Grade: ______/20

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Name (1 pt)

Problem 1 (9 pts)

The surface of very large piece of AISI302 stainless steel (k=15.1 W/[m·K], ρ=7962 kg/m^3, c=479 J/[kg·K]) is initially at a uniform temperature of T_i = 20°C. Suddenly the surface temperature is increased to a constant T_s=80°C.

(a) [1 pt] Calculate the thermal diffusivity of the steel, in m²/s.

(b) [8 pts] Estimate the temperature of the steel 1.5 cm below the surface after 30 seconds.

(a) $$\alpha = \frac{k}{\rho c} = \frac{15.1 \frac{\cancel{W}}{\cancel{m}\cdot\cancel{K}} \left\langle \frac{J}{\cancel{W}\cdot s} \right\rangle}{7962 \frac{\cancel{kg}}{m^3} \cdot 479 \frac{J}{\cancel{kg}\,\cancel{K}}}$$

$$= 3.96 \times 10^{-6}\ m^2/s \quad \longleftarrow \text{ANS}$$

(b) $$\frac{T_{(x,t)} - T_i}{T_\infty - T_i} = \text{erfc}\left[\frac{x}{2\sqrt{\alpha t}}\right]$$

$$\frac{T_{1.5cm,\,30s} - 20°C}{80°C - 20°C} = \text{erfc}\left[\frac{0.015\ \cancel{m}}{2 \cdot \sqrt{3.96\times10^{-6}\ \frac{\cancel{m^2}}{\cancel{s}} \cdot 30\ \cancel{s}}}\right]$$

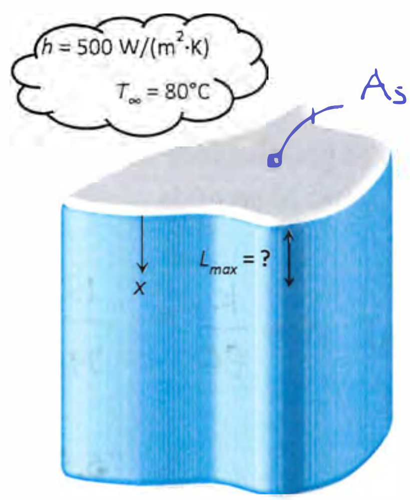
$$= \text{erfc}\,[0.688]$$

$$= 0.329$$

$$T_{1.5cm,\,30s} = 39.8°C \quad \longleftarrow \text{ANS}$$

Problem 2 (4 pts)

Rather than suddenly being exposed to a constant surface temperature, the steel in Problem 1 is suddenly exposed to a convective environment with $h = 500$ W/(m²·K) and T_∞=80°C.



You would like to treat the steel as having only one temperature at any location x at any time. What is the maximum depth, L_{max}, for which this assumption is a good approximation?

$$Bi = 0.1 = \frac{h L_{CHE}}{K} = \frac{h \; \forall / A_s}{K} = \frac{h \; \frac{L_{MAX} A_s}{A_s}}{K}$$

$$L_{MAX} = \frac{Bi \cdot k}{h} = \frac{(0.1)(15.1 \; W/(m \cdot K))}{500 \; W/(m^2 \cdot K)}$$

≈ 0.003 m $= 3.0$ mm ← ANS

Problem 3

(a) [2 pts] The last entry in the table for A_1 and λ_1 is for $Bi = \infty$. The best physical interpretation(s) is/are

- A. $L \rightarrow \infty$
- B. $k \rightarrow 0$
- C. $h \rightarrow \infty$
- D. $T_s \rightarrow T_\infty$ (Specified temperature boundary condition)
- E. Both C and D

(b) [1 pt] A small metal sphere initially at T_i is suddenly placed in a convective environment with T_∞ and h_∞. If $T_i > T_\infty$, what is true about the total amount of heat transfer out of the sphere after a time Δt?

- A. $Q_{t=\Delta t} < hA(T_i - T_\infty)\Delta t$
- B. $Q_{t=\Delta t} = hA(T_i - T_\infty)\Delta t$
- C. $Q_{t=\Delta t} > hA(T_i - T_\infty)\Delta t$

(c) [1 pts] When the Fourier number is greater than 0.2, it is a sign that you can...

- A. use the lumped capacitance method with little error
- B. use the one-term approximation of the infinite series solution for 1-D transient conduction
- C. go get your burrito out of the microwave 'cuz it's hot now

Also good!

(d) [2 pts] The solution to a semi-infinite cylinder for which r-direction temperature variations are small gives $T(r,z,t) \approx T(z,t)$. Can you now use the solutions to the fin equation for an infinitely log pin fin to find $T(z,t)$?

- A. Yes, always
- B. No, never
- C. Sometimes

Fin solutions assume steady heat transfer.