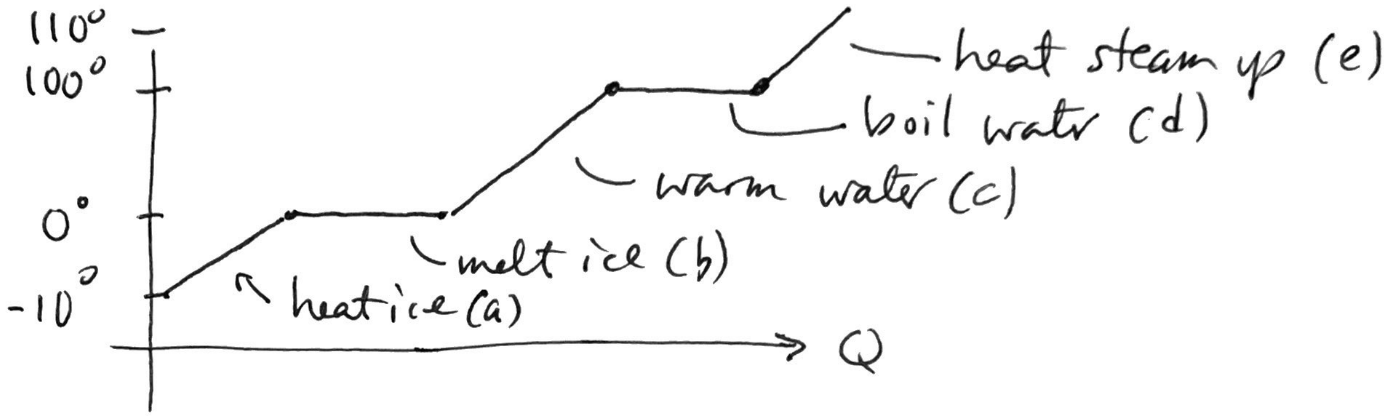
14B Heat Transfer

Review Heating a sub frozen block of ice untill we have super heated steam



Let $m_{ice} = 7\,kg$. How much heat is need to go from $-10°C$ to $110°C$?

(a) warm up ice: $Q = m\,c_{ice}\,\Delta T = (7\,kg)(2100\,\frac{J}{kg\,°C})(10°C)$
$= \underline{147\,kJ}$

(b) melt ice: $Q = m\,L_F = (7\,kg)(333{,}000\,J/kg) = \underline{2{,}331\,kJ}$

(c) warm the water: $Q = m\,c_{H_2O}\,\Delta T = (7\,kg)(4186\,\frac{J}{kg\,°C})(100°C)$
$= \underline{2{,}930\,kJ}$

(d) boil off all water: $Q = m\,L_v = (7\,kg)(2{,}260{,}000\,J/kg) =$
$= \underline{15{,}820\,kJ}$

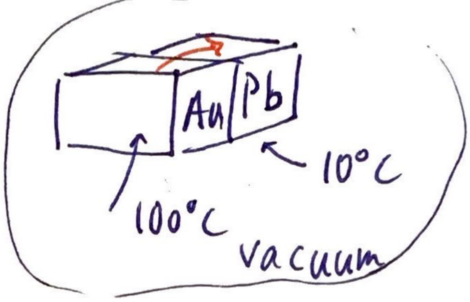
(e) heat the steam: $Q = m\,c_{steam}\,\Delta T = (7\,kg)(2010\,\frac{J}{kg\,°C})(10°C)$
$= \underline{140.7\,kJ}$

Total Q: $(147 + 2331 + 2930 + 15820 + 141)\,kJ = \boxed{21{,}369\,kJ}$

* Heat Transfer

We have three primary way to move heat.

- Conduction (objects in contact with each other, no motion)



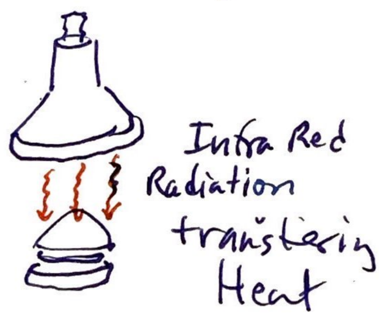
{ at the interface the wiggling atoms of one material wiggles the atoms of the next. This propagates through the object.

- Convection (moving the medium that transfers heat)

{ newer convection ovens move the internal air

- Radiation (Electromagnetic Radiation or Particle radiation)

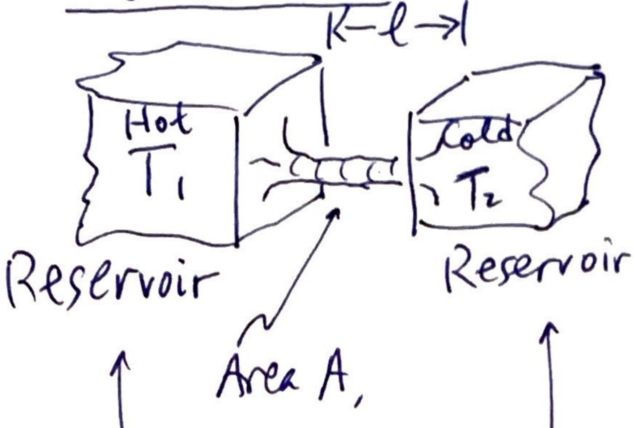
Heat Lamp



Video: In "The Martian" Mark Watney uses a thermonuclear device to heat a cabin up.

"the science behind 'The martian' staying warm on Mars"

⊛ Conduction



$$\frac{\Delta Q}{\Delta t} \propto \Delta T \qquad \frac{\Delta Q}{\Delta t} \propto \frac{1}{l}$$

$$\frac{\Delta Q}{\Delta t} \propto A$$

"Temperatures will not change"

rate of heat transfered

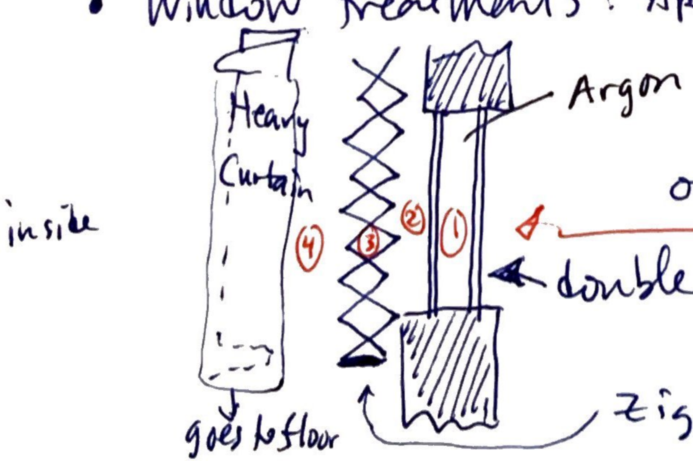
$$\boxed{\frac{\Delta Q}{\Delta t} = k \frac{A(\Delta T)}{l}}$$

k = thermal conductivity

- If k is larger we have a good thermal conductor
- If k is small then we have a good insulator

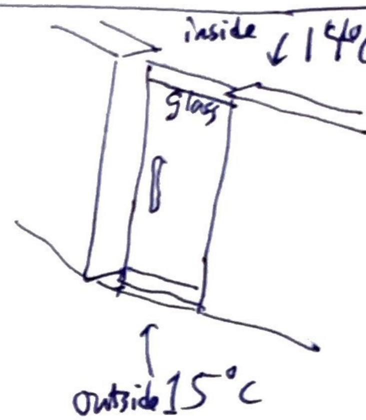
Silver	$k = 420\ J/°C/m/s = \boxed{420 \frac{J}{°C \cdot m \cdot s}}$
Goose Down	$k = 0.025\ \frac{J}{°C\,m\,s}$
Air	$k = 0.023\ J/°C \cdot m \cdot s$ → bubble wrap
Wood	$k = 0.1\ J/°C \cdot m \cdot s$
Glass	$k = 0.84$

- Window treatments: Application



4 layers of air slow heat loss in winter & heat injection in summer.

EX What is the heat loss (rate of heat loss) of a single pane of glass whose Area = 3.0 m² & thickness is 0.0032m.

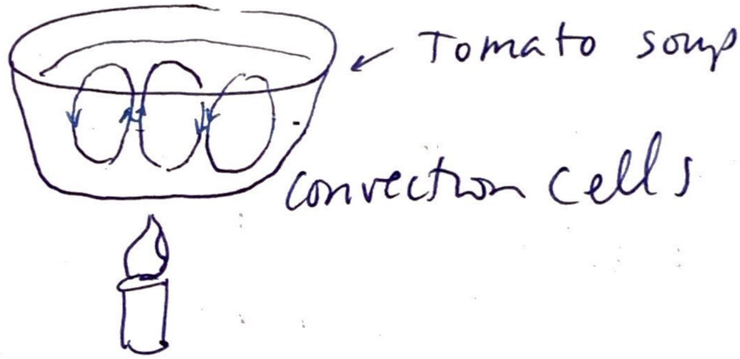


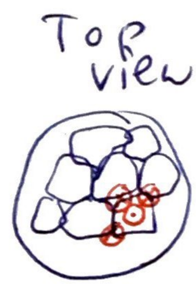
$$\frac{\Delta Q}{\Delta t} = k\,\frac{(T_H - T_C)}{l}\,A$$

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

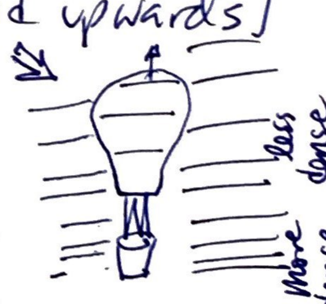
$$\boxed{\frac{\Delta Q}{\Delta t} = 790\ J/s}$$

⊛ Convection



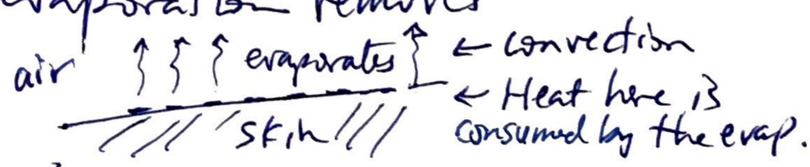


Hot medium is less dense and raises up at the surface it cools down and falls since it is now slightly more dense.
{Buoyancy force moves the hot liquid upwards}



EX Blood vessels transport heat in our bodies from the core to the limbs.

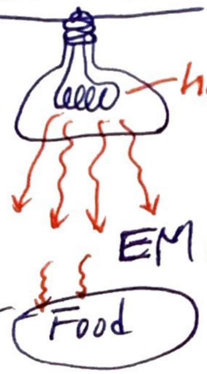
EX Sweating: water evaporation removes heat, L_V.



⊛ Radiation (EM radiation like Infrared)

microwave

Heat Lamp:

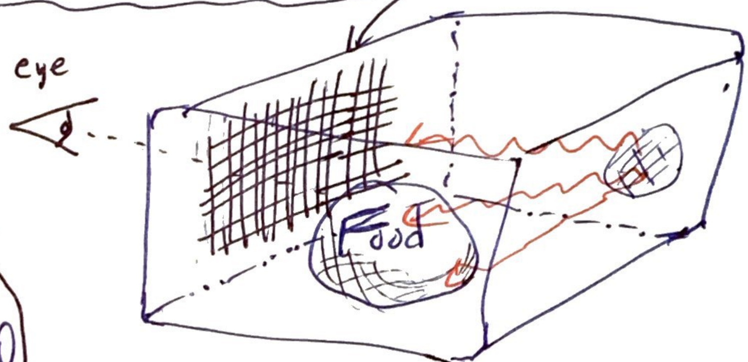


hot filament: electricity wiggles the metalic atoms, then they radiate EM radiation

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.



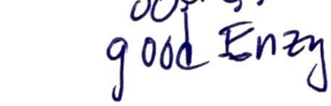
Microwave oven door: holes lets out visible EM but stop the microwave EM.

Wiggles the water molecule.

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

*"Convection & microwave" → turbo chef ovens

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



good Enzyme

Useless broken enzymes.

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

Radiation (cont.)

- $\frac{\Delta Q}{\Delta t} \propto T^4$ Stephan–Boltzmann Equation
- $\frac{\Delta Q}{\Delta t} \propto$ Surface Area exposed
- $\frac{\Delta Q}{\Delta t} \propto$ material

Together we get the S-B Law:

$$\frac{\Delta Q}{\Delta t} = \epsilon \sigma A T^4$$

σ: Boltzmann's constant.

ϵ: emissivity of the material

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

- shinny material like chrome : $\epsilon \approx 0$ reflects the radiation back.
- charcoal : $\epsilon \approx 1$, absorbs most of the impaling radiation

Application:

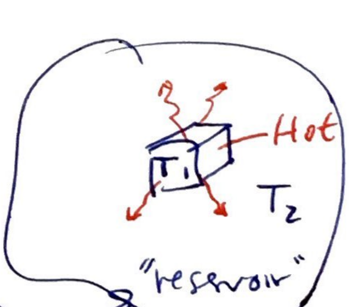
Hot climate? Drive white car

Cold Climate? Drive Black Car

(*) If there are two mediums and an object (medium #1) is in a reservoir (#2)

we use this formula

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



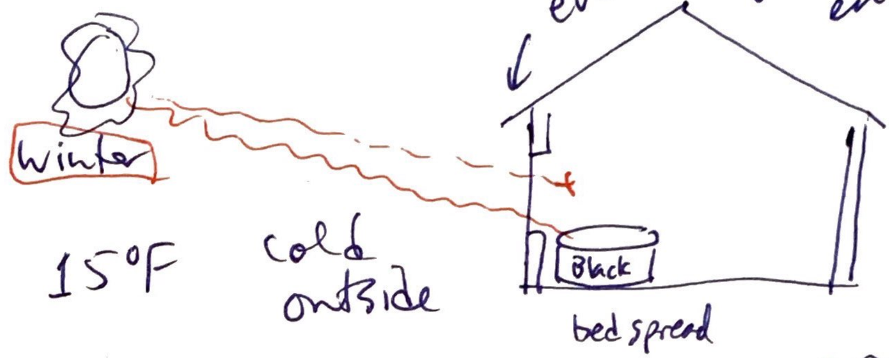
Definition of Reservoir:

heat lost from object #1 will not change the temperature in #2.

Application

* passive home heating

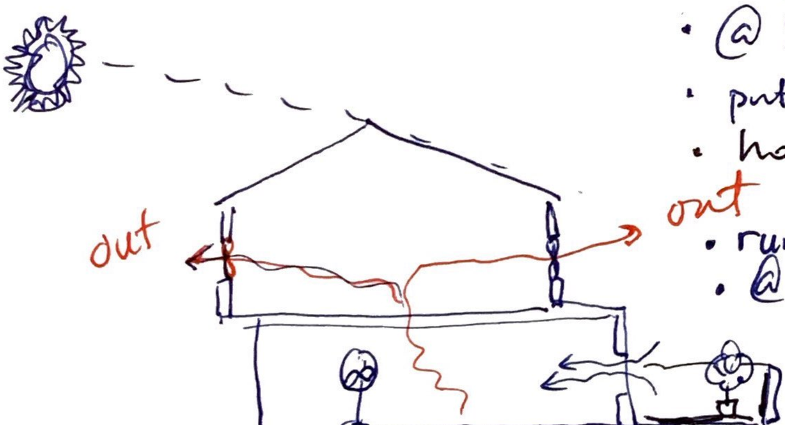
eve needs to allow the sun to enter windows in winter



eves need to block sun in summer

* passive home cooling

- @ 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

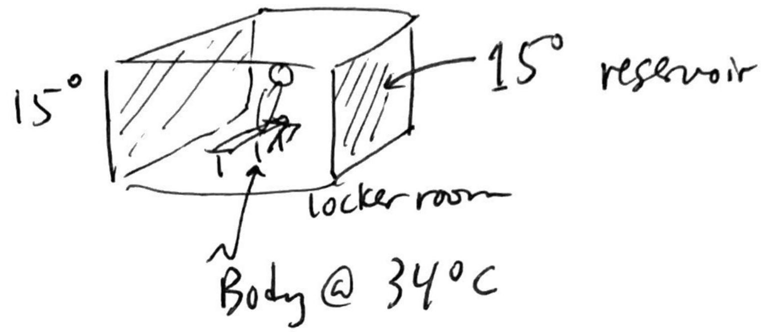


Installed a ceramic floor: retains coolness

All Night long the floor & walls & furniture is cooling down.

Ex Assume a person at the gym is working out in a dark room (dark blue walls)

↑ extracts heat from people.



Q: Estimate the body's heat loss
Assume $\epsilon = 0.7$, $T = 34°C$, $A_{body} = 1.5\,m^2$

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

T must be in Kelvin

$$= (0.7)\left(5.67\times10^{-8}\,\frac{W}{m^2\cdot K^4}\right)(1.5\,m^2)\left((273+34)^4 - (273+15°C)^4\right)$$

$$\boxed{\frac{\Delta Q}{\Delta t} = 120\,W}$$ or 120 Jouls lost /sec

{ We say that when an adult male is working out or is taking a test their body radiates @100W, like the lightbulb }

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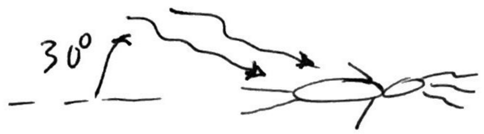
let the sun's rays fall on the person @ 30°



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

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

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

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

↑ half-body faces sun

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

end of chpt 14.

Up next: Thermodynamics (15)