ABE 30800 - Spring 2018
Examples Problems External and Internal Convection

Problem 1

The African elephant has developed the pinna or external ear that functions as a radiator-convector (see page 60 in the textbook for more discussion). The pinna can be modeled as a flat plate with air flowing over it.

(1) Find and plot the convective heat loss from the pinna as the surface temperature of the pinna ranges from 21°C to 36°C. Since, the temperature of the ears varied it could be hard to estimate the properties of the film you can use the air temperature that is at 20°C. Remember that an elephant has two ears!!, and heat is lost equally from both sides of the ear. The air velocity is 2m/s, the surface of one ear is 0.84m^2, and the average length of one side of the ear is 1m. Use table of properties of air.

(2) If the rate of metabolic heat production for a 2000 kg elephant is 1650 W, what is the maximum percentage of the metabolic heat that can be lost by convection through the pinna?

Problem 2

A glass-door fire screen panel is used to reduce heat loss from the room through the chimney. The panel has a height of 0.7m and a width of 1m and reaches a uniform temperature of 250°C. If the temperature of the room is maintained at 20°C and the air in, the room is considered still:

(a) Under what type of convection is heat transferred to the room? Explain the principles behind the type of convection you selected.

(b) Estimate the heat transferred to the room, please state all your assumptions.

Problem 3

Hot tub designers have found that for a typical hot tub system, water loss by evaporation is about 0.001 kg/s if the operating conditions are the ones illustrated in the schematic figure given below. Evaporation of water can be calculated as:

$$q_{w,evap} = h_m A\left(\rho_{w,sat} - \rho_{w,air}\right)$$

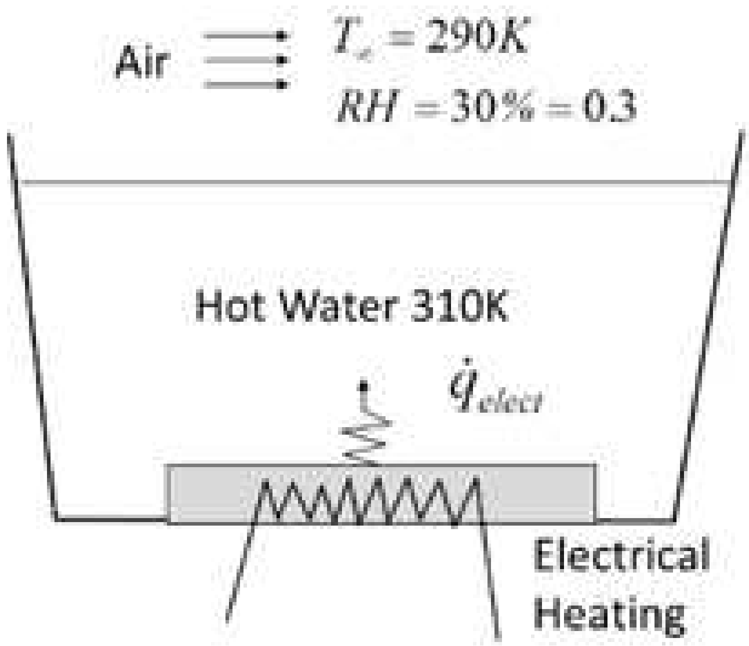
$\bar{h}_m$ (in m/s) is the mass convection coefficient, which is related to the heat transfer coefficient by the following equation:

$$\frac{\bar{h}}{\bar{h}_m} = \rho c \left(\frac{\alpha}{D_{w,air}}\right)^{2/3}$$

$D_{w,air}$ is the diffusion coefficient of water vapor in air and equals to 26x10^{-6} m^2/s. The other properties can be found or calculated in the Appendix of the textbook tables. Write all your assumptions in solving this problem.

(a) Estimate the power required to keep the temperature of the hot tube at 310K

(b) Give and briefly explain the mechanism under which the temperature of the water pool gets cool. Compare the energy used in each of these mechanisms.



Problem 4

An inventor is proposing a system to cool down a house without using an air conditioner system. The system is simple, air is routed from the house through a plastic pipe (k=0.15 W/m.K). The internal and external diameters of the pipe are D_i =0.15m and D_o=0.17m respectively, and the pipe is submerged in a body of water. The water temperature is near constant at 17°C, and the external convection coefficient is h_o=1,500 W/m^2.K.

(a) If air from the home enters the pipe at a temperature of $T_{a,in}$ = 30°C with a volumetric flow rate of $\dot{V}$ = 0.025 m^3/s, what pipe length L (only consider the length shown in the figure, i.e. ignore the bends and vertical sections) is needed to provide a temperature outlet temperature $T_{a,out}$ = 21°C?

(b) Estimate and compare the different heat resistances in the system (**consider a cylindrical geometry**). **Write clearly all your assumptions**