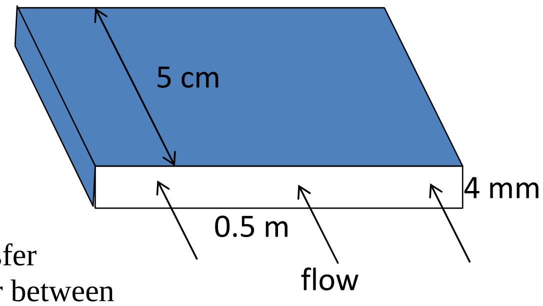
tn4780ta 2013-14
Part 2 Final Examination - 15 April 2014

Write your solutions *on your answer sheet*, not here. In all cases ***show your work***.
To avoid any possible confusion,
state the equation numbers and figure numbers of equations and figures you use.
Beware of unnecessary information in the problem statement.

1. Air flows through the slit-shaped gap between two aluminum cooling fins at a velocity of 20 m/s. The gap between fins (through which the air flows) is 4 mm wide; the gap is 0.5 m wide in the other direction. The path between the fins is 5 cm long in the direction of flow. What is the heat-transfer coefficient h for heat convective transfer between the air and the fins?
(20 points)



properties of air

$\mu = 1.75\text{x}10^{-5}$ Pa s $k = 0.025$ W/(m K) $\rho = 1.26$ kg/m^3 $C_p = 1006$ J/(kg K)

properties of aluminum

$\rho = 2701$ kg/m^3 $k = 229$ W/(m K) $C_p = 938.3$ J/(kg K)

2. A spherical solid of radius R, with thermal conductivity k, density ρ and heat capacity C_p, is heated by an internal reaction (generation rate S, in units W/(m^3)). After it comes to a very-hot steady state, heat transfer at the surface is controlled by radiation. The heat flux at the surface q_r is given by

$$q_r = A\,(T^4 - T_o^4) \quad \text{at } r = R$$

where A is a constant. (This equation is all you need to know about radiation to solve this problem.) Derive the steady-state temperature distribution in the solid, T(r).
(25 points)

3. The problem statement for problem 2 assumes that radiation is the important heat-transfer mechanism. An alternative would be to assume that Newton's law of cooling, i.e. convective heat transfer between the solid surface and the surrounding air, is the important means of heat transfer at the surface, for which

$$q_r = h\,(T - T_a) \quad \text{at } r = R$$

where T_a is the temperature of the air surrounding the solid and h is the heat-transfer coefficient. Explain clearly (in words) how you would decide which mechanism (radiation or convective heat transfer) is the important one, assuming you knew the value of T at the surface (r = R) as well as T_f and T_o, and the other parameters in this problem.
(13 points)

4. As noted in class, because of its nonlinear dependence on temperature, radiation does not become an important heat-transfer mechanism until temperature of the object becomes quite hot. Suppose that during the period of heating up to its final steady-state temperature, the sphere in Problem 2 has effectively *zero* heat transfer at its surface. (In other words, assume the surface is perfectly insulated.) At time t=0 the temperature of the sphere is T_i. Derive a formula for the time it takes the sphere to heat up to some higher temperature T_a with these assumptions. Assume during this time there are no temperature variations within the sphere.
(20 points)

5. Suppose a sphere of aluminum, 20 cm in diameter, is initially at 0°C. At time zero its surface is abruptly raised in temperature to 300°C. Then after 4 minutes the surface temperature is abruptly reduced to 100°C. What is the temperature at the center of the sphere 6 minutes after the start, i.e. 2 minutes after the second change in temperature?
(22 points)

<u>properties of aluminum</u>

ρ = 2701 kg/m^3 k = 229 W/(m K) C_p = 938.3 J/(kg K)