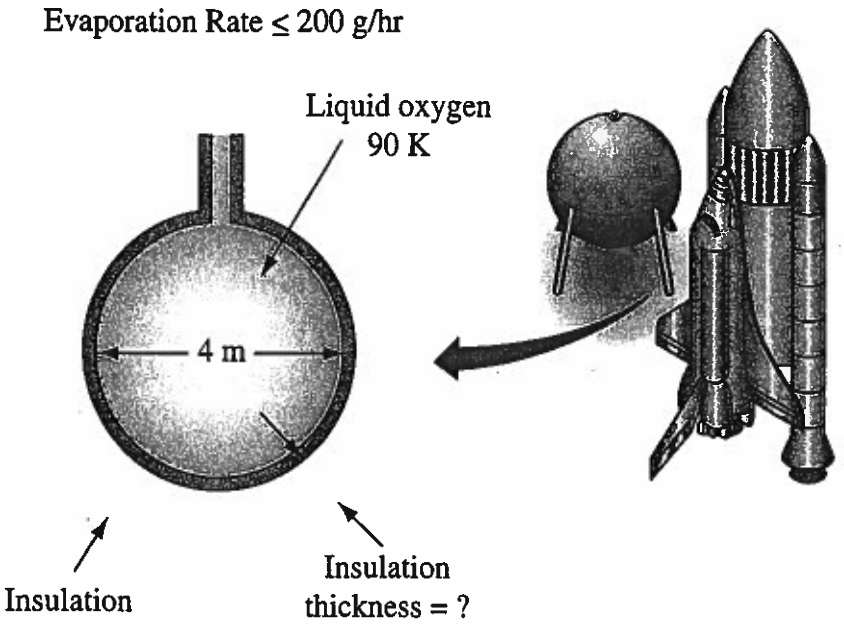
ASSIGNMENT #3

Spherical Problems / Resistance Concept

3–1 Liquid oxygen (LOX) for the space shuttle can be stored at 90 K prior to launch in a spherical container 4 m in diameter. To reduce the loss of oxygen, the sphere is insulated with superinsulation developed at the U.S. National Institute of Standards and Technology's Cryogenic Division; the superinsulation has an effective thermal conductivity of 0.00012 W/m K. If the outside temperature is 20°C on the average and the LOX has a heat of vaporization of 213 J/g, calculate the thickness of insulation required to keep the LOX evaporation rate below 200 g/h.

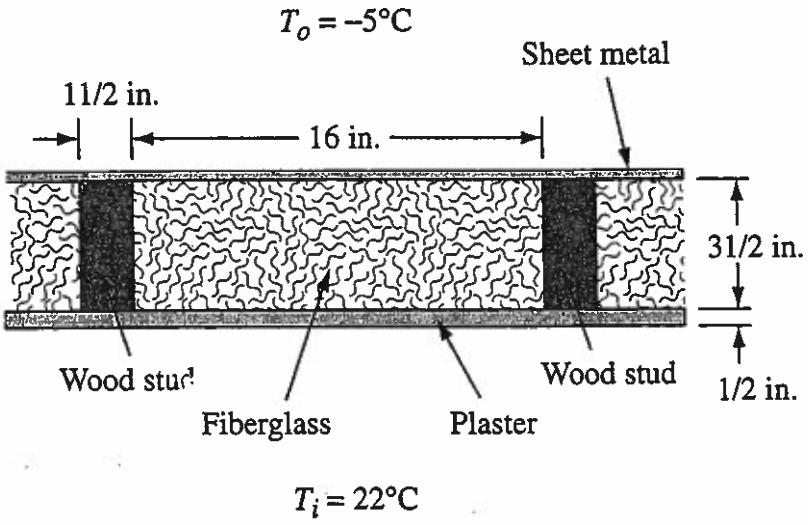


3–2 A hollow sphere with inner and outer radii of R_1 and R_2, respectively, is covered with a layer of insulation having an outer radius of R_3. Derive an expression for the rate of heat transfer through the insulated sphere in terms of the radii, the thermal conductivities, the heat transfer coefficients, and the temperatures of the interior and the surrounding medium of the sphere.

3–3 For the system outlined in Problem 3–2 , determine an expression for the critical radius of the insulation in terms of the thermal conductivity of the insulation and the surface coefficient between the exterior surface of the insulation and the surrounding fluid. Assume that the temperature difference, R_1, R_2, the heat transfer coefficient on the interior, and the thermal conductivity of the material of the sphere between R_1 and R_2 are constant.

3–4 Mild steel nails were driven through a solid wood wall consisting of two layers, each 2.5 cm thick, for reinforcement. If the total cross-sectional area of the nails is 0.5% of the wall area, determine the unit thermal conductance of the composite wall and the percent of the total heat flow that passes through the nails when the temperature difference across the wall is 25°C. Neglect contact resistance between the wood layers.

3–5 The ceiling of a tract house is constructed of wooden studs with fiberglass insulation between them. On the interior of the ceiling is plaster and on the exterior is a thin layer of sheet metal. A cross section of the ceiling with dimensions is shown below.



The *R*-factor describes the thermal resistance of insulation and is defined by

$$R - factor = L/k_{\text{eff}} = \Delta T/(q/A)$$

Calculate the *R*-factor for this type of ceiling and compare the value of this *R*-factor with that for a similar thickness of fiberglass. Why are the two different? (b) Estimate the rate of heat transfer per square meter through the ceiling if the interior temperature is 22°C and the exterior temperature is −5°C.