

Taken directly from Bejan Chapter 2 problems

2.24 The Japanese teapot *kyusu* has a hollow handle that feels cool to the touch even when the pot contains boiling water. This handle can be modelled as a hollow-cylinder fin, as shown on the right side of the figure, where

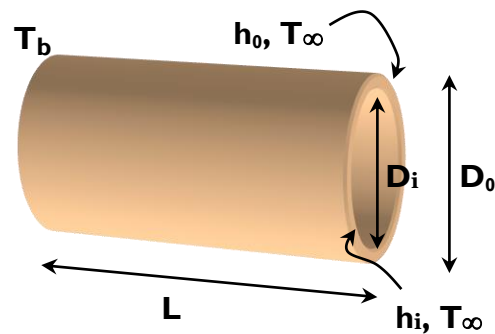
$$\begin{aligned}D_o &= 2 \text{ cm} \\D_i &= 1.5 \text{ cm} \\L &= 7 \text{ cm}\end{aligned}$$

$$\begin{aligned}h_o &= 10 \text{ W/m}^2\text{K} \\h_i &= 2 \text{ W/m}^2\text{K}\end{aligned}$$

$$\begin{aligned}T_b &= 50^\circ\text{C} \\T_\infty &= 15^\circ\text{C}\end{aligned}$$

The handle is made out of porcelain. The heat transfer coefficient on the outer surface of the handle is considerably larger than on the inner surface, because the buoyancy-driven air flow is more intense around the handle.

- calculate the appropriate parameter m of the hollow-cylinder fin and show that this fin is a “long fin”.
- calculate the distance from the base of the handle where the handle temperature is 30°C
- calculate the instantaneous heat transfer rate through the base of the handle.



2.26 Like everything else that we see from the first moments of conscious life, hair and fur are things that we take for granted. Their purpose seems obvious not only with respect to our own needs, but also for the survival of numerous other species. The insulation effect of hair can be explained through the argument that when the hair strands are sufficiently dense, they trap a blanket of air in the tight spaces created between the strands. Well known for its low thermal conductivity, this air blanket insulates the warm skin against the colder atmosphere.

The hair-covered surface is considerably more interesting when approached from the point of view – the function – of the individual hair strand. The thermal conductivity of hair material (roughly that of human skin, 0.37 W/mK) is 14 times greater than that of ambient air. It seems that one effect of the hair strands is to “extend” the warm surface into the cold atmosphere, in the same way that a population of cylindrical spines (pin fins) extends the heat transfer surface of a heat exchanger. This finning effect is, most certainly, an unwanted by-product of the true

function of the hair strands, which is to slow down the breeze that would otherwise blow by.

The fur of a lynx, for example, has a density of 9,000 strands/cm² and a cylindrical hair strand with a diameter of 27×10^{-6} m. The heat transfer coefficient between the hair strand and the surrounding air is 100 W/m²K, and the heat transfer coefficient between the bare portions of the skin and the same air flow is 10 W/m²K. The temperature difference between the skin surface and the air flow happens to be 10K. The fur-covered area under consideration is a square with side 10 cm.

- calculate the heat transfer rate that leaves the skin through the roots of all the hair strands. Treat each hair strand as a long fin.
- calculate the heat transfer rate released by the bare portions of the skin. Compare this contribution with the heat transfer current calculated in part a)
- estimate the order of magnitude of the distance of conduction penetration along the hair strand. In other words, for what length near its root is the hair strand significantly warmer than the surrounding air?
- verify that the heat transfer through one hair strand can be indeed modelled as one of unidirectional conduction.

