Lecture 2

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Contents

For a solid crystal, when heated such that it becomes a liquid, you need to add a "latent heat", and the Energy is used to break the crystal bonds.

1 basic concepts

1.1 heat capacity and latent heat

The heat capacity is defined as $c = \frac{Q}{\Delta T}$, so it's the Heat Q needed to raise the Temperature by ΔT. We also define the specific heat capacity c_v such that $c = c_v \cdot m$.

To transform a solid to a liquid, we need the latent heat L_m, so to raise the temperature from below the solid temperature to the liquid temperature, the required heat is $Q = c\Delta T + L_m$. Which we then also define as $Q = (c_v \Delta T + \ell_m)m$ where ℓ_m is the specific latent heat.

1.2 Thermal Radiation

1.2.1 Reflection, Absorption and Transfer

Every material Reflects, absorbs and transfers the incoming Thermal Radiation. We then have

$$J_Q = J_{Q,R} + J_{Q,a} + J_{Q,T} \tag{1}$$

Where the Reflectivity, Absorptivity and Transmissivity are defined as

$$\rho = \frac{J_{Q,R}}{J_Q} \tag{2}$$

$$\alpha = \frac{J_{Q,a}}{J_Q} \tag{3}$$

$$\tau = \frac{J_{Q,T}}{J_Q} \tag{4}$$

We also have the Emissivity

$$\epsilon = \alpha \tag{5}$$

Where for example for Black bodies $J_Q = J_{Q,a}$ and $\epsilon = \alpha = 1$. We also know, that for a Black body

$$J_Q = \sigma T^4 \tag{6}$$

and for real bodies

$$J_Q = \epsilon \sigma T^4 \tag{7}$$

In the Summer and Winter month, we want to keep our House cold, or warm. When we have a Temperature T_1 and T_2, and a wall between it with thickness Δx then there is a Flux J_Q through it. With a temperature difference $\Delta T = T_2 - T - 1$. We define T_1 be inside and T_2 be outside.

If we double the Temperature difference, then the Flux is also doubled.

If we double the width of the wall, then the Flux is halfed. We therefore define

$$J_Q = \lambda \frac{\Delta T}{\Delta x} = \underbrace{\pm}_{?} \lambda \nabla T \tag{8}$$

where λ is the thermal conductivity.

1.3 Heat conduction experiment

The temperature curve of just the hot block is linear when looking at the temperature on a logarithmic scale, thus:

$$\log\left(T - T_{Room}\right) \propto -t \tag{9}$$

Thus

$$T - T_{Room} = \Delta T \propto e^{-t/c} \tag{10}$$

And for the temperature difference of the hot and cold block we have

$$T_h - T_c \propto e^{-t/\tau_1} \tag{11}$$

We also see that both materials had different Temperature changes.

$$\Delta T_B = 30K \tag{12}$$

$$\Delta T_Y = 60K \tag{13}$$

Blue = hot, Yellow = cold

Then

$$\frac{\Delta T_h}{\Delta T_c} = \frac{Q/c_h}{Q/c_c} = \frac{c_h}{c_c} = \frac{1}{2} \tag{14}$$

1.4 Thermal Conduction, boundary condition

$$J_Q = -\lambda \nabla T \tag{15}$$

$$Q = c \Delta T \tag{16}$$

use Energy conservation in the form of the continuity equation.

$$\frac{\partial Q}{\partial t} + V \nabla J_Q = 0 \tag{17}$$

$$\frac{\partial Q}{\partial t} - \lambda V \nabla^2 T = 0 \tag{18}$$

$$c \frac{\partial T}{\partial t} - \lambda V \nabla^2 T = 0 \tag{19}$$

$$\frac{\partial T}{\partial t} - \frac{\lambda V}{c_v m} \nabla^2 T = 0 \tag{20}$$

$$\frac{\partial T}{\partial t} - \frac{\lambda}{c_v \rho} \nabla^2 T = 0 \tag{21}$$