FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI

MECHANICAL ENGINEERING DEPARTMENT

HARMATTAN SEMESTER POSTGRADUATE EXAMINATION

Course Title: Advanced Heat Transfer **Course Code:** MEE 861

Instruction: Answer **ALL** questions **Date:** November 13, 2017

1. The operations manager for a metals processing plant anticipates the need to repair a large furnace and has come to you for an estimate of the time required for the furnace interior to cool to a safe working temperature. The furnace is cubical with a 16 m interior dimension and 1 m thick walls for which density is 2600 kg/m^3, specific heat capacity is 960 J/kgK, and thermal conductivity is 1W/mK. The operating temperature of the furnace is 900°C, and the outer surface experiences convection with ambient air at 25°C and a convection coefficient of 20 W/m^{2}K. (a) Use the finite difference procedure to estimate (time) the time required for the inner surface of the furnace to cool to a safe working temperature of 35°C. *Hint*: Consider a two-dimensional cross section of the furnace, and perform your analysis on the smallest symmetrical section. (b) Anxious to reduce the furnace downtime, the operations manager also wants to know what effect circulating ambient air through the furnace would have on the cool-down period. Assume equivalent convection conditions for the inner and outer surfaces.

2. A flat-plate solar collector is constructed as shown in Figure 1. A glass plate covers the blackened surface, which is insulated. Solar energy at the rate of 750W/m^2 is transmitted through the glass and absorbed in the blackened surface. The surface heats up and radiates to the glass and also loses heat by convection across the air gap, which has k_e/k =1.4. The outside surface of the glass loses heat by radiation and convection to the environment at 30°C with h = 20 W/m^{2}°C. It is assumed that the glass does not transmit any of the thermal radiation and has emissivity = 0.9. The blackened surface is assumed to have emissivity = 1.0 for all radiation. Determine the temperatures of the glass and inside surface.
T_{glass}, T_{inside}

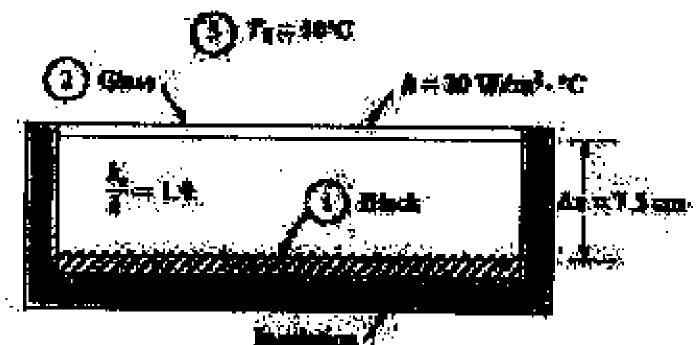

Figure 1

3. A long cylindrical nuclear fuel rod, 50 mm inside diameter, is surrounded by an annular layer of aluminium cladding 10 mm thick. Within the fuel rod, heat is generated by fission. The rate of generation per unit volume , Sn, is given by the following expression.

$S_n = S_{no}\left[1 + 0.5\left(\frac{r}{R_F}\right)^2\right]$ Where S_{no} = 100 MW/m^3 is the heat per unit volume produced at r = 0, r is the distance from the axis of the fuel rod, R_F is the radius of the fuel rod.

If the outer surface of the cladding is maintained at a uniform temperature of 150oC, calculate the maximum temperature in the fuel rod. The thermal conductivity of the fuel rod and cladding are 30 W/mK and 120 W/mK, respectively.

4. Radioactive wastes (k_{rw} = 20 W/mK) are stored in a spherical, stainless steel (k_{ss} = 15 W/mK) container of inner and outer radii equal to r_i = 0.5 m and r_o = 0.6 m. Heat is generated volumetrically within the wastes at a uniform rate of q = 10^5 W/m^3, and the outer surface of the container is exposed to a water flow for which h = 1000 W/m^{2}K and T_∞ = 25°C. (a) Evaluate the steady-state outer surface temperature, $T_{s,o}$. (b) Evaluate the steady-state inner surface temperature, $T_{s,i}$. (c) Obtain an expression for the temperature distribution, $T(r)$, in the radioactive wastes.

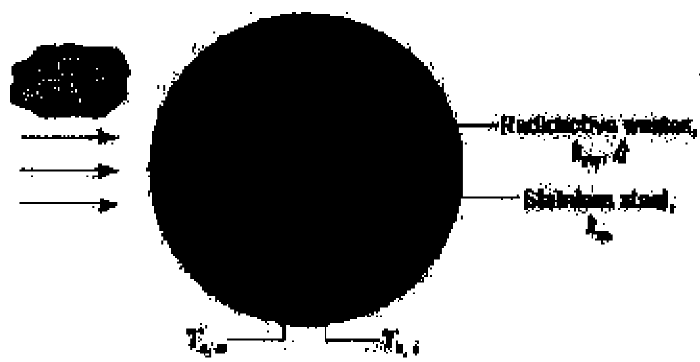

Figure 2

5. A cooling pot commonly used for storing water in the rural areas of our country is made of porous material. A small amount of water diffuse through the material and evaporate from the surface. The evaporation of the water cools the surface of the pot and a temperature driving force is established. Assuming the following values at the surface temperature of the pot, Ts;

Prandtle number	=	0.72
Schmidt number	=	0.61
Density of air	=	ρ
Viscosity of air	=	μ
Thermal conductivity of air	=	k
Specific heat of air	=	c_p
Free stream velocity of air, V_∞	=	3 m/s
Latent heat of vapourization of water	=	L
Vapour pressure of water	=	P
Partial pressure of water in ambient air	=	P_o

Find an expression for the temperature of ambient air.