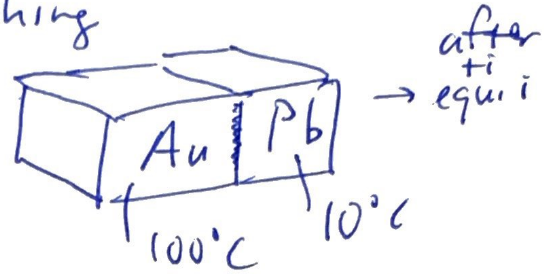
14B Heat Transfer

There are three ways to transfer heat

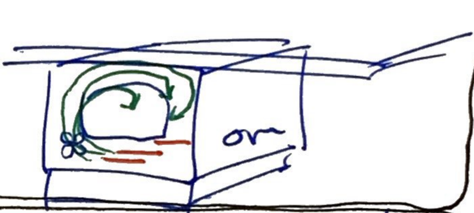
- **Conduction**: place solid objects next to each other, touching



@ the interface the vibration of one substance causes the other to vibrate more rapidly also.

- **Covection**: (moving the heat from one locatin to the other - liquid or air)

  EX Convection oven



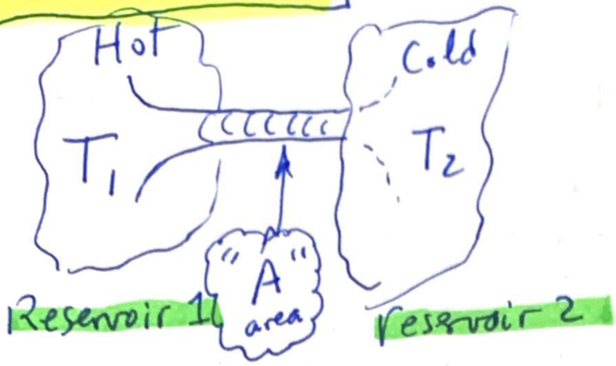
  EX Forced air in Heating Systems @ Home/Car

- **Radiation**: (Electromagnetic Radiatin or Particle radiation)

  EX Heat Lamp
  Infrared
  No moving air

  EX In the "martian" mark Watney used a mars' rover's thermonuclear electricity generatin device to heat the Personell transporter.

⊛ Conduction



Rate of Heat transfer

- $\frac{\Delta Q}{\Delta t} \propto \Delta T$, Larger Difference in Temp. means faster transfer rate
- $\frac{\Delta Q}{\Delta t} \propto$ Area
- $\frac{\Delta Q}{\Delta t} \propto \frac{1}{\text{length}}$

$$\Rightarrow \quad \boxed{\frac{\Delta Q}{\Delta t} = k\,\frac{A \cdot \Delta T}{l}}$$

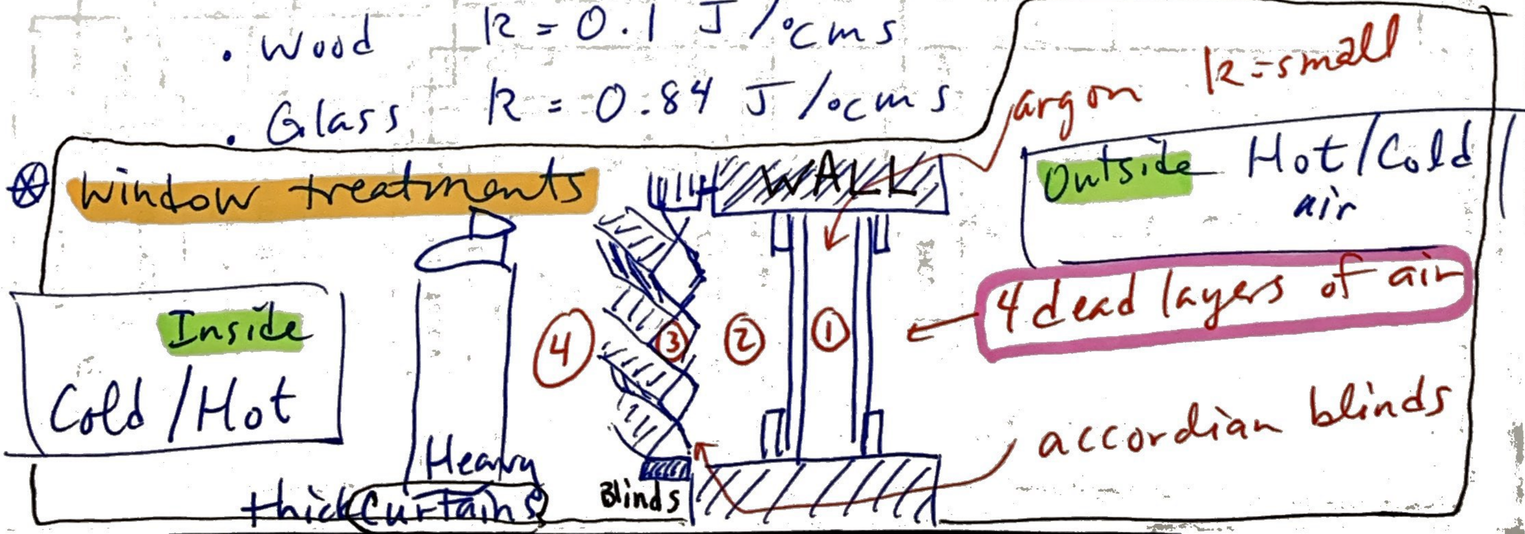
rate of heat transfer for conduction

k = coefficient of thermal conductivity

k is large ⇒ good thermal conductor
k is small ⇒ good thermal insulator

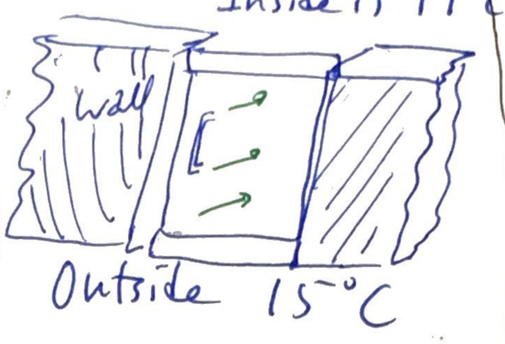
(ex)
- Silver $k = 420\ J/°C/m/s = 420\ \frac{J}{°C \cdot m \cdot s}$
- Goose Down $k = 0.025\ J/°Cms$
- Air $k = 0.023\ J/°Cms$
- Wood $k = 0.1\ J/°Cms$
- Glass $k = 0.84\ J/°Cms$

⊛ Window treatments



EX What is the rate of heat loss of a single pane of glass whose area is $3.0 m^2$ and thickness is 0.0032 m

$$\frac{\Delta Q}{\Delta t} = \frac{k(T_H - T_c)A}{l}$$



$$= \left(0.84 \frac{J}{°C\,m\,s}\right)\left(\frac{15°C - 14°C}{0.0032\,m}\right)(3\,m^2)$$

k_{glass}

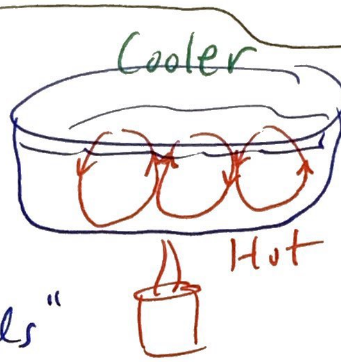
$$\Rightarrow \boxed{\frac{\Delta Q}{\Delta t} = 790\,J/s}$$

790 Joules lost every second.

④ Convection

Liquid cools at top, heats at bot

⇒ "Convection cells"



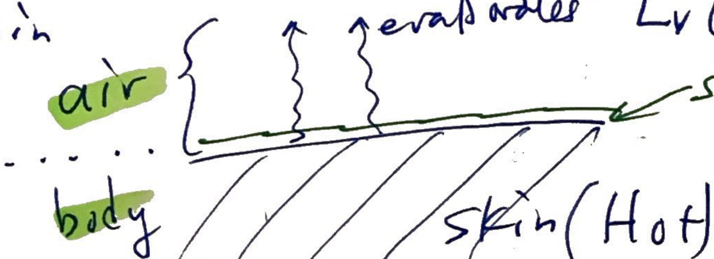
Tomato Soup

• Heat is being transfered.

Hot medium is less dense and Bouyancy forces the liquid up. But there it cools and becomes more dense and sinks back down.

EX Blood vessels transports heat in our bodies

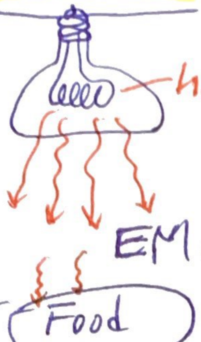
EX Sweating: water evaporation removes heat from our skin



⊛ Radiation (EM radiation like Infrared)

microwave

Heat Lamp:

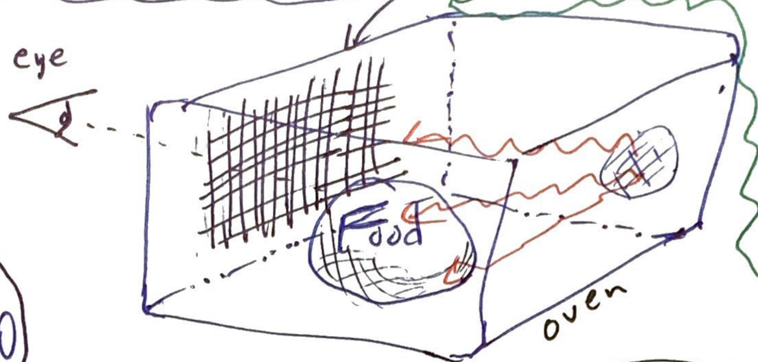


hot filament: electricity wiggles the metalic atoms, then they radiate EM radiation

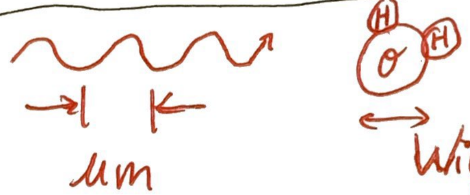
EM rays will then wiggle the Food's surface's atoms, which then propagates to the inside.

(radiation wiggles the atoms in the surface of the food.

Microwave ovens are similar but the radiation is "tuned" to H_2O structure.



Microwave Oven door: holes lets out visible EM but stop the microwave EM.



Wiggles the water molecule.

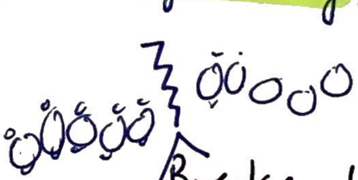
That wiggling is "Temperature" that spreads to the surrounding material

*"Convection & microwave" → turbochef ovens

NOTICE: ((90.7 FM, → democracynow.org, thom hartman {pod-cast}))

¡ microwaves destroy good enzymes!..

good Enzyme



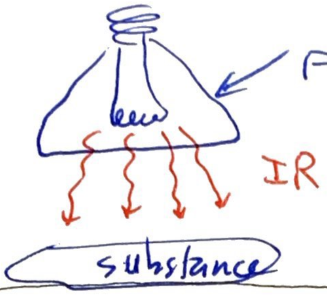
Useless broken enzymes.

Breaks at the "water-like" molecule in the enzyme.

Bottom Line: Fighting weight? Ditch the microwave!

The convection model uses fluid dynamic eqns with specific heat together.

<u>Radiation (Cont.)</u> (Electromagnetic heat transfer)



Filament heats up. EM Radiation is emitted. This transfers heat to our substance

Model : $\frac{\Delta Q}{\Delta t} \propto T^4$ Stephan-Boltzmann

also $\frac{\Delta Q}{\Delta t} \propto A$ of exposed surface

also $\frac{\Delta Q}{\Delta t} \propto$ type of material being irradiated.

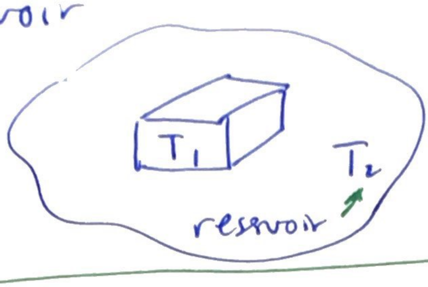
$\Rightarrow$ $$\frac{\Delta Q}{\Delta t} = \epsilon \sigma A T^4$$ Stephan-Boltzmann Law

σ = Boltzmanns Const = $5.76 \times 10^{-8}\ W/m^2/K^4$

ϵ = emissivity of a material

- $\epsilon = 0$ shinny reflect energy
- $\epsilon = 1$ black like charcoal absorbs energy

* For two mediums, object next to a reservoir

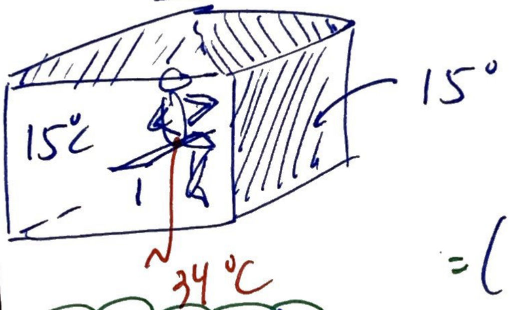


$$\frac{\Delta Q}{\Delta t} = \epsilon \sigma A \left(T_1^4 - T_2^4\right)$$

(ϵ: emitter (hotter))

EX Assume a person in the gym is working out in a dark room (dark blue walls).

* Estimate the body's heat Loss of the person sitting on the bench in the blue room if $\epsilon = 0.7$ (body insulation), $T_{Body} = 34°C$, $A_{body} = 1.5\,m^2$



$$\frac{\Delta Q}{\Delta t} = \epsilon \sigma A \left(T_{Hot}^4 - T_{cold}^4\right)$$

$$= (0.7)\left(5.67 \times 10^{-8} \frac{W}{m^2 \cdot K^4}\right)(1.5\,m^2)\left[(273+34)^4 - (273+15)^4\right]$$

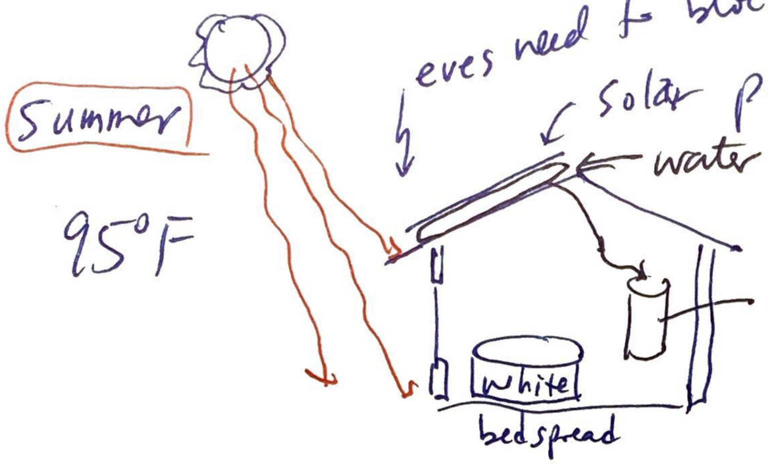
$$= \underline{120 \text{ Joules lost per sec}}$$

Blue (dark) walls will not re-reflect your heat

Note: While taking exams, people generate 100 W of heat.

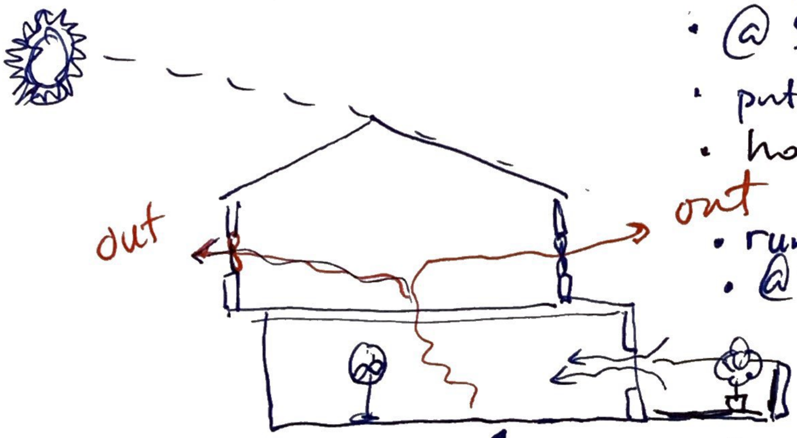
Application

(*) passive home heating



(*) passive home cooling {saves $1000/summer}

- @ 3pm turn on interior fans
- @ 5pm open windows: up & down stairs
- put fans in upstairs blowing out
- hose down the patio with water every 30 minutes till 7pm (4X)
- run fans all night Long
- @ 7am button down the house
  - close windows
  - lower blinds upstair
  - Keep doors closed



Installed a ceramic floor: retains coolness
All Night long the floor & walls & furniture is cooling

Ex on the beach

Q: what is the rate of increase of heat from the Sun on a tanning body on the beach?

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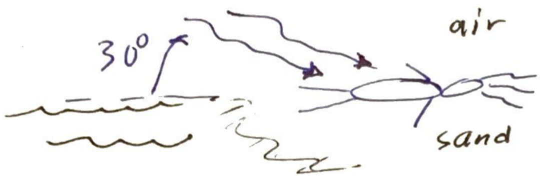
let the sun's rays fall on the person @ 30°



$\epsilon = 0.70$ body
use solar constant
1000 W/m²

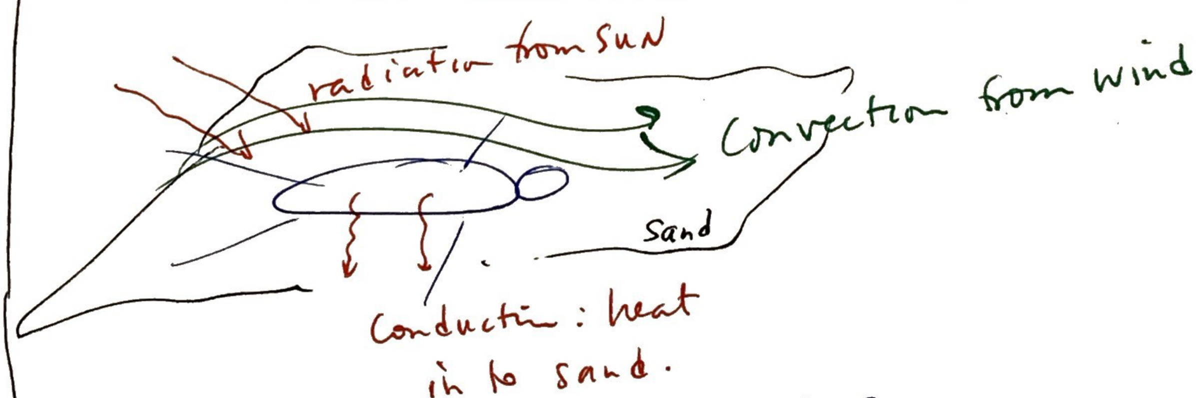
$$\frac{\Delta Q}{\Delta t} = (1000\ \mathrm{W/m^2})\,\epsilon\,(A \sin\theta)$$

$k(T_H^4 - T_C^4)$ "solar constant of 1000 W/m² replaces"

$$= \left(1000\ \frac{\mathrm{W}}{\mathrm{m^2}}\right)(0.7)\left(\frac{1.5\,\mathrm{m^2}}{2}\right)\sin(30^\circ)$$

↑ half-body faces sun

$$\boxed{\frac{\Delta Q}{\Delta t} = 250\,\mathrm{W}\ \text{rate of heat absorbed}}$$



end of chpt 14.

Up next: Thermodynamics (15)