<u>Code Number :</u>..............

HEAT TRANSFER QUALIFYING EXAM

August 2017

One book allowed (closed notes)

Answer all questions

All questions have equal weight

TIME: 3.0 hrs

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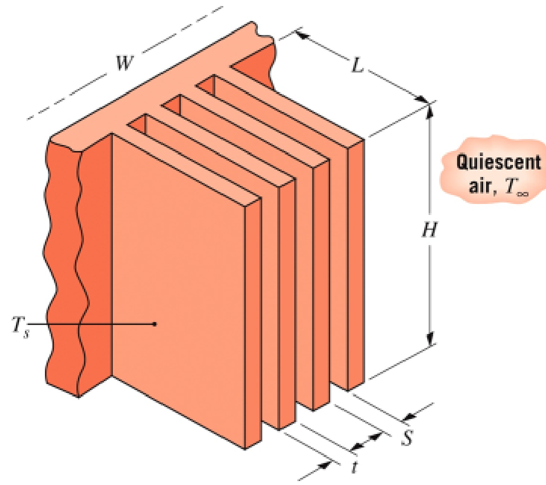
Problem 1. An array of vertical rectangular fins is used to cool an electronic device mounted in quiescent, atmospheric air at $T_\infty = 27°C$ as shown in the schematic. Each fin has $L = 30$ mm and $H = 200$ mm and operates at an approximately uniform temperature of $T_s = 77°C$.



(a) There exists an optimum fin spacing S, and explain why. Estimate the optimum value of S for the prescribed condition. Assume each fin surface is a vertical plate in an infinite, quiescent medium.

(b) For the optimum value of S and a fin thickness of $t = 3.4$ mm, estimate the rate of heat transfer from the fins for an array of width $W = 400$ mm.

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Problem 2. Two spherical balls of the same dimension but different materials are uniformly heated in a convection oven. During the subsequent cooling process, the temperature in the ball should not be less than 200°C. The ball diameter is 50 mm. One ball is made of pure aluminum (k = 237 W/m·K, ρ = 2702 kg/m3, c_p = 903 J/kg·K) and the other one is made of Teflon (k = 0.3 W/m·K, ρ = 2200 kg/m3, c_p = 970 J/kg·K).

To what uniform temperature should each ball be heated in the oven if the ball sits on a conveyor for 5 min while exposed to convection cooling with ambient air at 27°C and with a convection heat transfer coefficient of 12 W/m^2·K.

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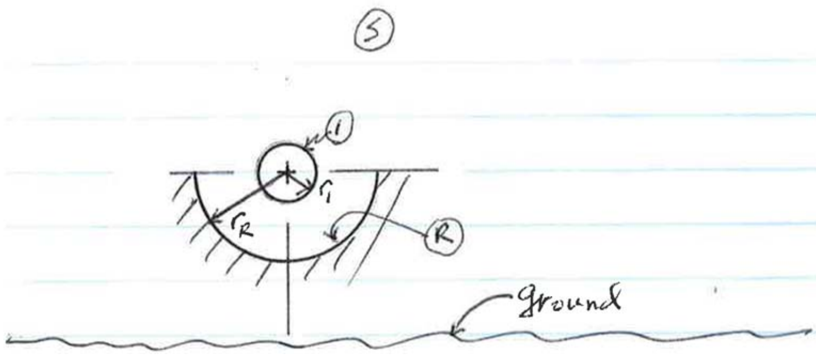
Problem 3. A long thin-walled pipe is suspended horizontally and has water at 101.3 kPa condensing on its inside surface. The cylinder is made of anodized aluminum and has an outside radius of $r_R = 5$ cm. A semi-circular reflector with radius $r_R = 15$ cm, is concentric with the pipe. The reflector $\boxed{R}$ has a reflectivity $\rho = 0.95$ and is oriented so that it faces upward towards the night sky $\boxed{S}$. The effective night sky temperature is -20 °C. The reflector is perfectly insulated on its non-reflective (downward facing, convex) side. Assume that the ambient air is still.



a. Calculate all relevant view-factors (a.k.a. angle-factors)
b. Calculate the rate of heat loss per unit length of the pipe.
c. Calculate the temperature of the reflector.

Note: the view factor for the reflector to itself can be calculated using

$$F_{RR} = 1 - \frac{2}{\pi}\left(\sqrt{1 - r^2} + r \sin^{-1} r\right)$$

where $r = r_1/r_R$.

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Problem 4. A submerged steel pipe (k = 20 W/m/°C) carries oil at 0.25 m^3/s across a river. The interior diameter of the pipe is 20 cm and the exterior diameter is 21 cm. At one bank of the river, the mean temperature of the oil is 90 °C and at the other bank it is 80 °C. The river flows at 3 m/s and the temperature of the water is 10 °C. Estimate the submerged length of the pipe.