Code Number :..............

HEAT TRANSFER QUALIFYING EXAM

August 2018

One book allowed (closed notes)

Answer all questions

All questions have equal weight

TIME: 3.0 hrs

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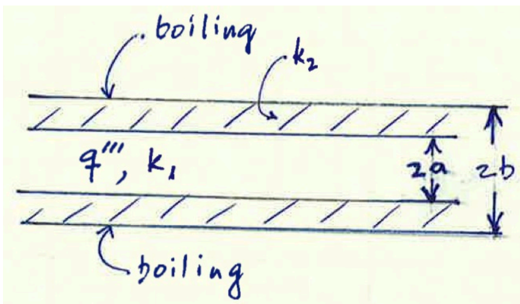
Problem 1 A laminated plate consists of an internal layer of metal ($-a \leq x \leq +a$) sandwiched by layers of a different metal ($-b \leq x \leq -a$ and $a \leq x \leq b$). The inner layer is 2 cm thick ($a = 1$ cm) and has a thermal conductivity of 50 W m^{-1} K^{-1} and volumetric heat generation of 10^6 W m^{-3}. The outer layers are 1 cm thick and in perfect contact with the inner layer. The outer layers have conductivity of 20 W m^{-1} K^{-1} and no heat generation. The plate is immersed in water at 1 atm. Assuming that the water at the outer surface of the plate is subject to pool boiling (i.e., assume a very large value of the heat transfer coefficient h) and that the thickness of the cladding on each side is 1 cm, determine the steady-state temperature 1) at the centerline of the plate and 2) at the interface of the two solid materials.

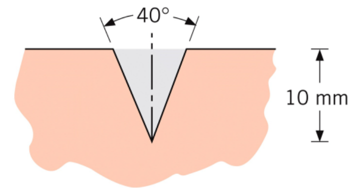


Problem 2. Consider a thin walled pipe made of a highly conducting metal. The pipe has a diameter of 5 cm. Water enters at 57 °C and exits at 47 °C with a mass flow rate of $\dot{m} = 0.25$ kg s^{-1}. Air at 20 °C flows across the pipe at a velocity of 10 m s^{-1}. Estimate the length of the pipe needed to achieve these conditions.

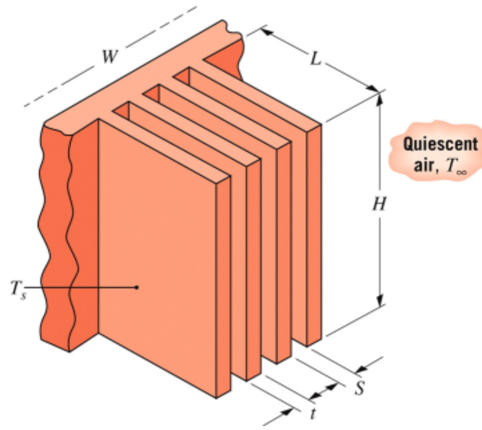
Problem 3. Consider a long V groove that is 10 mm deep machined on a block. The block is maintained at 727°C. The groove surfaces are opaque and diffuse for which $\alpha_\lambda = 0.85$ for $\lambda \leq 3$ μm, $\alpha_\lambda = 0.57$ for 3 μm $< \lambda \leq 5$ μm, and $\alpha_\lambda = 0.15$ for $\lambda > 5$ μm.

(a) Determine the total emissivity of the groove surface.

(b) Compute the radiant flux leaving the groove to its surroundings at 27°C.



Problem 4. Consider an array of vertical rectangular fins used to cool an electronic device mounted in quiescent, atmospheric air at $T_\infty = 27°C$. Each fin has the length of $L = 30$ mm and the height of $H = 200$ mm. The fin base temperature is maintained at $T_b = 127°C$. The fin is made of aluminum with $k = 205$ W/m·K.



(a) Viewing each fin surface as a vertical plate in an infinite, quiescent medium, estimate the optimum value of a fin spacing S for the prescribed condition.

(b) Calculate the heat transfer coefficient assuming that the surface of each fin ($T_s = 127°C$) is at the uniform temperature, which is the same as the base temperature.

(c) Using the computed "h" from (b) and for the optimum value of S and a fin thickness of t =1.6 mm, estimate the heat transfer rate from the fin array (including the prime surface) of width $W = 350$ mm. For Part (c), the fin array is no longer at the constant temperature, and the temperature decrease along the fin length should be accounted for.