

Question 1:

We need to calculate $m = \sqrt{\frac{hP}{kA}} = \sqrt{20 \frac{\pi(0.01)}{52(\pi(\frac{0.01}{2})^2)}} = \sqrt{153.8} = 12.4 \text{ m}^{-1}$ (2 marks)

We should rearrange the long fin equation to have x as the argument.

$$x = -\frac{1}{m} \ln\left(\frac{\theta}{\theta_0}\right)$$

We know that $\theta_0 = (600 - 28) = 572\text{C}$ and $\theta = (40 - 28) = 12\text{C}$ (2 marks)

So the distance for safe handling from the base is:

$$x = -\frac{1}{12.4} \ln\left(\frac{12}{572}\right) = 0.31 \text{ m} \quad (1 \text{ mark})$$

So the safe distance from the surface of the fire is: 310 mm. The poker is 100 mm in the fire and 600 mm long in total, so it can be held safely 410 mm from the base, which is 190 mm from the top. (1 marks)

In other words you can safely touch the top 19 cm of the poker without getting burnt. [6 marks total]

Question2:

The fin effectiveness is given by the ratio of the actual heat loss through the fin/the heat loss without the fin (1 mark for exact solution) it can have values from 0 to infinity. (1 mark)

The fin efficiency is the ratio of the actual heat loss through the fin / the heat loss from an ideal fin (1 mark). It can have values from 0 to 1 (1 mark).

An ideal fin is one where the surface temperature of the extruded surface is **the same as the base of the fin**. (2 marks explaining highlighted concepts)

Question 3:

The Shape factor S is given as: $S = \frac{2\pi L}{\ln\left(\frac{4L}{D}\right)} = \frac{2\pi(1.5)}{\ln\left(\frac{4(1.5)}{0.5}\right)} = 3.79 \text{ m}$ (2 mark)

The heat flow is given as $\dot{q} = kS(T_1 - T_2) = 1.2(3.79)(60 - 10) = 227\text{W}$ (2 mark)

This is the heat loss from the drum which needs to be replaced, so a value of 227W will be correct. [4 marks total]

Question 4:

Quite simply the heat flow is given by:

$$\dot{q} = kS(T_2 - T_1)$$

The shape factor S is (2 marks):

$$S = \frac{2\pi L}{\ln\left(\frac{1.08w}{D}\right)} = \frac{2\pi(0.07)}{\ln\left(1.08\left(\frac{0.04}{0.01}\right)\right)} = 0.30 \text{ m}$$

So the heat flow from the battery to the surface is (2 marks):

$$\dot{q} = 0.32(0.30) * (45 - 20) = 2.4\text{W}$$

Question 5:

i) Shape factor for fins is (2 for correct perimeter and area) 2 for putting all together and 1 marks for putting right units:

$$m = \sqrt{\frac{hP}{kA}} = \sqrt{\frac{(35)(\pi(0.0025))}{237 \left(\pi\left(\frac{0.0025}{2}\right)^2\right)}} = \sqrt{236} = 15.37\text{m}^{-1}$$

ii) They can use 0.03m for length of fin or 0.03125 m if they add the end correction, I will accept both i
Efficiency given by:

$$\eta = \frac{\tanh(15.37(0.03))}{15.37(0.03)} = 0.935$$

iii) Interfin area of base plate $A_{if} = 2.01E - 3 m^2$

So heat loss from base is (2mark) $\dot{q}_{base} = A_{if}h(\Delta T) = 2.01E - 3(35)(70) = 4.925W$

Heat loss from one fin is (2 mark):

$$\dot{q}_{fin} = hA_f\eta\Delta T = 35\pi(0.0025)(0.03)(0.935)(70) = 0.5397 W$$

So total heat loss is (1 mark): $\dot{q}_{base} + 100\dot{q}_{fin} = 4.925 + 100(0.5397) = 58.895W$

iv) Fin effectiveness is heat loss through heat sink/heat loss without heat sink.

$$\epsilon = \frac{58.895}{6.125} = 9.6$$

Question 6:

(a) Explicit solution because temperature are from the initial step.

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

$$(T_1^0 - T_2^0) + (T_3^0 - T_2^0) = \left(\frac{\rho c}{k}\right) \left(\frac{A}{A}\right) \left(\frac{\Delta x^2}{dt}\right) (T_2^1 - T_2^0)$$

$$(T_1^0 - T_2^0) + (T_3^0 - T_2^0) = \left(\frac{\Delta x^2}{\alpha dt}\right) (T_2^1 - T_2^0)$$

$$T_2^1 = T_2^0 + Fo(T_1^0 - T_2^0) + Fo(T_3^0 - T_2^0) \quad (1 \text{ mark for changing to } Fo)$$

$$T_2^1 = T_2^0(1 - 2Fo) + FoT_1^0 + FoT_3^0 \quad (1 \text{ mark for collecting to temperatures})$$

1 mark for clear steps

(c)

$$(1 - 2Fo) \geq 0, \text{ or } Fo \leq 0.5$$

Question 7:

Biot number is $Bi = \frac{h\Delta x}{k_{solid}}$, Ratio of thermal resistance through a solid to thermal resistance into the solid

Nusselt number is $Nu = \frac{hL}{k_{air}}$, Ratio of heat loss due to convection compared to the heat loss that would occur from the surface if there was only conduction.

Therefore, the values of thermal conductivity are different. In Biot it is for the solid, while in the Nusselt number the thermal conductivity is for the air.