F00

Notre Dame University Faculty of Engineering Mechanical Engineering Dep.

TEST– MEN310 (Heat Transfer)

November 10, 2000

1. Consider the base plate of a 1200-W iron that has a thickness of L=0.5cm, and a base area of A=300cm^2. The base plate is made of stainless steel. Its inner face is subjected to uniform heat flux generated by the resistance heaters inside, and its outer face loses heat to the surroundings at T_∞=20°C by convection (h=80W/m$^{2\circ}$C). Determine the temperature distribution across the base plate and evaluate the temperature at its inner and outer surfaces. Radiation effects are assumed to be negligible.

2. Steam in a heating system flows through tubes whose outer diameter is D_1= 3cm and whose walls are maintained at a temperature of 120°C. Circular copper fins of outer diameter D_2= 6cm and constant thickness t=2mm are attached to the tube. The space between fins is 3mm, and thus there are 200 fins per meter length of the tube. Heat is transferred to the surroundings at T_∞=25°C, with a heat transfer coefficient of h=60W/m$^{2\circ}$C. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins.

3. Consider an Aluminum fin of triangular cross-section with length L=5cm, base thickness b=1cm, and infinite width w in the direction normal to the plane of paper as shown in fig.P3. The base of the fin is maintained at a temperature of T_0=200°C, and the fin is loosing heat to the surrounding medium at T_∞=25°C with a heat transfer coefficient h=15W/m$^{2\circ}$C. Using the finite difference method with six equally spaced nodes along the fin in the x-direction, determine the temperature distribution, the rate of heat transfer from the fin for w=1m and the fin efficiency.

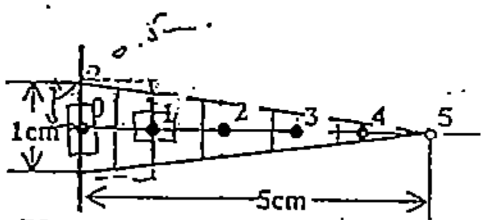
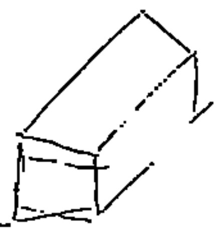


Fig.P3



Points: 1 (30%), 2 (30%) and 3 (40%).

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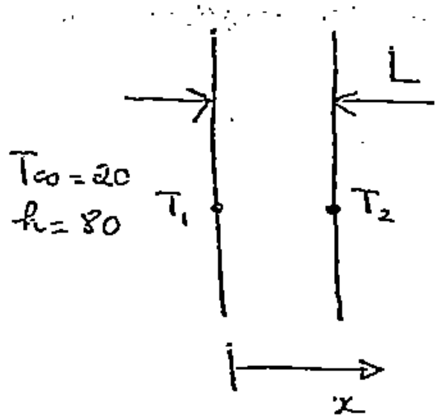
#1)

$q = 1200\,W$

$L = 0.5\,cm$

$A = 300\,cm^2$

$k = 17\,W/m\,°C$



$\dot{q}V = q$

$\hookrightarrow \dot{q} = \dfrac{1200}{300\times10^{-4}\times0.005} = 8\times10^{6}\,W/m^3$

$q = q_{convection} \longrightarrow 1200 = hA(T_1 - T_\infty) = 80\times0.03\,(T_1 - 20)$

$\hookrightarrow T_1 = 520°C$

$q = q_{conducted} \longrightarrow 1200 = q = \dfrac{\Delta T}{R} = (T_2 - T_1)\cdot\dfrac{kA}{L}$

$\hookrightarrow 1200 = \dfrac{T_2 - 520}{0.005}\times17\times0.03 \longrightarrow T_2 = 531.764°C$

$T = C_1 X + C_2$

$X = 0 \longrightarrow T = T_1 = C_2$

$X = L \longrightarrow T_2 = C_1(0.005) + 520 = 531.764 \longrightarrow C_1 = 2352.8$

$\hookrightarrow \boxed{T = 2352.8\,X + 520}$

#2) Refer to Test- March 28, 2001.

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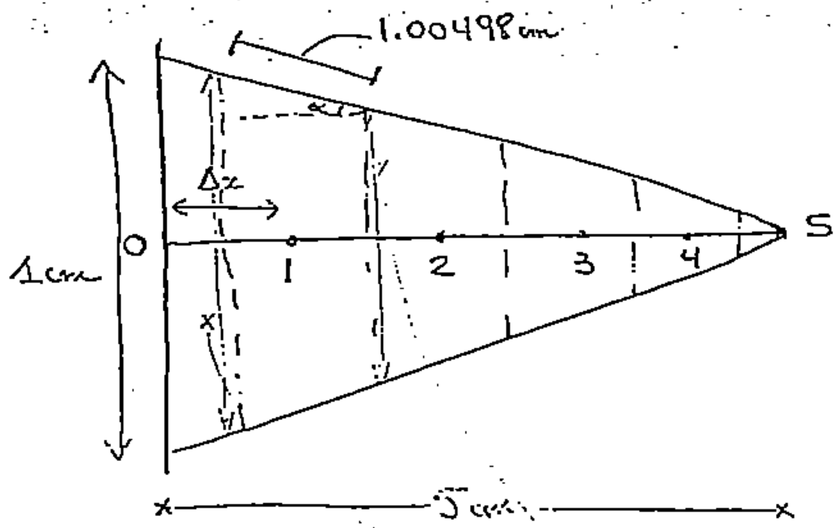

$T_o = 200°C$
$T_\infty = 25°C$
$h = 15\ W/m^2\,°C$
$k = 202\ W/m°C$

#3

Node 1:

$$\frac{T_o - T_1}{R_{01}} + \frac{T_2 - T_1}{R_{12}} + 2 \cdot \frac{T_\infty - T_1}{R_{1\infty}} = 0$$

$\frac{x}{1} = \frac{4.5}{5} \rightarrow x = 0.00$ m

where $R_{01} = \frac{0.01}{202 \times 0.009\,w} \longrightarrow \frac{1}{R} = 181.8\,w$

w: width

$R_{12} = \frac{0.01}{202 \times 0.007\,w} \longrightarrow \frac{1}{R} = 141.4\,w$

$\frac{x}{1} = \frac{3.5}{5} \rightarrow x = 0.007$ m

$R_{1\infty} = \frac{1}{15 \times 0.0100498\,w} \rightarrow \frac{1}{R} = 0.150747\,w$

$$\hookrightarrow \boxed{-323.501494\,T_1 + 141.4\,T_2 + 36367.53735 = 0}$$

Node 2: $\frac{T_1 - T_2}{R_{12}} + \frac{T_3 - T_2}{R_{23}} + 2 \cdot \frac{(T_\infty - T_2)}{R_{2\infty}} = 0$

$R_{23} = \frac{0.01}{202 \times 0.005\,w} \longrightarrow \frac{1}{R} = 101\,w$

$\frac{x}{1} = \frac{2.5}{5} \rightarrow x = 0.005$ m

$$\hookrightarrow \boxed{141.4\,T_1 - 242.701494\,T_2 + 101\,T_3 + 7.53735 = 0}$$

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Node 3: $\dfrac{T_2 - T_3}{R_{23}} + \dfrac{T_4 - T_3}{R_{34}} + 2.\dfrac{(25 - T_3)}{R_{3\infty}} = 0$

$R_{34} = \dfrac{0.01}{202 \times 0.003w} \longrightarrow \dfrac{1}{R} = 60.6w$ $\qquad \dfrac{X}{1} = \dfrac{1.5}{5} \rightarrow X = 0.003$

$\hookrightarrow \boxed{101 T_2 - 161.901 T_3 + 60.6 T_4 + 7.53735 = 0}$

Node 4: $\dfrac{T_3 - T_4}{R_{34}} + \dfrac{T_5 - T_4}{R_{45}} + 2.\dfrac{(25 - T_4)}{R_{4\infty}} = 0$

$R_{45} = \dfrac{0.01}{202 \times 0.001w} \longrightarrow \dfrac{1}{R} = 20.2w$ $\qquad X = \dfrac{0.5}{5} = 0.1\ cm$

$\hookrightarrow \boxed{60.6 T_3 - 81.1015 T_4 + 20.2 T_5 + 7.53735 = 0}$

Node 5: $\dfrac{T_4 - T_5}{R_{45}} + 2.\dfrac{(25 - T_5)}{R_{5\infty}} = 0$

$R_{5\infty} = \dfrac{1}{15 \times 0.0100495 \times 0.5w} \longrightarrow \dfrac{1}{R} = 0.0753735w$

$\hookrightarrow \boxed{20.2 T_4 - 20.350747 T_5 + 3.768675 = 0}$

Solving $\longrightarrow$ $T_1 = 198.7204\ °C$ $\qquad T_4 = 194.91°C$

$T_2 = 197.445°C$ $\qquad T_5 = 193.6523°C$

$T_3 = 196.175°C$

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$$\cdot\; q = 2 \sum h\overset{a\,w}{A}(T_\infty - T_i)$$

$$\hookrightarrow q = 2\Big[hA(25-198.72) + hA(25-197.445) + hA(25-196.175)$$
$$+ hA(25-194.91) + \frac{hA}{2}(25-193.6523)\Big]$$

$$q = 2\times 15\times 0.0100498\Big[25-198.72+25-197.445+25-196.175$$
$$+25-194.91+0.5\times 25-0.5\times 193.6523\Big]$$

$$\boxed{q = -232.6255 \text{ Watts}}$$

- q when all fin is @ 200°C

$$q = 2hA(T_\infty - T) = -15\times 0.0100498\times 5(200-25)\times 2$$

$$\hookrightarrow q = -263.80725 \text{ Watts.}$$

$$\eta = \frac{q}{q_{200°C}} = 0.8818 \longrightarrow 88.18\%$$

$\cdot$ checking figure 2-11 $\longrightarrow L = 0.05;\ t = 0.01 \longrightarrow \eta \approx 90\%$

$\longrightarrow$ checked.