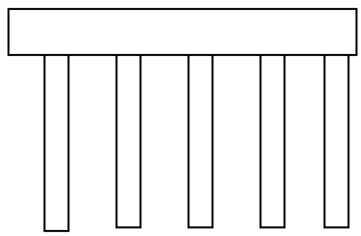
Spring 2024

Qualifying Exam Heat Transfer

Show all work and write assumptions for full credit

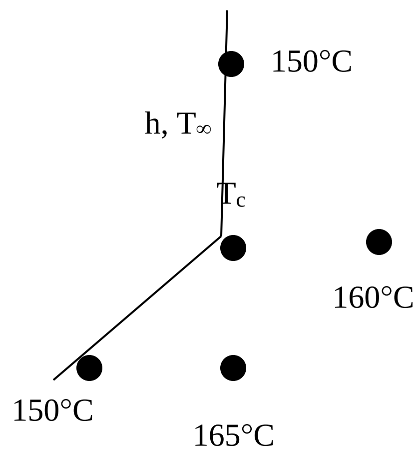
1. (50 points) Rectangular fins with k = 250W/mK and thickness t=2 mm and length L = 3cm are on a 2cm x2cm chip base. The chip base is 5mm thick, is made of material with k = 2.5 W/mK and puts out 20W total power. Air at 25°C flowing around the fins induces a heat transfer coefficient of 150 W/m^2K. There are 5 fins and 5 2mm spacings (see picture below). You may assume the back and sides of the chip are insulated.
   A. (40 points) Find the base temperature.
   B (10 points) If the maximum temperature in the chip cannot exceed 90°C, will this design work? Prove it.



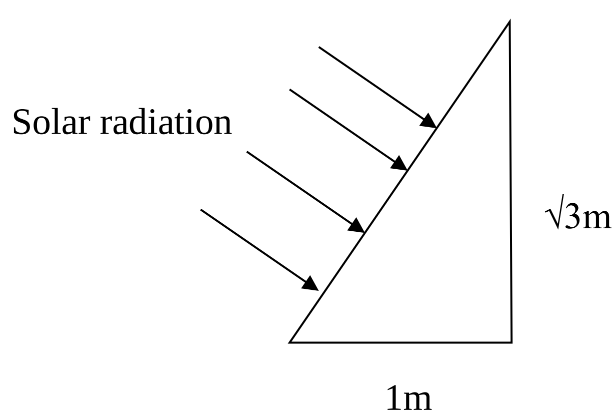
2. (50 points) A 4x1m aluminum rectangular beam is initially at 450°C and is suddenly exposed to a convection environment at 100°C with a h = 120 W/m^2K.
   A) (50 points) How long will it take for the temperature to reach 250°C a distance 1.5 m along the x-axis from the origin?
   B) (10 extra points) If thermal stress is induced if a variation of 100°C over 1 meter occurs, would it occur in this situation? (need to prove it)

3. (50 points) A lead plate is exposed to water at 25°C with a heat transfer coefficient of 10W/m^2K. The current temperatures for the nodes are seen below.

A. (25 points) Determine a forward difference expression for node c for $\Delta x=\Delta y=0.01$m.
B. (10 points) What is the maximum timestep that you can have to ensure stability?
C. (15 points) Determine the T_c temperature after one timestep when it is currently 155°C. (If you were not able to obtain an expression in part B, use the timestep for a corner node)



4. (70 points) A hollow right triangular solar collecting device has incident solar radiation on the hypotenuse side. The radiation maintains the temperature at 90°C. The two other surfaces have emissivities of 0.9 and temperatures of 40 and 50°C, respectively. You may assume that all solar radiation is transmitted through the collector side which appears to be black on the inside. The sides of the device are 1m and √3m respectively.
   A. (50 points) Determine the net heat transfer from the inside of the hypotenuse.
   B. (20 points) If the rate of solar radiation on the collector is 900 W/m^2, what percentage is collected by the solar device? What do you think caused this difference?



5. (35 points) A flat rear window of an automobile is of height 0.5m and contains a fine mesh heater that can provide uniform heating q" (W/m^2). The exterior air is -10°C moving parallel at 20m/s. $\nu = 20.93 \times 10^{-6}$, k = 0.03 W/mK, Pr = 0.70
   - **A.** (25 points) Determine the heating rate needed to maintain the window at an average temperature of 15°C.
   - **B.** (10 points) What is the maximum temperature?

6. (40 points) Material A is generating heat at a rate of 11.25 x $10^3 W/m^3$ and is 40 cm thick and has a thermal conductivity of 10 W/mK. Material B is 50 cm thick and has a thermal conductivity of 116.8W/mK. Material C is 30 cm thick and has an unknown thermal conductivity. The structure is cooled by a fluid at 25°C with a heat transfer coefficient of 10 W/m^2K on the left side and 100 W/m^2K on the right side. Schematic not drawn to scale.
   - **A.** (20 points) If the maximum temperature occurs 15cm from the left fluid surface interface, determine the heat fluxes to the fluid through the left and right sides.
   - **B**. (20 points) Find the thermal conductivity of C.