Code Number : 2

HEAT TRANSFER QUALIFYING EXAM

August 2011

OPEN BOOK (only one book allowed)

Answer all questions

All questions have equal weight

TIME: 3.0 hrs

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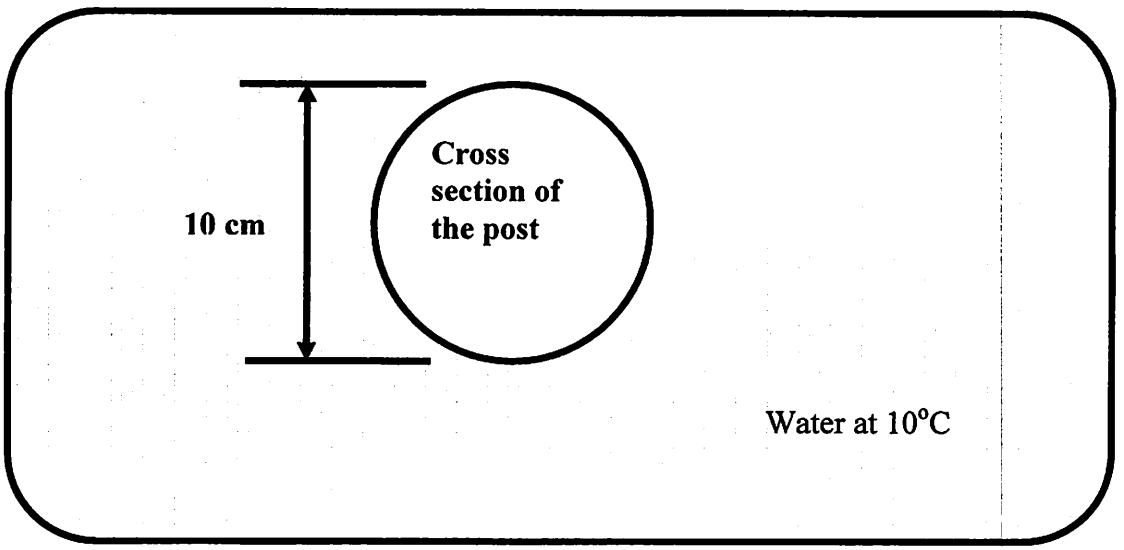
1. A hemispherical concave (it curves inward) dimple of radius 10 cm is in a wall. The dimple is maintained at 200 °C, and its surface has an emissivity of 0.85. The wall is surrounded by a *large* enclosure that is maintained at -196 °C. The surface of the enclosure has been painted with a paint that has an emissivity of 0.1. The surface area of a sphere is $4 \pi r^2$ and the area of a circle is πr^2.
    a. Using the view factor (angle factor) reciprocity and summation relations to determine the relevant view factors.
    b. Calculate the heat transfer from the dimple to the surroundings.

2. The trailer of truck contains saturated liquid nitrogen as -196 °C. The truck is traveling at 100 km/h and the ambient air temperature is 25 °C. The top of the trailer may be considered a 12 m long flat plate. Assume that the nitrogen is insulated from the atmosphere by 5 cm of foam insulation, such as urethane. The insolation (heat flux due to the sun) on the top surface is 500 W/m^2. Estimate the steady state temperature of the top surface of the trailer if the surface has emissivity in the infrared spectrum of ε=0.6 and absorptivity in the solar spectrum of α=0.3.

3. A circular post made of wood composite is produced by mixing wood, PVC and talc powder and extruding the mixture through a die. The extrudate is then cooled by convection by passing the lumber through a water bath attached to the die. Neglecting longitudinal conduction (in the long direction of the post), find how long it will take for the post to have a core temperature that drops from 170°C to 90°C (temperature at which the material has sufficient rigidity to be handled). If the material is pushed out of the die at 1m/s how long should the bath be? Use the diagram below to obtain the relevant dimensions for the cross section. The properties of the wood composite mixture are: $k = 10$ W/mK, $\rho = 700$ kg/m^3, $c_p = 1000$ J/kgK. The heat transfer coefficient of the surrounding water is $h = 350$ W/m^{2}K and the water is at 10°C.



4. The horizontal surface of a freezer is covered with a frost layer having a thickness of 2mm. The freezer is open to allow the frost to melt. If the compartment is exposed to ambient air at 20°C and the air is quiescent, estimate the time it will take for the frost to melt. You can assume that the frost is at the melting point of water and that it has a mass density of 700 kg/m3 and a heat of fusion of 333 kJ/kg.