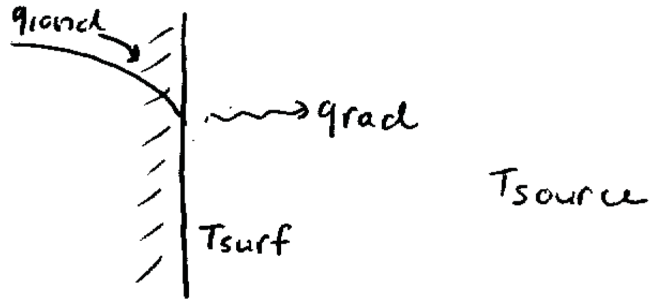
3.044 MATERIALS PROCESSING

LECTURE 8

Radiation:



$$-k\frac{\partial T}{\partial x} = -\varepsilon\sigma\left[T_{surf}^4 - T_{source}^4\right]$$

$$\boxed{M = \varepsilon\sigma\frac{L}{k}T_{surf}^3}$$

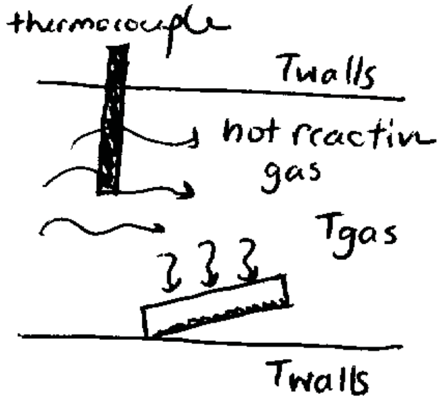
$$\frac{\partial T}{\partial t} = \alpha\nabla^2 T$$

$$\boxed{q = \varepsilon\sigma(T_{surf}^4 - T_{source}^4)}$$

$\Rightarrow$ Very few analytical solutions, some charts

Date: March 5th, 2012.

CVD: Chemical Vapor Deposition



At steady state the thermocouple outputs a temperature reading T_{TC}
TC is heated by gas (convection)

$$\overbrace{-h(T-T_f)A}^{\text{in}} = \overbrace{\varepsilon\sigma(T_{\mathrm{surf}}^4 - T_{\mathrm{source}}^4)A}^{\text{out}}$$

$$T_{\mathrm{TC}} = T_f - \frac{\varepsilon\sigma}{h}(T_{\mathrm{surf}}^4 - T_{\mathrm{source}}^4)$$

$$T_{\mathrm{TC}} \neq T_f$$

$$T_f \approx 1000°\mathrm{C}, \quad T_{\mathrm{wall}} \approx 500°\mathrm{C},$$

$$\varepsilon = 0.1, \quad h = 100\frac{\mathrm{W}}{\mathrm{m^2K}}$$

$$\boxed{T_{TC} \approx 830°\mathrm{C}, \quad \Delta T \approx \underline{\underline{200°\mathrm{C}}}}$$

Conclusions:

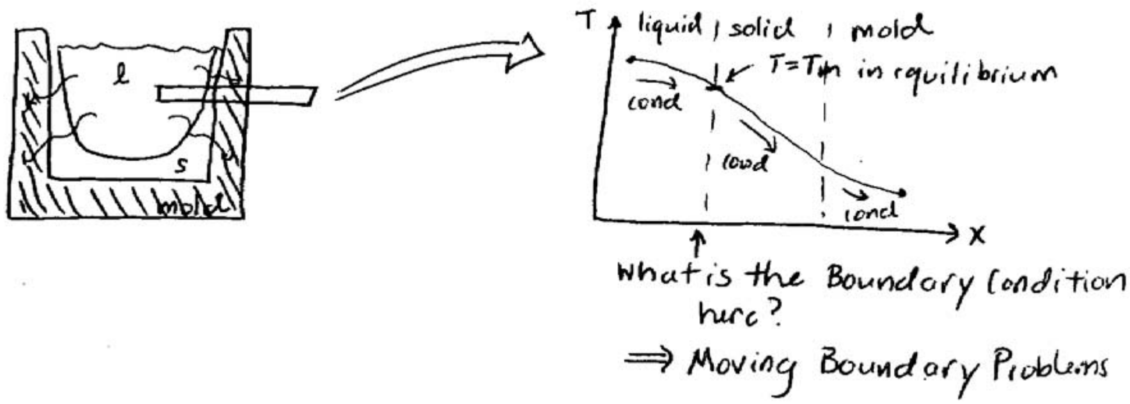
1. Objects that "see" cold surroundings are colder than you think
2. If an object "sees" a hot source it can be unexpectedly hot
3. "In vacuum" indicates no convection → radiation must be important

Topics Covered So Far:

Heat	Beat	Mix
heat transfer	solid mechanics	diffusion
	fluid mechanics	phase transition

$\Rightarrow$ Next step is to discuss heat transfer combined with diffusion and phase transformations

Solidification: Heat transfer plus phase transition, single component solidification



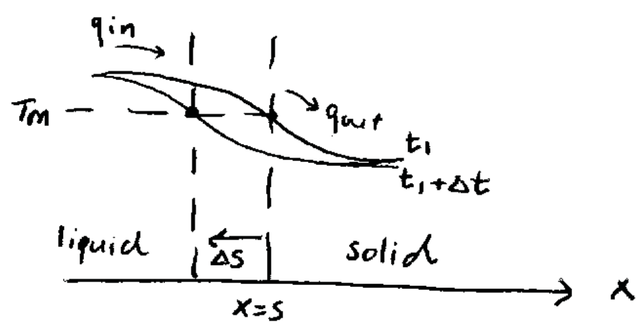
What are the B.C at the solid/liquid interface?

1. $T = T_m$
2. heat balance:

$$\overbrace{-k_s \left.\frac{\partial T}{\partial x}\right|_s}^{q_{\text{in}}} = \overbrace{-k_l \left.\frac{\partial T}{\partial s}\right|_l}^{q_{\text{out}}}$$

3. heat of fusion

Look closely:



$$q_{in} = -k_l \left.\frac{\partial T}{\partial x}\right|_{x=s,l}$$

$$q_{out} = -k_s \left. \frac{\partial T}{\partial x} \right|_{x=s,s}$$

$$\text{Fusion:} \quad - H_f \left[\frac{kJ}{kg} \right]$$

In time Δt the interface moved $\Delta s \Rightarrow$ Volume transformed $= A\Delta s$

$$\boxed{\underbrace{\left(-k_l \frac{\partial T}{\partial x}\right) A}_{\text{in}} + \underbrace{\left(k_s \frac{\partial T}{\partial x}\right) A}_{\text{out}} - \underbrace{H_f \rho \left(\frac{\Delta s}{\Delta t}\right) A}_{\text{Heat of Fusion}} = 0}$$

$$\begin{aligned} \text{where} \quad \frac{\Delta s}{\Delta t} = \frac{\partial s}{\partial t} &= \text{interface velocity} \\ &= \frac{-k_s \left.\frac{\partial T}{\partial x}\right|_s - k_l \left.\frac{\partial T}{\partial x}\right|_l}{H_f \rho} \\ &= \frac{k}{H_f \rho} \left[\left.\frac{\partial T}{\partial x}\right|_s - \left.\frac{\partial T}{\partial x}\right|_l \right] \text{(within factor of two)} \end{aligned}$$