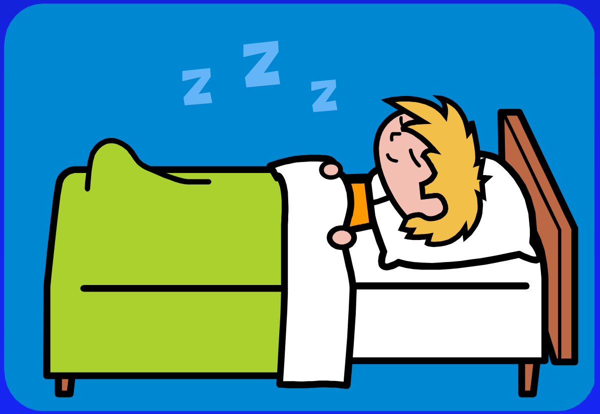
Conduction ACT

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

A) A thin cotton sheet

B) A thick wool blanket

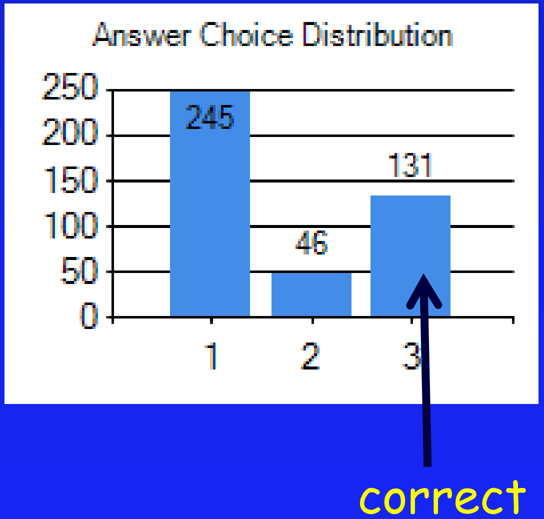
C) Either one



Preflight 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.



The area between the sheet and the blanket is not getting hotter or colder. The same amount of heat flows.

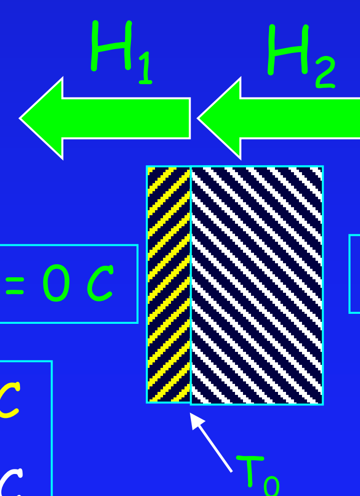
Conduction w/ 2 layers ACT

- 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



Outside: $T_C = 0$ C

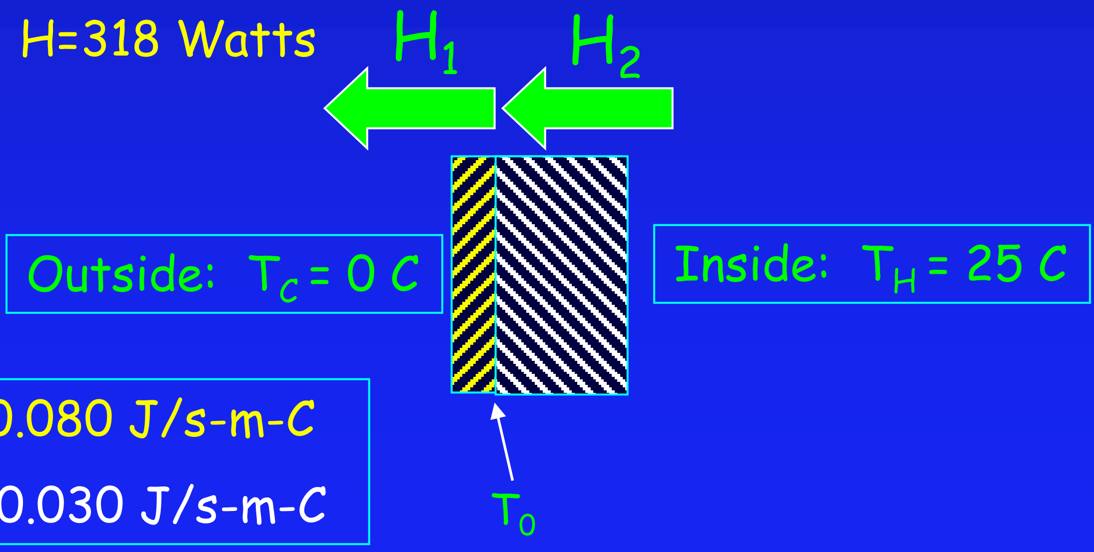
Inside: $T_H = 25$ C

$\Delta x_1 = 0.02$ m $A_1 = 35$ m^2 $\kappa_1 = 0.080$ J/s-m-C

$\Delta x_2 = 0.075$ m $A_2 = 35$ m^2 $\kappa_2 = 0.030$ J/s-m-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 Watts



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 ACT

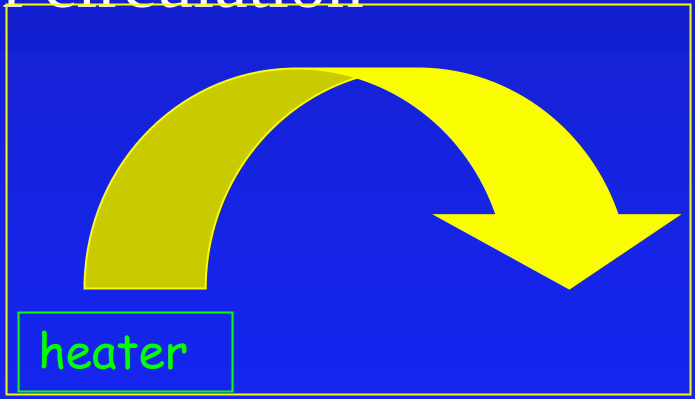
- Which marbles will fall last?

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
  - ➔ $I_{emit} = Q/t = eA\sigma T^4$
    - » 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

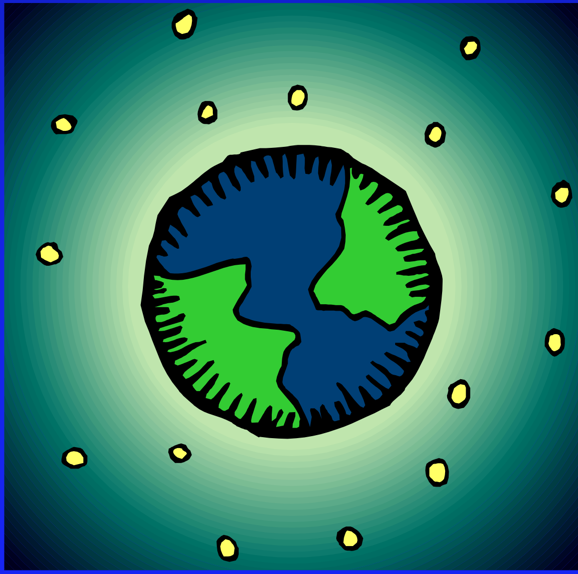
The Earth has a surface temperature around 270 K and an emissivity of 0.8, while space has a temperature of around 2 K. What is the net power radiated by the earth into free space?

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

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

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

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



Preflight

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.

Black absorbs heat so the asphalt is hotter

The black asphalt contains salt.

I want summer!

physics

Summary

- Conduction - contact
- Convection - fluid motion
- Radiation