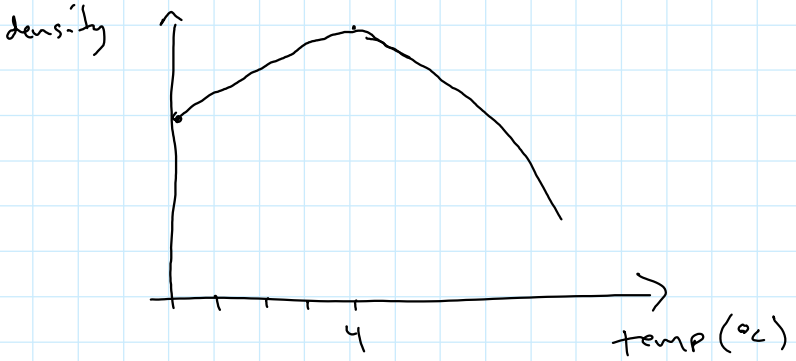
Phy 2B 3/4

Wednesday, March 4, 2015 10:03 AM

Temp and heat continued

4°C water:



Specific heat: c

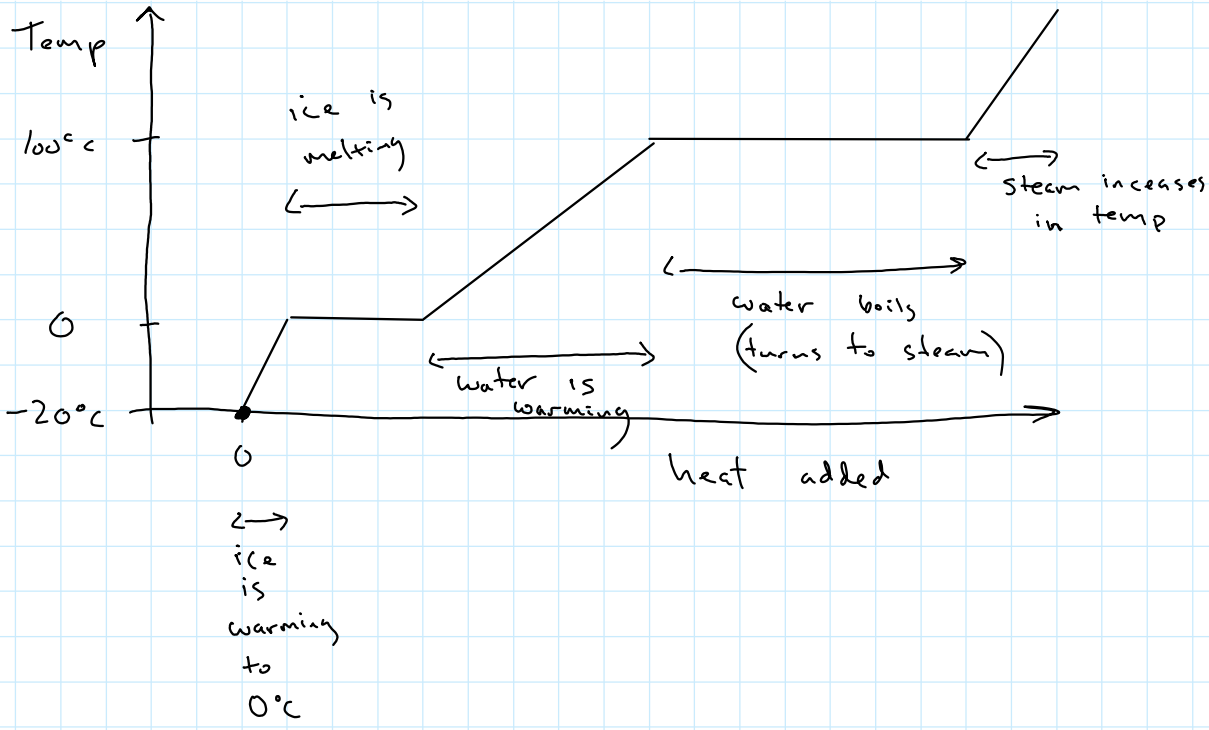
$$Q = c\,m\,\Delta T$$

↑ heat needed to change m (kg) of a substance by ΔT degrees

Phase changes

Solid → Liquid → gas

Start with Ice (solid water) at -20°C and add heat



$$Q = mL_f \leftarrow \text{melting / Freezing}$$

or

$$Q = mL_v \leftarrow \text{boiling / condensing}$$

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example:

2 kg of ice at $-10^\circ c$

Find Q needed to turn it into

2 kg of steam at $100^\circ c$

Water $L_f = 33.5 \times 10^4 \ \frac{J}{kg}$

$L_v = 22.6 \times 10^5 \ \frac{J}{kg}$

$c = 4186 \ \frac{J}{kg\ K}$

ice $c = 2090 \ J$

kg K

$$Q = Q_{\text{warm ice to } 0^\circ C} + Q_{\text{melt ice}} + Q_{\text{warm water to } 100^\circ C} + Q_{\text{vaporize water}}$$

$$= c_{ice} m \Delta T + m L_f + c_{water} m \Delta T + m L_v$$

$$= (2090)(2)(10) + (2\text{ kg})\left(33.5 \times 10^4 \frac{J}{kg}\right) + (4186)(2\text{ kg})(100) + (2\text{ kg})(22.6 \times 10^5)$$

$$= 6.07 \times 10^6 \text{ J}$$

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Al 0.155 kg @ −196 °C

water 0.08 kg @ 15 °C

$$C_{Al} = 653 \frac{J}{kg\ K}$$

Find Q to get Al to 0°C:

$$Q_{\substack{Al \\ -196 \to 0}} = C_{Al} m_{Al} \Delta T$$

$$= (653)(0.155)(196)$$

$$= 19,838 \text{ J}$$

Find Q we get from cooling water to 0°C:

$$\left| Q_{\substack{water \\ 15 \to 0}} \right| = C_{water} m_{water} \Delta T_{water}$$

$$= (4186)(0.08)(15)$$

$= 5,023 \text{ J}$

Find Q to freeze all water:

$$Q = m_{water} L_f$$

$$= (0.08)\ 33.5 \times 10^4$$

$$= 26,800 \text{ J}$$

So, we know we have a final temp of 0°C with some water frozen

$$Q_{into\ Al} = Q_{out\ of\ water}$$

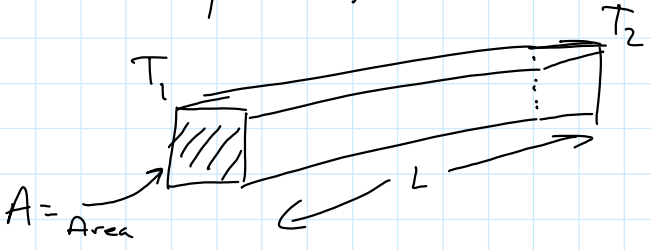
$$C_{Al}\, m_{Al}\, \Delta T_{\substack{Al \\ -196 \to 0}} = C_{water}\, m_{water}\, \Delta T_{\substack{water \\ 15 \to 0}} + m_{frozen} L_f$$

$$19,838 \text{ J} = 5023 \text{ J} + m_{Frozen}(33.5 \times 10^4)$$

$$m_{frozen} = 0.044 \text{ kg}$$

Heat transfer

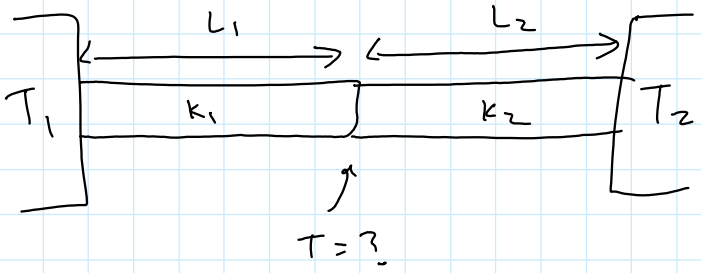
Conduction - transmission of heat directly through a material (Solid)



k = thermal conductivity
depends on material

t = time

$$Q = k A \left(\frac{\Delta T}{L}\right) t$$



if $T_2 > T_1$ $\quad A_1 = A_2$

$$Q_{\text{through material 2}} = Q_{\text{through material 1}}$$

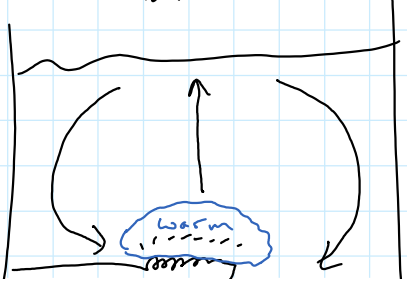
$$k_2 A_2 \frac{(T_2 - T)}{L_2} t = k_1 A_1 \frac{(T - T_1)}{L_1} t$$

Solve for T given $T_1, T_2, L_1, L_2, k_1, k_2$

if $A_1 = A_2$

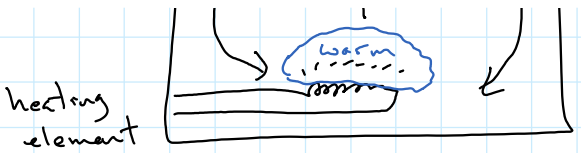
Convection (fluids → liquid or gas)

The transmission of heat due to the actual motion of the fluid itself



convection currents

warm / less dense fluid rises

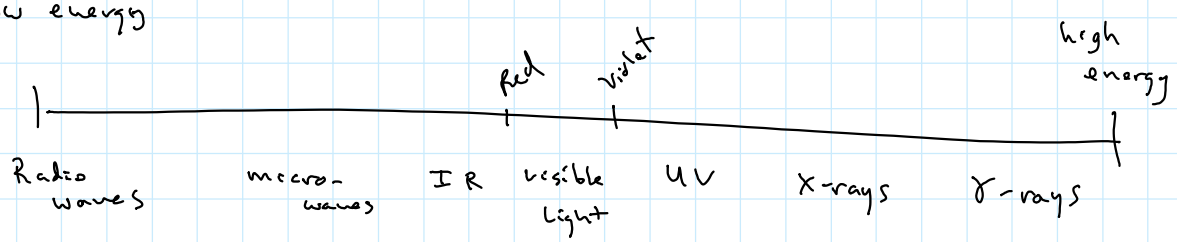


warm / less dense fluid rises

cool / more dense fluid sinks

Radiation - the transmission of heat by means of an electromagnetic wave

Electromagnetic Spectrum:



Power radiated: $P = e \sigma A T^4$

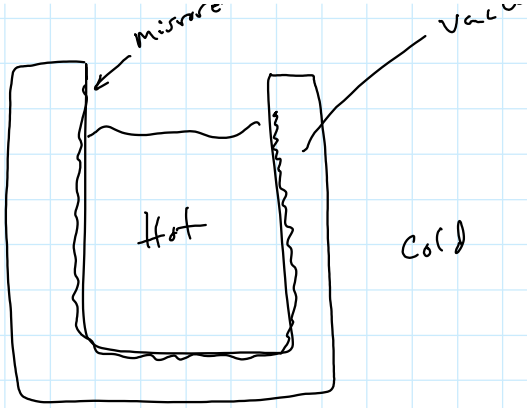
T in K

Net Power radiated: $P_{Net} = e \sigma A (T^4 - T_s^4)$

T: object's temp; T_s: temp of surroundings

$T > T_s$ radiates more than it absorbs

$T < T_s$ absorbs more than it radiates



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Ideal gas law: $PV = NkT$

P = pressure

V = Volume

N = Number of molecules

k = boltzman constant

T = temperature in K