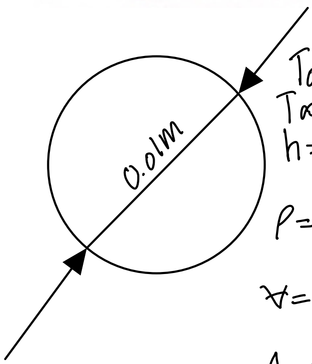
2-15. A grape of 1-cm diameter, initially at a uniform temperature of 20°C, is placed in a refrigerator in which the air temperature is 5°C. If the heat transfer coefficient between the air and the grape is 20 W/(m^2 · °C), determine the time required for the grape to reach 10°C. [For the grape, $k = 0.6$ W/(m · °C), $\rho = 1100$ kg/m^3, and $c = 4200$ J/(kg · °C).]
Answer 7.00 *min.*



$T_0 = 20°C$

$T_\infty = 5°C$

$h = 20 \frac{W}{m^2 C}$

$\rho = 1100 \frac{kg}{m^3}$

$V = \frac{\pi d^3}{6}$ (sphere)

$A = \pi d^2$

$$\frac{V}{A} = \frac{\frac{\pi d^3}{6}}{\pi d^2} = \frac{d}{6} = \frac{0.01}{6}$$

$$Bi = \frac{h L_c}{k} = \frac{20(0.01)}{0.6(6)} = 0.055 < 0.1 = \text{lumped heat analysis}$$

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{-\left(\frac{h(A)}{\rho(V)C_p}\right)T}$$

$$\frac{10-5}{20-5} = e^{-\left(\frac{20\times 3}{1100(0.005)(4200)}\right)T}$$

$$\frac{5}{15} = e^{-(0.0025974)T}$$

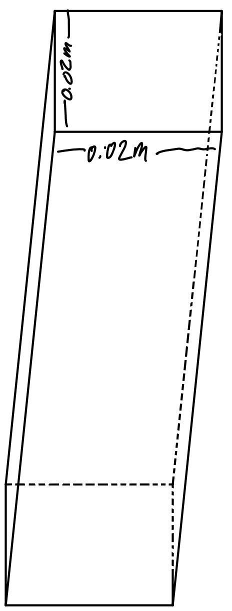
$$\ln\left(\frac{5}{15}\right) = -0.0025974(T)$$

$$-1.0986 = -0.0025974(T)$$

$$T = 422.94 \text{ sec} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$\boxed{T = 7.05 \text{ min}}$$

2-26. A clay column with cross section 2 cm by 2 cm is initially at a uniform temperature of 200°C. Suddenly, the surfaces are subjected to convective cooling with a heat transfer coefficient of 10 W/($m^2 \cdot$ °C) into ambient air at 25°C. Calculate the temperature of the column 10 min after the start of the cooling. Compare this temperature with that of a plane wall 5 cm thick of the same material and under the same conditions. [For the clay column, $k = 1.28$ W/(m · °C), $\rho = 1458$ kg/m^3, and $c = 880$ J/(kg · °C).]



Cross Section
0.02m X 0.02m

$T_0 = 200°C$
$h = 10 \ W/m^2 \cdot C$
$T_\infty = 25°C$
$T = 10 \min = 600 \ Sec$
$K = 1.28 \ W/m \cdot C$
$\rho = 1458 \ Kg/m^3$
$C_p = 880 \ J/kg \cdot C$

$$Bi = \frac{h L_c}{k} \qquad L_c = \frac{V}{A} = \frac{L \cdot L \cdot H}{4 \cdot L \cdot H} = \frac{L}{4}$$

$$= \frac{10(0.02)}{1.28(4)}$$

$= 0.039 < 0.1$ There fore lumped heat capacity Analysis

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{-\frac{hA}{V\rho c} t}$$

$$\frac{T-25}{200-25} = e^{-\left(\frac{10(4)}{1458(880)(0.02)}\right)600}$$

$$\frac{T-25}{175} = e^{-(0.935279)}$$

$$T = 93.68°C$$

Compare
- Wall @ L=0.05m → $L_s = \frac{V}{A_s} = \frac{L \cdot \cancel{A}}{2 \cdot \cancel{A}}$

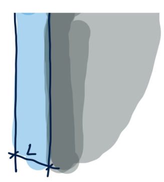
$$L_s = \frac{L}{2}$$

$$m = \frac{10 (W/m^2 \cdot c°) \cdot \frac{1}{\frac{L}{2}}}{1458 \frac{kg}{m^3} \cdot 880 \ J/kg°C}$$

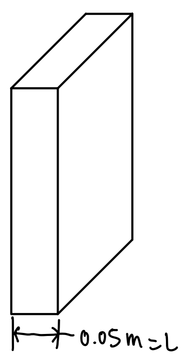
$= 0.003$

$$T_{(600)} = \left(e^{-0.003 \cdot 600}\right) \cdot 175 + 25°$$

$$\boxed{T_{(600)} = 53.9°C}$$



$$Bi = \frac{h L_s}{k} = \frac{10 (W/m^2 \cdot c) \ \frac{0.05}{2}}{1.48 (W/m \cdot °c)} = 0.168$$



$$Bi = \frac{h L_c}{K} \qquad L_c = \frac{V}{A} = \frac{L \cdot A}{2 \cdot A} = \frac{L}{2}$$

$$= \frac{10(0.05)}{1.28(2)} = .195 > .1$$

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{-\frac{hA}{\rho C_p V} \cdot t}$$

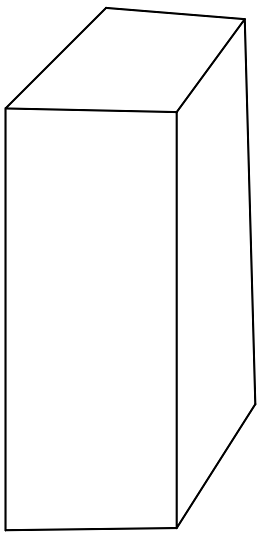
$$\frac{T-25}{200-25} = e^{-\left(\frac{10(2)}{1458(880)(0.05)}\right)600}$$

$$\frac{T-25}{175} = e^{-(.18705)}$$

$$T = 170.14$$

6-10 A thick wood wall [$\alpha = 0.82 \times 10^{-7}\ \mathrm{m^2/s}$ and $k = 0.15\ \mathrm{W/(m{\cdot}℃)}$] is initially at a uniform temperature of 20℃. The wood may ignite at 400℃. If the surface is exposed to hot gases at $T_\infty = 500℃$ and the heat transfer coefficient between the gas and the surface is $45\mathrm{W/(m^2{\cdot}℃)}$, how long will it take for the surface of the wood to reach 400℃?

Answer: 597.6 sec.



$\alpha = 0.82 \times 10^{-7}\ m^2/s$
$K = 0.15\ W/m\cdot C$
$T_0 = 20°C$
$T = 400°C$
$T_\infty = 500°C$
$h = 45\ W/m^2$
$T = ?\ sec$

Since wall is stated to be Thick I'll use eq:

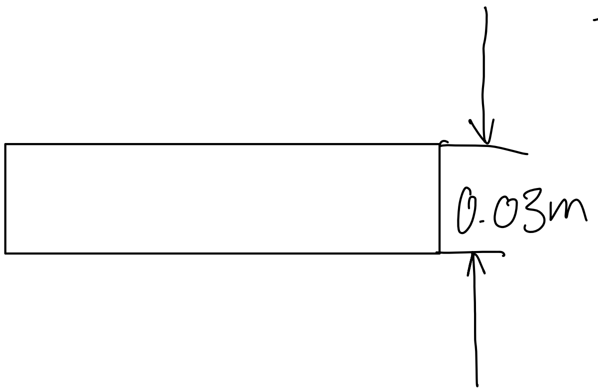
$$\frac{T - T_0}{T_\infty - T_0} = 1 - e^{\frac{h^2 \alpha t}{k^2}} \times \mathrm{erf}\left(\frac{h\sqrt{\alpha t}}{k}\right)$$

$$\ln\left(\frac{T - T_0}{T_\infty - T_0}\right) = \frac{h^2 \alpha t}{k^2} \times \frac{h\sqrt{\alpha t}}{k}$$

$$\ln\left(\frac{400 - 20}{500 - 20}\right) = \frac{45^2 \times 0.82 \times 10^{-7}\, t}{0.15^2} \times \frac{45\sqrt{0.82 \times 10^{-7}\, t}}{0.15}$$

$$\boxed{t = 597.6\ sec}$$

6-14 A marble plate [$\alpha = 1.3 \times 10^{-6}\ m^2/s$ and $k = 380\ W/(m \cdot ℃)$] of thickness 3 cm is initially at a uniform temperature of 130℃. The surfaces are suddenly lowered to 30℃. Determine the center-plane temperature 2 *min* after the lowering of the surface temperature.



$T_0 = 130°C$
$T_\infty = 30°C$
$T = ?\ °C$
$t = 2min = 120\ sec$
$\alpha = 1.3 \times 10^{-6}\ m^2/s$
$k = 380\ W(m°C)$
$h_{air} = 100\ W/m^2 C$

$Bi = \frac{hL_c}{k} = \frac{100\left(\frac{0.03}{6}\right)}{380}$

$Bi = 0.016 < 0.1$

Lumped heat Capacity Analysis

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{-\left(\frac{hA_s}{\rho c V}\right)t}$$

$$\alpha = \frac{k}{\rho c p} = \rho c p = \frac{k}{\alpha} = \frac{380}{1.3 \times 10^{-6}} = 2.92 \times 10^{8}$$

$$\frac{A}{V} = \frac{(L^2 \cdot L^2 \cdot L^2)2}{L^3} = \frac{6L^2}{L^3} = \frac{6}{L} = \frac{6}{0.03}$$

$$\frac{A}{V} \cdot \frac{h}{\rho c p} = \frac{6}{0.03} \cdot \frac{100}{2.92 \times 10^{8}} = 6.8493e^{-5}$$

$$\frac{T-30}{130-30} = e^{-(6.8493e^{-5})120}$$

$$\frac{T-30}{100} = 0.9918$$

$$\boxed{T = 129.18}$$

Group Project

Since our Group Project focus Cooling Drink with in a Certain time frame (5 mins), we can use The transient Heat transfer methods We learned in Class. First we shall determine the Biot number if The Biot Number is less than 0.1 Than We Can Calculate the Change in thermal energy Stored due to the the transient Process. If The Biot number is Graeter than 0.1 Than you need to use the Gaussian Error function method for the Semi-infinte Body Or use the exact Solution method, and if the fourier Number is Grater Than 0.2 we Can use The One-term Approximation method.