CANKAYA UNIVERSITY

FACULTY OF ENGINEERING

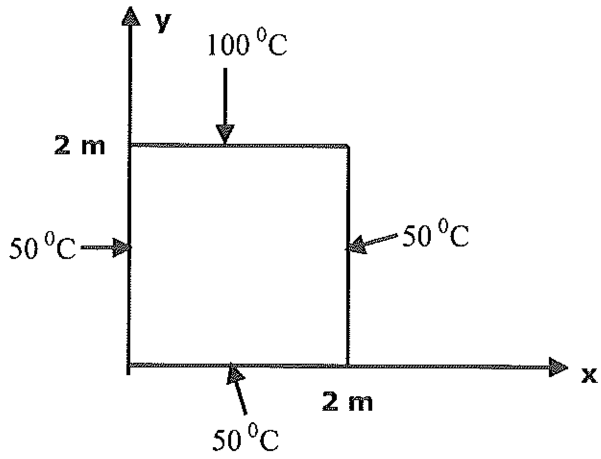
MECHANICAL ENGINEERING DEPARTMENT

ME 313 HEAT TRANSFER

CHAPTER-4

EXAMPLE SOLUTIONS

1. Consider two dimensional problem show below,



Consider rectangular plate given in the figure. Calculate the temperature at the midpoint of the plate for the case in which x=1 m, y=1 m.

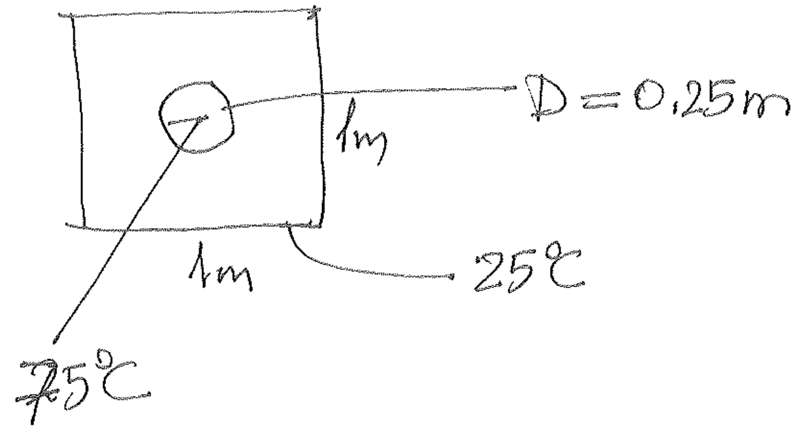
$$\frac{T-T_1}{T_2-T_1} = \left(\frac{2}{\pi}\right)\left(\frac{2}{1}\right)\left(\frac{\sinh\left(\frac{\pi}{2}\right)}{\sinh(\pi)}\right)\sin\left(\frac{\pi}{2}\right)$$

$$+\frac{2}{\pi}\left(\frac{2}{3}\right)\left(\frac{\sinh\left(\frac{3\pi}{2}\right)}{\sinh(3\pi)}\right)\sin\left(\frac{3\pi}{2}\right)+\dots$$

$$=0.2499$$

$$T = 50+0.25(50) = 62.5\,^\circ C$$

2. A hole of diameter D = 0.25 m is drilled through the center of a solid block of square cross section with w = 1 m on a side. The hole is drilled along length l = 2 m of block, which has thermal conductivity k = 150 W/m.K. A warm fluid passing through the hole maintains an inner surface temperature of $T_1 = 75^{o}C$, while the outer surface of the block is kept at $T_2 = 25^{o}C$. What is the rate of heat transfer through the block?



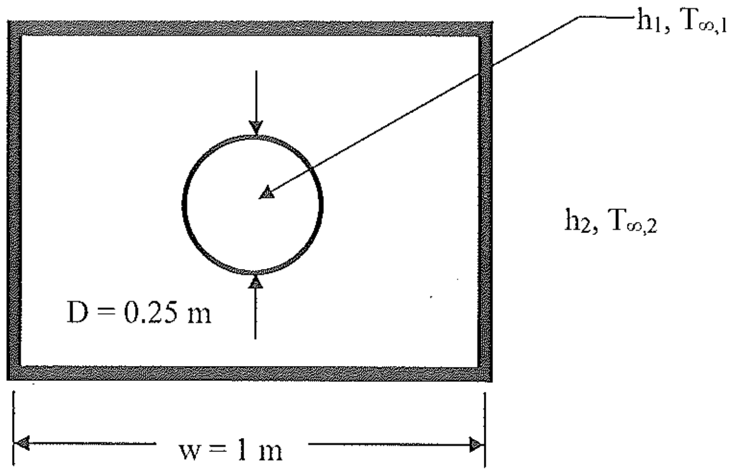
$$S = \frac{2\pi L}{\ln\left(\frac{1.08W}{D}\right)}$$

$$= \frac{(2\pi)(2)}{\ln\left(\frac{1{,}08 \times 1}{0{,}25}\right)} = 8{,}59\ m$$

$$q = kS\Delta T$$

$$= (8{,}59)(150)(75-25) = 64425\ W$$

3. A hole of diameter D = 0.25 m is drilled through the center of a solid block of square cross section with w = 1 m on a side. The hole is drilled along the length, l = 2 m, of the block, which has a thermal conductivity of k = 150 W/m.K. The outer surfaces are exposed to ambient air, with $T_{\infty,2}$ = 25 °C and h_2 = 4 W/m^2.K, while hot oil flowing through the hole is characterized by $T_{\infty,1}$ = 300 °C and h_1 = 50 W/m^2.K. Determine the corresponding heat rate and surface temperatures.



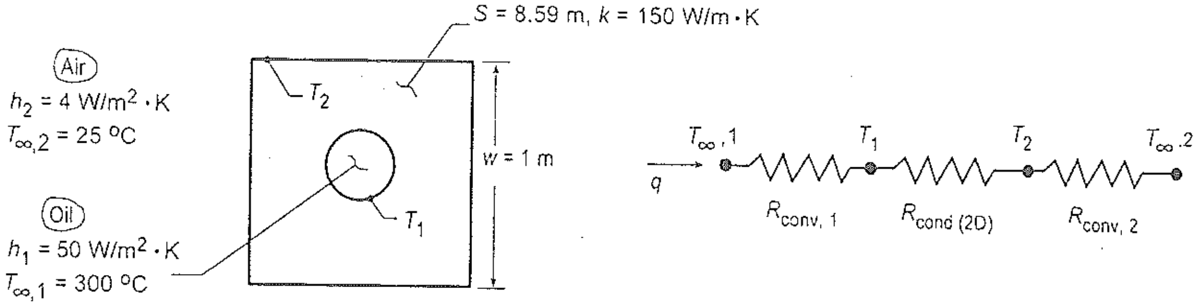
see next page
for solution

3)

KNOWN: Dimensions, shape factor, and thermal conductivity of square rod with drilled interior hole. Interior and exterior convection conditions.

FIND: Heat rate and surface temperatures.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, two-dimensional conduction, (2) Constant properties, (3) Uniform convection coefficients at inner and outer surfaces.

ANALYSIS: The heat loss can be expressed as

$$q = \frac{T_{\infty,1} - T_{\infty,2}}{R_{conv,1} + R_{cond(2D)} + R_{conv,2}}$$

where

$$R_{conv,1} = \left(h_1 \pi D_1 L\right)^{-1} = \left(50\,W/m^2 \cdot K \times \pi \times 0.25\,m \times 2\,m\right)^{-1} = 0.01273\,K/W$$

$$R_{cond(2D)} = (Sk)^{-1} = (8.59\,m \times 150\,W/m \cdot K)^{-1} = 0.00078\,K/W$$

$$R_{conv,2} = \left(h_2 \times 4wL\right)^{-1} = \left(4\,W/m^2 \cdot K \times 4\,m \times 1\,m\right)^{-1} = 0.0625\,K/W \quad .$$

Hence,

$$q = \frac{(300-25)^{\circ}C}{0.076\,K/W} = 3.62\,kW \qquad <$$

$$T_1 = T_{\infty,1} - qR_{conv,1} = 300^{\circ}C - 46^{\circ}C = 254^{\circ}C \qquad <$$

$$T_2 = T_{\infty,2} + qR_{conv,2} = 25^{\circ}C + 226^{\circ}C = 251^{\circ}C \qquad <$$

COMMENTS: The largest resistance is associated with convection at the outer surface, and the conduction resistance is much smaller than both convection resistances. Hence, $(T_2 - T_{\infty,2}) > (T_{\infty,1} - T_1) >> (T_1 - T_2)$.