MSE-321 – Thermodynamics and Heat Transfer

SFU

Quiz 3- Dec.,1st , 2017

Student Name: **Student Number:**

1- Consider a very long rectangular fin attached to a flat surface such that the temperature at the end of the fin is essentially that of the surrounding air, i.e. 20˚C. Its width is 5.0 cm; thickness is 1.0 mm; thermal conductivity is 200 W/m·˚K; and base temperature is 40˚C. The heat transfer coefficient is 20 W/m^2·˚K. Estimate the fin temperature at a distance of 5.0 cm from the base and the rate of heat loss from the entire fin**. (40 Score)** **(10–113)**

Assumptions **1** Steady operating conditions exist. **2** The temperature along the fins varies in one direction only (normal to the plate). **3** The heat transfer coefficient is constant and uniform over the entire fin surface. **4** The thermal properties of the fins are constant. **5** The heat transfer coefficient accounts for the effect of radiation from the fins.

Properties The thermal conductivity of the fin is given to be $k = 200$ W/m·°C.

Analysis The fin temperature at a distance of 5 cm from the base is determined from

$$m = \sqrt{\frac{hp}{kA_c}} = \sqrt{\frac{(20\ \text{W/m}^2.^\circ\text{C})(2\times 0.05 + 2\times 0.001)\text{m}}{(200\ \text{W/m.}^\circ\text{C})(0.05\times 0.001)\text{m}^2}} = 14.3\ \text{m}^{-1}$$

$$\frac{T - T_\infty}{T_b - T_\infty} = e^{-mx} \longrightarrow \frac{T - 20}{40 - 20} = e^{-(14.3)(0.05)} \longrightarrow T = \mathbf{29.8^\circ C}$$

The rate of heat loss from this very long fin is

$$\dot{Q}_{\text{long fin}} = \sqrt{hpkA_c}\,(T_b - T_\infty)$$
$$= \sqrt{(20)(2\times 0.05 + 2\times 0.001)(200(0.05\times 0.001)}\,(40 - 20)$$
$$= \mathbf{2.9\ W}$$

(See back of the page)

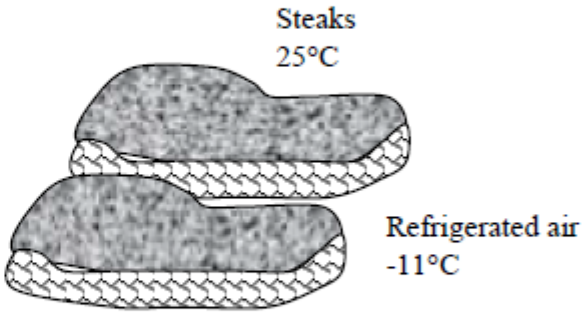
2- In a meat processing plant, 2-cm-thick steaks (k = 0.45 W/m.˚C and $\alpha = 0.91 \times 10^{-7}$ m^2/s) that are initially at 25˚C are to be cooled by passing them through a refrigeration room at -11˚C. The heat transfer coefficient on both sides of the steaks is 9 W/m^2.˚C. If both surfaces of the steaks are to be cooled to 2 ˚C, determine how long the steaks should be kept in the refrigeration room. What are the required assumptions for your solution? **(60 Score)** **(11 – 44)**

Assumptions **1** Heat conduction in the steaks is one-dimensional since the steaks are large relative to their thickness and there is thermal symmetry about the center plane. **3** The thermal properties of the steaks are constant. **4** The heat transfer coefficient is constant and uniform over the entire surface. **5** The Fourier number is $\tau > 0.2$ so that the one-term approximate solutions (or the transient temperature charts) are applicable (this assumption will be verified).

Properties The properties of steaks are given to be $k = 0.45$ W/m.°C and $\alpha = 0.91\times10^{-7}$ m^2/s

Analysis The Biot number is

$$Bi = \frac{hL}{k} = \frac{(9\ \text{W/m}^2.^\circ\text{C})(0.01\ \text{m})}{(0.45\ \text{W/m.}^\circ\text{C})} = 0.200$$



The constants λ_1 and A_1 corresponding to this Biot number are, from Table 11-2,

$$\lambda_1 = 0.4328 \quad \text{and} \quad A_1 = 1.0311$$

The Fourier number is

$$\frac{T(L,t)-T_\infty}{T_i-T_\infty} = A_1 e^{-\lambda_1^2 \tau} \cos(\lambda_1 L/L)$$

$$\frac{2-(-11)}{25-(-11)} = (1.0311)e^{-(0.4328)^2 \tau} \cos(0.4328) \longrightarrow \tau = 5.085 > 0.2$$

Therefore, the one-term approximate solution (or the transient temperature charts) is applicable. Then the length of time for the steaks to be kept in the refrigerator is determined to be

$$t = \frac{\tau L^2}{\alpha} = \frac{(5.085)(0.01\ \text{m})^2}{0.91\times10^{-7}\ \text{m}^2/\text{s}} = 5590\ \text{s} = \mathbf{93.1\ min}$$

Good Luck. Sam Behfarshad