Code Number :_____

HEAT TRANSFER QUALIFYING EXAM

August 2015

One book allowed

Answer all questions

All questions have equal weight

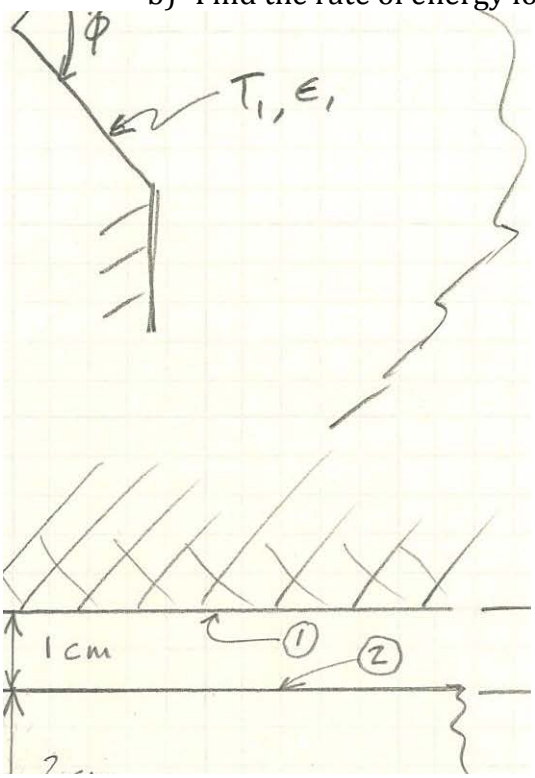
TIME: 3.0 hrs

Prepared by: Profs. A. Bénard and N. Wright

1. You would like to cool a warm bottle of soda rapidly by plunging it in a water stream. If the bottle is initially at 30 °C and the stream is at 12 °C, and the stream flows at 4 m/s, find how long it will take for the bottle and its content to reach 15 °C. Assume that both the bottle and the soda inside are at the same uniform temperature. The heat capacity of the glass bottle is 750 J/kg K and that of water is 4181 J/kg K. The mass of the bottle is 0.75 kg and there is one liter of soda. The bottle can be approximated as a cylinder of 8 cm in diameter and 12 cm in height, and the flow is maintained perpendicular to the bottle. Do you think it's a good approximation to assume that the glass is at the same temperature as the soda? When would this be a good approximation? Use properties of water at 295 K for computing various quantities.

2. Emerald ash borers (invasive insects) have been killing a large number of ash trees in the US. Extreme cold weather however may destroy a large percentage of emerald ash borer larvae. A recent study from the Forest Service (Venette and Abrahamson) in Minnesota showed that 5% of the insects die at 0 °F (-18 °C) , 34% at -10 °F, 79% at -20 °F and 98% at -30 °F (-34 °C). If the outside temperature of a large tree (idealized as a semi-infinite solid with a radius of 35 cm) has reached -40 °C, how deep inside a tree should an ash borer be buried to avoid dying from cold exposure with a 95% survival probability? How deep inside will the temperature reach -34 °C? Assume that the surface temperature of a tree has plunged to -40 °C and stays at this temperature for 10 hours, from an initial temperature of -10 °C. Neglect the curvature of the tree trunk. Use the following properties for an ash tree wood: $k = 0.17$ W/m K, $\rho = 850$ kg/m^3, $C_p = 1200$ J/kg K.

3. A 90° notch is in a wall, as shown in the figure. Surface 1 has and emissivity of ε = 0.7 and is maintained at a temperature of 200 °C. Surface 2 has an emissivity of ε = 1 and is maintained at a temperature of 100 °C. The surroundings are at a temperature of 20 °C. Assume uniform radiosity, gray-body behavior, and that Kirchhoff's law applies. The notch may be assumed to extend infinitely into the page.
    a) Find ALL of the angle (view) factors for this system.
    b) Find the rate of energy lost per unit area from surface 1.



4. Consider two plates that may be assumed to be infinite in the *x*- & *y*-directions. They are separated in the *z*-direction by 1 cm. Surface (1) of the top plate has a temperature of 1 °C, conductivity of 6 W m^{-1} K^{-1}, and emissivity of 0.9. Surface (2) on the bottom plate, which is 3 cm thick, has conductivity of 0.1 W m^{-1} K^{-1} and emissivity of 0.9. Surface (3) on the bottom plate has steam at a pressure of 1 atmosphere condensing on it.
    a. Calculate the steady-state temperature of surface 2.
    b. Calculate the rate of heat gain by surface 1.