Heat Transfer Assignment 3 — Fins and Shapes

Instructions

ξ is a parameter related to your student ID, with ξ_1 corresponding to the last digit, ξ_2 to the last two digits, ξ_3 to the last three digits, etc. For instance, if your ID is 199225962, then $\xi_1 = 2$, $\xi_2 = 62$, $\xi_3 = 962$, $\xi_4 = 5962$, etc. Keep a copy of the assignment — the assignment will not be handed back to you. You must be capable of remembering the solutions you hand in.

Question #1

Fins are frequently installed on tubes by a press-fit process. Consider a circumferential aluminum fin having a thickness of 1.0 mm to be installed on a 2.5-cm-diameter aluminum tube. The fin length is 1.25 cm, and the contact conductance may be taken from the tables for a 100-μinch ground surface. The convection environment is at 20° C, and $h = 125$ W/m^2·°C. Calculate the heat transfer for each fin for a tube wall temperature of 200° C. What percentage reduction in heat transfer is caused by the contact conductance?

Question #2

In certain locales, power transmission is made by means of underground cables. In one example an 8.0-cm-diameter cable is buried at a depth of 1.3 m, and the resistance of the cable is 1.1×10^{-4} Ω/m. The surface temperature of the ground is 25° C, and $k = 1.2$ W/m·°C for earth. Calculate the maximum allowable current if the outside temperature of the cable cannot exceed 110° C. Hint: the heat generation in an electrical cable of length L due to Joule heating is $LR_{\text{elect}}I^2$ in Watts with R_{elect} the resistance in Ohms and I the current in amperes and L the length of the cable in meters.

Question #3

A thin rod of length L and constant cross section area has its two ends connected to two walls which are maintained at temperatures T_1 and T_2, respectively. The rod loses heat to the environment at T_∞ by convection. Derive an expression (i) for the temperature distribution in the rod and (ii) for the total heat lost by the rod through convection.

Question #4

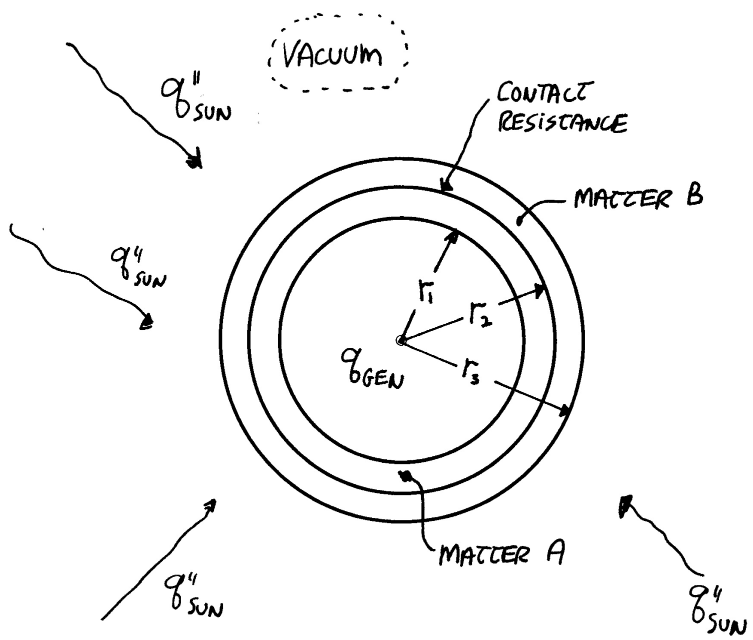
Show that the fin efficiency of a fin with a rectangular cross-section and an insulated tip corresponds to:

$$\eta_{\mathrm{f}} = \frac{\tanh\left(\sqrt{2}\cdot L^{1.5}\cdot\left(\frac{h}{kA_{\mathrm{m}}}\right)^{0.5}\right)}{\sqrt{2}\cdot L^{1.5}\cdot\left(\frac{h}{kA_{\mathrm{m}}}\right)^{0.5}}$$

with $A_{\mathrm{m}} \equiv L \cdot t$ with L the length of the fin, t the thickness of the fin, k the thermal conductivity, and h the convective heat transfer coefficient. Outline all assumptions.

Question #5

Consider a micro satellite in the shape of a hollow sphere orbiting around the earth in space as follows:



Electrical circuits located within the satellite generate power with the amount q_{gen} (in Watts). The temperature within either matter A or matter B can not exceed 600 K for safety reasons. The incoming radiation heat flux from the sun varies between being 0 and being $q''_{\text{sun}} = 1200\ \mathrm{W/m^2}$. The radiation heat flux from the sun may reflect on adjacent solar panels and may thus englobe the micro satellite from all directions. The thermal conductivities are of $k_{\mathrm{A}} = 0.5\ \mathrm{W/mK}$ and of $k_{\mathrm{B}} = 0.2\ \mathrm{W/mK}$, while the contact conductance between matter A and matter B is of $h_{\mathrm{c}} = 24.68\ \mathrm{W/m^2K}$. Knowing that the outer surface of the micro-satellite is a black body, and that the dimensions are of $r_1 = 8$ cm, $r_2 = 9$ cm, $r_3 = 10$ cm, do the following:

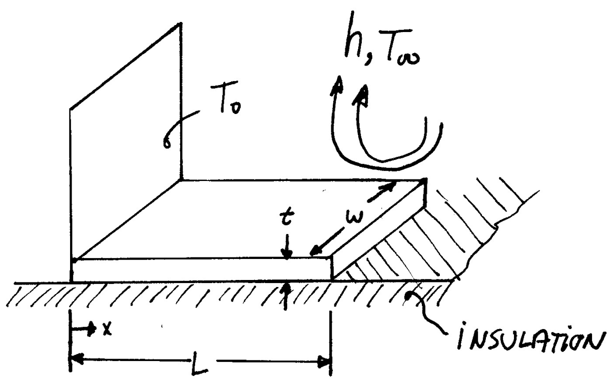
(a) Indicate where the maximum temperature will occur (i.e. the precise location within either matter A or matter B).

(b) Find the maximum allowable q_{gen} that maintains the temperature within both matter A and matter B to less than 600 K.

(c) Find the temperature on the outer surface of the satellite when the maximum temperature within either matter A or B is of 600 K.

Question #6

Consider a rectangular fin resting on a table as follows:



Knowing that the fin tip is **not** insulated, that $W \gg L$, and that there is no heat transfer between the fin and the table, do the following:

(a) Find the temperature at the fin tip (at $x = L$) as a function of T_0 and T_∞.

(b) Find the heat transfer at the fin base (at $x = 0$)

Note: you can **not** assume that the thickness t is much smaller than the length L. Outline all assumptions.

Answers

1. 45.2 W.
2. 1181 A.
3. $q = kAm(\cosh(mL) - 1)(T_2 + T_1 - 2T_\infty)/\sinh(ml)$.
5. 141.4 W.
6. $T_\mathrm{L} = T_\infty + \frac{T_0 - T_\infty}{\cosh(mL) + \frac{h}{km}\sinh(mL)}$

Due on Wednesday April 3rd at 9:00. Do Questions #1, #5, and #6 only.