# MCL 242 Heat and Mass Transfer
## Major Examination

Max. Marks:80

November 19, 2017

**Note: Pl answer questions neatly showing calculations wherever required. Marks will be deducted for untidy work and when calculations steps are not shown at all. While using the tables, you may use nearest values WITHOUT interpolation.**

1. **Consider the following relation**

$$q_1 = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1-\epsilon_1}{\epsilon_1 A_1} + \frac{1}{A_1 F_{12}} + \frac{1-\epsilon_2}{\epsilon_2 A_2}}$$

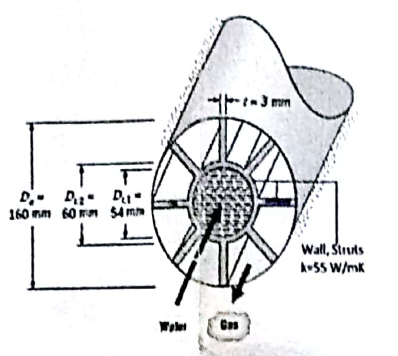
(i) Under what conditions is the above relation valid?
(ii) What is the physical meaning of quantities $q_1$ and $F_{12}$?
(iii) Show that under certain conditions, the above relation can be reduced to the following. Clearly state the relevant conditions.

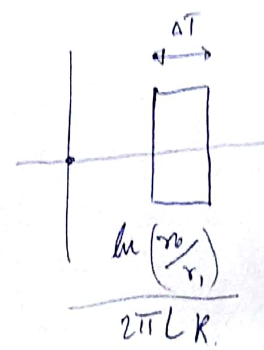
$$q_1 = \sigma \epsilon_1 A_1 (T_1^4 - T_2^4)$$

(iv) Give an example of a practical situation in which the relation given in (iii) is valid. Choose realistic values of the quantities on the right hand side and hence compute $q_1$ for that case. How will this information about $q_1$ be useful in practice for an engineer? (2+2+3+3)

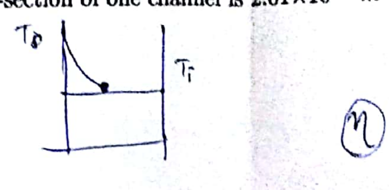
2. (i) What fraction of solar radiation is in the infrared range if the sun's temperature is taken to be 5780 K?
(ii) A spherical furnace of inner diameter 70 cm has a small circular opening of diameter 2 cm for multi-purpose use. What fraction of radiation from the remaining part of the furnace walls escapes from this opening? Assume the furnace walls to be diffuse and gray and the gases in the furnace to be transparent to the radiation emitted from the furnace walls. (2+3)

3. In a container insulated with polystyrene foam of thickness 50 mm, pudding at 80°C is poured and the container closed immediately. How much time will it take for the effect of the hot pudding to penetrate to a distance which is one tenth of the insulation thickness. Assume the other two dimensions of the insulation to be much larger than its thickness and neglect curvature effects. The ambient temperature is 10°C. The thermal diffusivity of the insulation material can be taken to be $1.46\times10^{-6} m^2/s$. Assume the temperature of the pudding does not change in this period. (5)



4. Hot flue gases coming from a furnace are to be used to heat water for an industrial process. The heat exchanger required for this purpose is proposed to have the cross section as shown in the figure. The water initially at 30°C is to flow through the inner tube at a mass flow rate of 0.46 kg/s, while flue gases at 800 K are to flow in the counter direction at a flow rate of 0.25 kg/s. The heat exchanger has a length of 3 m and water as well as gas flow can be considered to be fully developed. The struts are made of a metal with thermal conductivity 55 W/m K. The hydraulic diameter of one channel bounded by the struts is 44.6 mm and the area of cross-section of one channel is $2.01\times10^{-3}$ $m^2$. Neglecting the thermal resistance due to



the thickness of the tube, find the effectiveness, the LMTD and the number of transfer units for this heat exchanger. Hence find the outlet temperatures of water and flue gases. Neglect radiation heat transfer.(27)

5. Answer the following in ONLY One-Two sentences: (2×3+3×9=33)

(a) The analogy between heat and mass transfer helps in using the results of one in case of the other. Give one difference between the two related to the boundary conditions which one must keep in view while formulating a diffusion mass transfer problem.

(b) What do you mean by Colburn j factor? What is its significance in heat transfer?

(c) Why is the heat transfer coefficient between a surface and a fluid very high when the fluid is changing phase?

(d) A coating is to be selected for the absorber plate of a solar collector, show on a plot, the ideal variation of spectral emissivity and spectral absorptivity of this coating with wavelength? Give reasons for the shape of the plot drawn by you.

(e) Show that in case of a fluid flowing through a tube whose walls are subjected to constant heat flux, the mean temperature varies linearly in the axial direction in the thermally developing as well as fully developed regions. In a practical situation, how can you achieve constant heat flux?

(f) How is the mass transfer coefficient related to the concentration gradient of one component in the medium under consideration? What relations will you use to find this coefficient in the case of mass transfer of paraffin from a slab of paraffin to ambient air, if the boundary layer is laminar?

(g) What are the two prime types of condensation? Which one is preferred and why? What do you mean by pool boiling?

(h) Draw the variation in $Nu_x$ and $h_x$ with x in the case of a laminar boundary layer flow with the solid surface maintained at constant temperature.

(i) Do you expect the heat transfer coefficient in the thermally developing length of a tube to be higher or lower than the fully developed heat transfer coefficient? Give reasons.

(j) How do you define thermal full development in a pipe flow with hot fluid flowing in the pipe and pipe walls maintained at constant temperature lower than that of the fluid?

(k) Write the expression for heat transfer between two large parallel surfaces in the presence of a radiation shiled. What is the purpose of the shield?

(l) In natural convection next to a hot vertical plate, which non-dimensional numbers does Nusselt number at any given location on the plate depend upon? Give the expressions using standard symbols and a simple sketch.

$Re = \frac{\rho V x}{\mu}$ $Nu = \frac{h_x x}{k}$ $Nu = \frac{h L_c}{k_f}$

$\frac{f}{2} = St\, Pr^{2/3}$

$\Delta q = m C_p \Delta T$

J/kg K

$\frac{1}{x^2}$