1. A poker is placed into a fire in a room which is at 28 °C. The cylindrical shaped poker is 600 mm long and has a diameter of 10 mm. 100 mm of the poker is inserted into the fire and the material of the poker below that point is at a constant temperature of 600 °C. Assuming that the poker acts as a fin, and using the values given below, estimate the maximum distance from the cold end of the poker that you could safely hold the poker if you are comfortable with holding metal at 40°C.

Assumptions: Assume that the poker is a long fin with temperature difference at location x ($\theta(x)$) given by:

$$\theta(x) = \theta_0 \, e^{-mx}, \text{where } m = \sqrt{\frac{hP}{kA}}$$

Properties:
Heat transfer coefficient of convection around the poker $h = 20 \, W/m^2 \, K$
Thermal conductivity of poker: $k_{poker} = 52 W/mK$ [6 marks]

2. (a) State the definition of the fin effectiveness and the fin efficiency relative to the heat loss from an ideal fin, the heat loss without the fin, and the real heat loss through the fin and comment on the expected ranges of the two values. [4 marks]

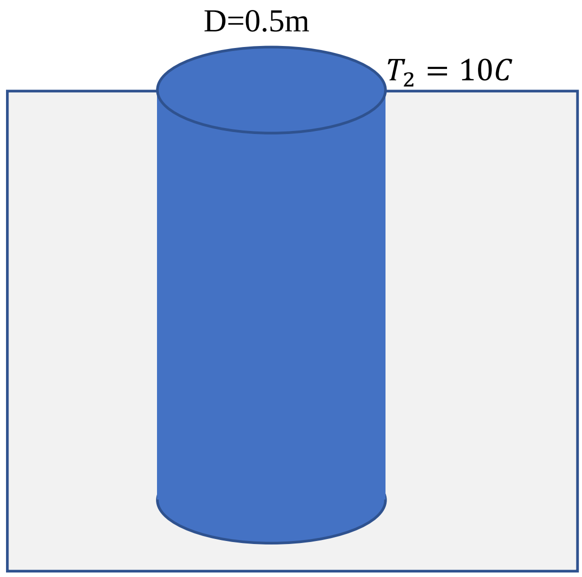
(b) Explain clearly the definition of an ideal fin [2 marks]

3. A 1.5 metre drum that has a diameter of 0.5 m is buried to its lid in the garden. It is filled with water and a heater inserted that maintains the temperature at 60 °C.
The lid is a good insulator so that no heat is lost through the lid, but the walls are in contact with soil and heat can be lost in that direction. The soil has a thermal conductivity of $k = 1.2 W/mK$

Using the information in the diagram, estimate the power of the heater needed to maintain the temperature at 60 °C inside the drum [4 marks]

For heat flow from a vertical isothermal cylinder of length L buried in a semi-infinite medium (L>>D),

$$S = \frac{2\pi L}{ln\left(\frac{4L}{D}\right)}$$



4. A battery is embedded in a block of resin ($k = 0.32\ W/mK$) as shown in Figure Q1. Using the values given, what will be the maximum heat flow that you can have from the battery to the surface of the resin if the battery cannot go above T_1 =45 °C and assuming that the surface of the resin is at the ambient temperature of T_2 =20 °C.

You can use the shape factor S equation: $S = \frac{2\pi L}{\ln\left(1.08\frac{w}{D}\right)}$ [4]

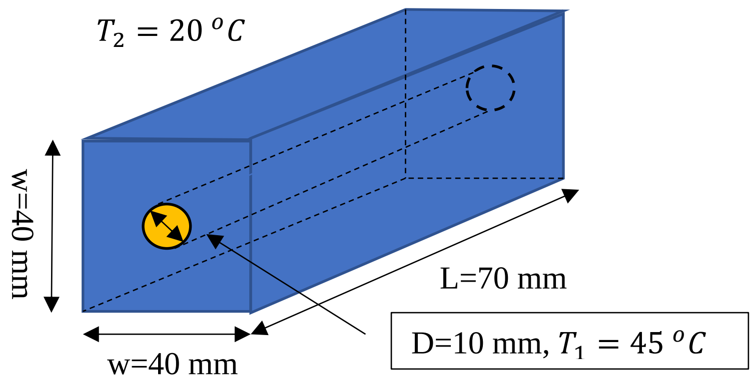


Figure Q1: Battery embedded in resin

5. A hot plate at 100 °C is cooled by attaching 30 mm long and 2.5 mm diameter aluminium pin fins ($k = 237\ W/mK$) to the surface to improve the cooling rate. There are 100 pins in a 10 x 10 array on the plate, and the plate is 50 mm x 50 mm in size. Assume that the surrounding medium is at 30 °C and that the heat transfer coefficient from all surfaces is $35\ W/m^2K$. The rate of heat transfer from the flat plate without fins is 6.125 W. The interfin area between the pin fins is $A_{if} = 2.01 \times 10^{-3} m^2$. The surface area of one pin fin is $A_{fin} = 2.36 \times 10^{-4} m^2$.

i) What is the value of the shape factor m for this design of pin fins? [5]

ii) What is the efficiency of the fins assuming that the adiabatic tip assumption is valid? [3]

iii) What will be the rate of heat transfer from the complete heat sink including the remaining base plate after the pin fins are attached? [5]

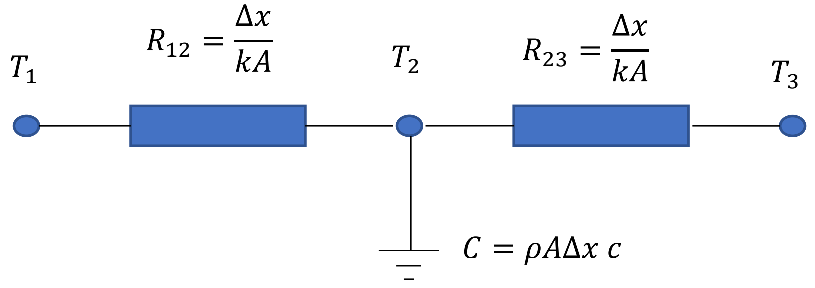
iv) What is the effectiveness for the entire heat sink including the base plate? [2]

Efficiency in adiabatic tip approximation is given by:

$$\eta = \frac{\tanh(m\ L_c)}{m(L_c)}$$

6. Fig Q6 shows the resistance network for internal nodes in an unsteady problem. Eq. Q6 shows the balance of energy in this resistance network.

Fig Q6



$$\frac{kA}{\Delta x}(T_1^0 - T_2^0) + \frac{kA}{\Delta x}(T_3^0 - T_2^0) = \rho A \Delta x c \frac{T_2^1 - T_2^0}{dt} \quad (Eq. Q6)$$

(a) Are we using the explicit or implicit solution of the differential equation? [2]

(b) Rearrange the equation in terms of the Fourier number and collect each temperature term. Show working. Marks are given for clarity of presentation. [3]

(c) What is the criteria for stability for this internal node? [2]

7. Biot number and Nusselt number are both in the form $\frac{hL}{k}$. What are their physical significance and emphasise the differences between these in terms of the variables employed? [4]