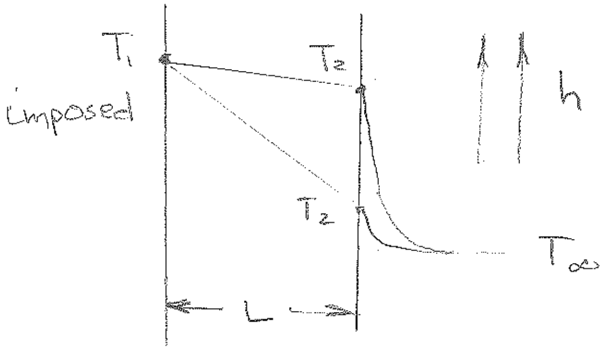
Look at steady H.T. through plane wall exposed to convection. J. Hill

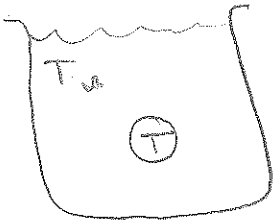


$$kA\frac{(T_1 - T_2)}{L} = hA(T_2 - T_\infty)$$

$$\frac{T_1 - T_2}{T_2 - T_\infty} = \frac{\frac{L}{kA}}{\frac{1}{hA}} = \frac{R_{COND}}{R_{CONV}} = \frac{hL}{k} = \text{Biot \#}$$

Bi is a measure of ΔT in solid rel. to ΔT in fluid.

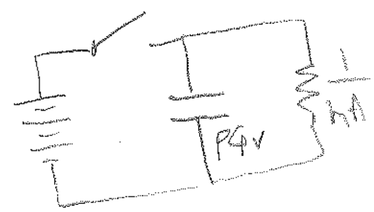
For $Bi \ll .1$ we can neglect ΔT in solid.



$$hA(T - T_\infty) = -\rho c_p V \frac{dT}{dt}$$

let $\theta = T - T_\infty$

$$hA\theta = -\rho c_p V \frac{d\theta}{dt}$$



$R_t = \frac{1}{hA}$ Thermal resist.

$C_t = \rho c_p V$ Thermal Cap.

$\tau = R_t C_t = \frac{\rho V c_p}{hA}$

$$-\frac{hA}{\rho c_p V}\, dt = \frac{d\theta}{\theta}, \quad \theta_i = T_i - T_\infty$$

$$-\frac{hA}{\rho c_p V}\int_0^t dt = \int_{\theta_i}^{\theta} \frac{d\theta}{\theta}$$

$$-\frac{hAt}{\rho c_p V} = \ln\frac{\theta}{\theta_i} \Rightarrow \boxed{\frac{T - T_\infty}{T_i - T_\infty} = \exp\left[-\left(\frac{hA}{\rho c_p V}\right)t\right]}$$

$$Q = \int_0^t q\, dt = \int_0^t hA(T - T_\infty)\, dt$$

$$= hA(T_i - T_\infty)\int_0^t \exp\left[-\left(\frac{hA}{\rho c_p V}\right)t\right]$$

$$= -\frac{\rho c_p V}{hA}\, hA(T_i - T_\infty)\exp\left[-\left(\frac{hA}{\rho c_p V}\right)t\right]_0^t$$

$$Q = \rho c_p V(T_i - T_\infty)\left[1 - \exp\left(-\frac{hA}{\rho c_p V}\right)t\right]$$