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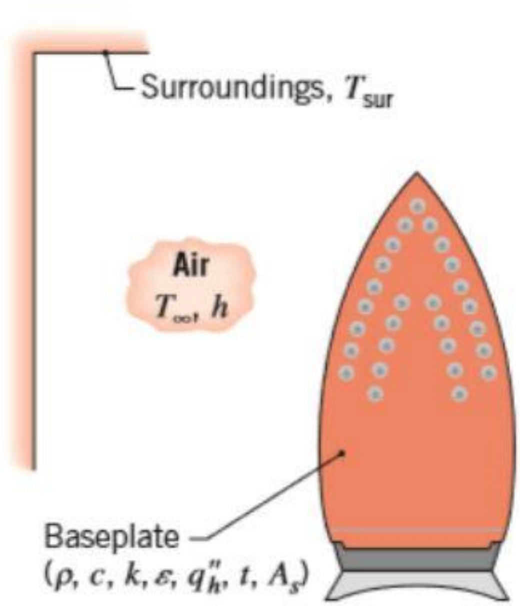
Project 2

BME 333

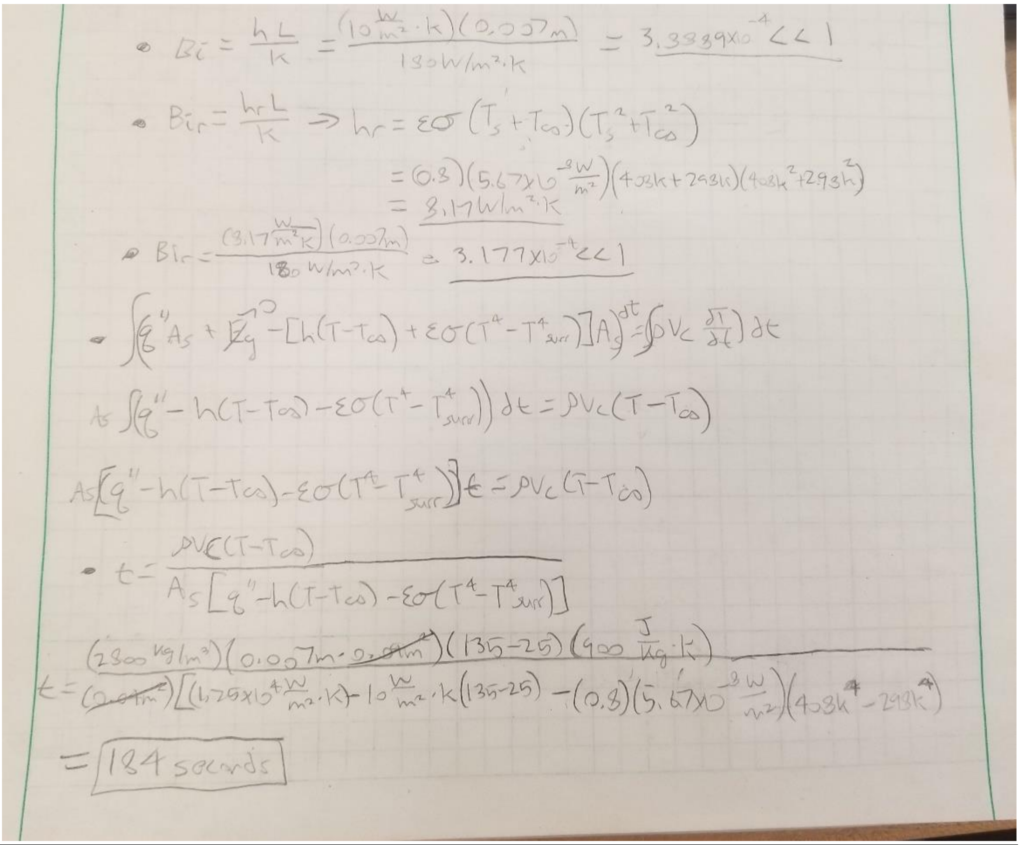
Given: L = 7mm, ρ = 2800 kg/m3, c = 900J/kg*K, k = 180 W/m*K, ε= 0.80, T∞= Tsur= 25°C, As= 0.040 m^2, q_h'' = 1.25 x 104 W/m2*K, h = 10W/m2*K.

Find: estimate the time required for the plate to reach a temperature of 135°C.

Sketch:



Analytical Solution:



$$Bi = \frac{hL}{k} = \frac{(10\frac{W}{m^2\cdot K})(0.007m)}{180 W/m^2\cdot K} = 3.3889\times10^{-4} << 1$$

$$Bi_r = \frac{h_r L}{k} \Rightarrow h_r = \varepsilon\sigma(T_s+T_\infty)(T_s^2+T_\infty^2)$$

$$= (0.8)(5.67\times10^{-8}\tfrac{W}{m^2})(408K+293K)(408K^2+293K^2)$$

$$= \underline{8.17 W/m^2\cdot K}$$

$$Bi_r = \frac{(8.17\frac{W}{m^2 K})(0.007m)}{180 W/m^2\cdot K} = \underline{3.177\times10^{-4} << 1}$$

$$\int\left(q_s'' A_s + \cancel{\dot{E}_g}^{\,0} - [h(T-T_\infty)+\varepsilon\sigma(T^4-T_{surr}^4)]A_s\right)dt = \int \rho V c \frac{dT}{dt}\, dt$$

$$A_s\int\left(q_s'' - h(T-T_\infty) - \varepsilon\sigma(T^4-T_{surr}^4)\right)dt = \rho V c(T-T_\infty)$$

$$A_s\left[q_s'' - h(T-T_\infty) - \varepsilon\sigma(T^4-T_{surr}^4)\right]t = \rho V c(T-T_\infty)$$

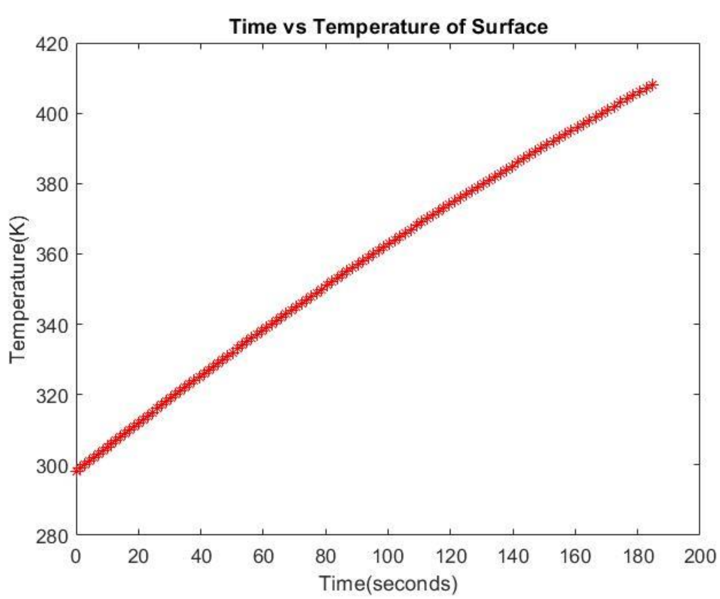
$$t = \frac{\rho V c(T-T_\infty)}{A_s[q_s'' - h(T-T_\infty) - \varepsilon\sigma(T^4-T_{surr}^4)]}$$

$$t = \frac{(2800 kg/m^3)(0.007m\cdot\cancel{0.01m^2})(135-25)(900\frac{J}{kg\cdot K})}{(\cancel{0.01m^2})[(1.25\times10^{4}\frac{W}{m^2\cdot K}) - 10\frac{W}{m^2\cdot K}(135-25) - (0.8)(5.67\times10^{-8}\frac{W}{m^2})(408K^4-293K^4)]}$$

$$= \boxed{184 \text{ seconds}}$$

As seen in the calculations, the time required to heat the surface to 135°C is about 184 seconds.

For the code, the exact time that it was able to calculate is 184.79 seconds, in the graph right below we see the comparison of the time vs the temperature of the surface:



The graph looks almost linear with a little bit of a bend out in the middle which means that right before it hit the temperature required, it was approaching the max temperature it would have been able to reach based off the parameters given.