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UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program: B.Tech PSE | **Semester – III**
Subject (Course): Heat and Mass Transfer Processes | **Max. Marks : 100**
Course Code : GNEG353 | **Duration : 3 Hrs**
No. of page/s:

Section A | **Answer all Questions** | **5X4 = 20 Marks**

1. (CO5) In a solar pond salt is placed at the bottom of the pond 1.5 m deep. The surface is flushed constantly so that the concentration of salt at the top layer is zero. The salt concentration at the bottom layer is 5 kg mole/m^3. Determine the rate at which salt is washed off at the top at steady state conditions per m^2. $D = 1.24 \times 10^{-9}$ m^2/s.
2. (CO1) Water flows at a velocity of 1m/s through a pipe of 25mm ID and 30 OD and 3 m length. Air at 30°C flows across the tube, with a velocity of 12 m/s. The inlet temperature of the water is 60°C. Determine the exit temperature. The thermal conductivity of the tube material is 47 W/mK.
3. (CO4) Determine the emissivity of water vapor in a spherical gas body of 2 m dia when the partial pressure of water vapor is 0.05 atm and the temperature of the mixture is 1000 K. The total pressure is 1 atm.
4. (CO5) In order to avoid pressure build up ammonia gas at atmospheric pressure in a pipe is vented to atmosphere through a pipe of 3 mm dia and 20 m length. Determine the mass of ammonia diffusing out and mass of air diffusing in per hour. Given $D = 0.28 \times 10^{-4}$ m^2/s, M = 17 kg/kg mole
5. (CO3) Define effectiveness of heat exchanger. Derive equation for effectiveness of a parallel flow heat exchanger.

Section B | **Answer all Questions** | **5X8 = 40 Marks**

6. (CO1) Derive general heat conduction equation in spherical co-ordinates.
7. (CO4) Define total emissive power (Eb) and intensity of radiation (Ib). Show that $Eb = \pi \times Ib$.
8. (CO3) Derive an expression for Logarithmic Mean Temperature Difference (LMTD) for counter flow heat exchanger stating the assumption made.
9. (CO5) A well is 40 m deep and 9 m dia and the atmospheric temperature is 25°C. The air at the top is having a relative humidity of 50%. Determine the rate of diffusion of water vapor through the well $D = 2.58 \times 10^{-5}$ m^2/s. Assume the partial pressure is equal to saturation pressure at 25°C = 0.03169 bar.
10. (CO4) Determine the fraction of the radiation leaving the base of the cylindrical enclosure that escapes through a coaxial ring opening at its top surface. The radius and the length of the enclosure are r1 = 10 cm and L = 10 cm, while the inner and outer radii of the ring are r2 = 5 cm and r3 = 8 cm, respectively.

Section C **Answer all Questions** **2X20 = 40 Marks**

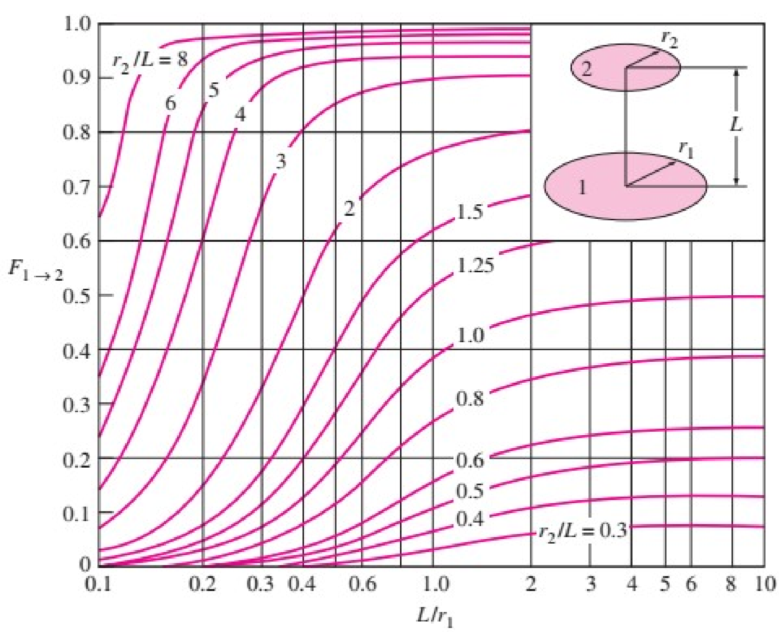
11. (CO4) Consider the 5-m X 5-m X 5-m cubical furnace, whose surfaces closely approximate black surfaces. The base, top, and side surfaces of the furnace are maintained at uniform temperatures of 800 K, 1500 K, and 500 K, respectively. Determine (a) the net rate of radiation heat transfer between the base and the side surfaces, (b) the net rate of radiation heat transfer between the base and the top surface, and (c) the net radiation heat transfer from the base surface.

(Or)

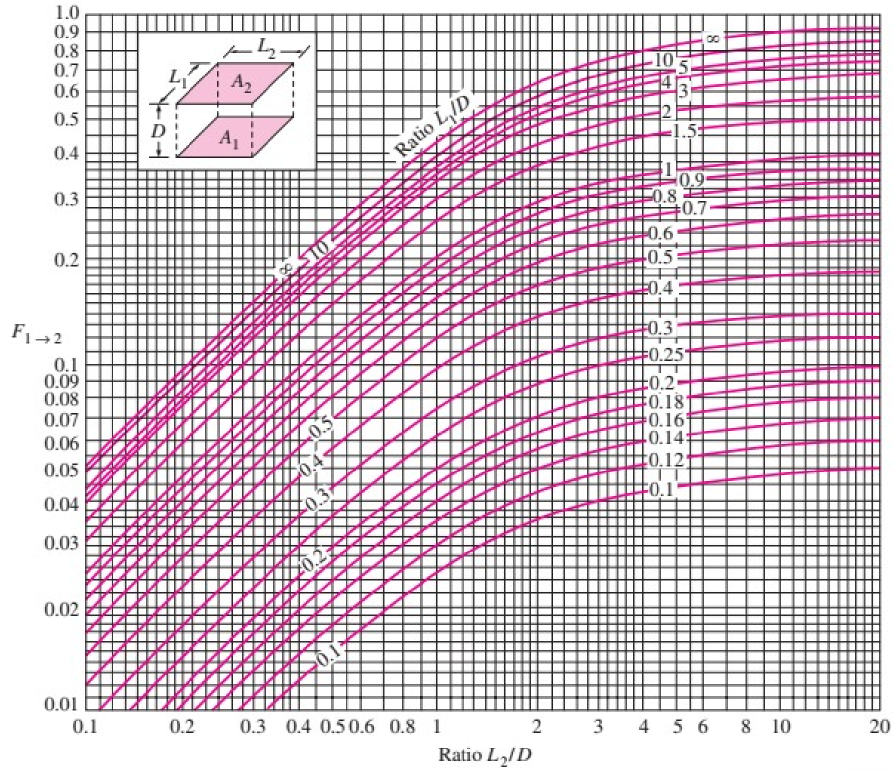
(CO5) (a) Air at 25°C and 20% RH flows through a pipe of 25 mm ID with a velocity of 5.2 m/s. The inside surface is constantly wetted with water and a thin water film is maintained throughout. Determine the water evaporated per m2 surface area. Given v = 15.7×10^{-6} m^2/s, Sc = 0.60 $D_{ab} = 0.26 \times 10^{-4}$ m^2/s

(CO5) (b) Pure water at 20°C flows over a slab of salt at a velocity of 1 m/s. At the interface the concentration of salt is 380 kg/m3. Determine over a length of 1 m the average convection coefficient for mass transfer and also the rate of diffusion of salt into the water. Assume turbulent flow from the leading edge. D = 1.2 × 10–9 m2/s, density of water = 1000 kg/m3, kinematic viscosity = 1.006×10^{-6} m^2/s, Sc = $1.0006 \times 10^{-6}/1.2 \times 10^{-9} = 838.33$.

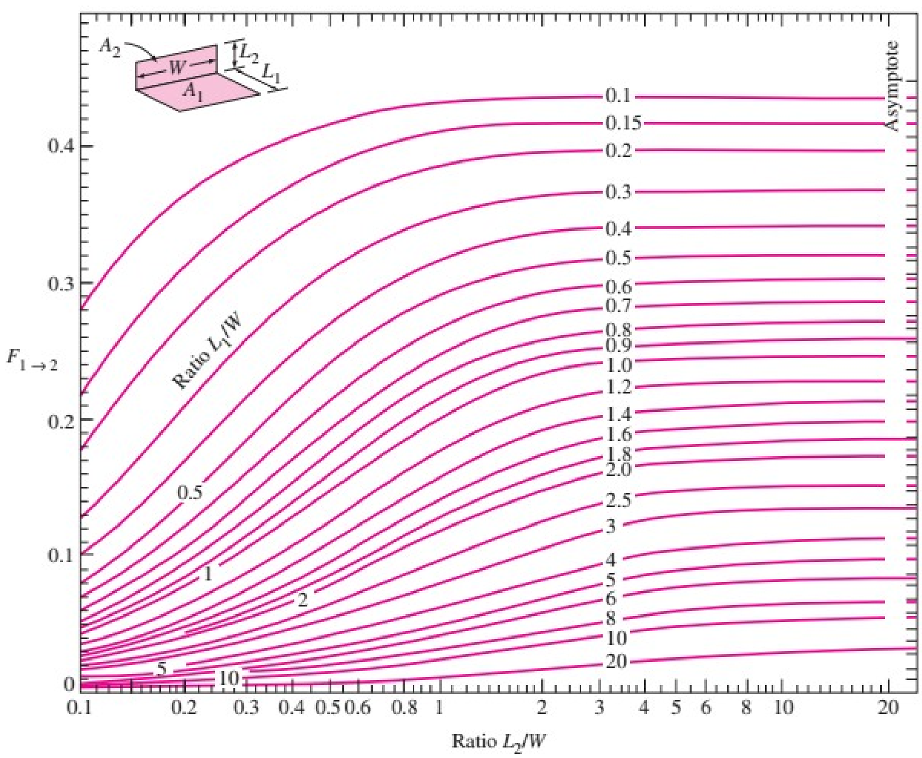
12. (CO4) Consider a cylindrical furnace with r_0 = H = 1 m. The top (surface 1) and the base (surface 2) of the furnace has emissivities 0.8 and 0.4, respectively, and are maintained at uniform temperatures T_1 = 700 K and T_2 = 500 K. The side surface closely approximates a blackbody and is maintained at a temperature of T_3 = 400 K. Determine the net rate of radiation heat transfer at each surface during steady operation and explain how these surfaces can be maintained at specified temperatures.



View factor between two coaxial parallel disk



View factor between two aligned parallel rectangle of equal size



View factor between two perpendicular rectangles with a common edge.

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Section A — **Answer all Questions** — **5X4 = 20 Marks**

1. (CO5) Air at 25°C and 50% RH flows over water surface measuring 12 m × 6 m at a velocity of 2 m/s. Determine the water loss per day considering flow direction is along the 12 m side. $D = 0.26 \times 10^{-4}$ m^2/s, $Sc = 0.60$, $\nu = 15.7 \times 10^{-6}$ m^2/s.
2. (CO2) By dimensional analysis show that for natural convection heat transfer the Nusselt number (Nu) can be expressed as a function of Grashof number (Gr) and Prandtl number (Pr).
3. (CO4) State and explain Wein's displacement Law and Kirchoff's Law of radiation. Describe Electrical Analogy for radiation heat transfer
4. (CO5) A tank contains a mixture of CO_2 and N_2 in the mole proportions of 0.2 and 0.8 at 1 bar and 290 K. It is connected by a duct of sectional area 0.1 m2 to another tank containing a mixture of CO2 and N2 in the molal proportion of 0.8 and 0.2. The duct is 0.5 m long. Determine the diffusion of CO2 and N2. $D = 0.16 \times 10^{-4}$ m^2/s.
5. (CO3) Discuss the importance of heat exchangers for industrial use.

Section B — **Answer all Questions** — **5X8 = 40 Marks**

6. (CO5) Benzene liquid at 25°C is in a cylindrical glass jar of 5 cm dia at the bottom. Air column is 30 cm above the liquid. The air in the jar is stationary. Sufficient movement exists at the top to remove the diffused vapor so that the partial pressure of vapor at the top can be assumed as zero. Determine the diffusion rate. The partial pressure at the interface is 0.1 bar. $D = 0.0962 \times 10^{-4}$ m^2/s R = 8315/78,
7. (CO4) Prove that intensity of normal radiation is $1/\pi$ times the emissive power.
8. (CO3) Derive equation of Logarithmic Mean Temperature Difference (LMTD) for parallel flow Heat-exchanger.
9. (CO3) Hot oil is to be cooled in a double-tube counter-flow heat exchanger. The copper inner tubes have a diameter of 2 cm and negligible thickness. The inner diameter of the outer tube (the shell) is 3 cm. Water flows through the tube at a rate of 0.5 kg/s, and the oil through the shell at a rate of 0.8 kg/s. Taking the average temperatures of the water and the oil to be 45°C and 80°C, respectively, determine the overall heat transfer coefficient of this heat exchanger. $\rho = 990$ kg/m3, Pr = 3.91, k = 0.637 W/m · °C, $\nu = \mu/\rho = 0.602 \times 10^{-6}$ m2/s.
10. (CO4) The surface A1 and A2 having emissivities of 0.6 and 0.4 are maintained at 800 K and 400 K. (i) Determine the heat exchange between the surfaces per unit length considering these are long with the third side open and at 400 K. (ii) If surface 3 is well insulated, so that the surface is non absorbing determine the heat exchange.

Section C **Answer all Questions** **2X20 = 40 Marks**

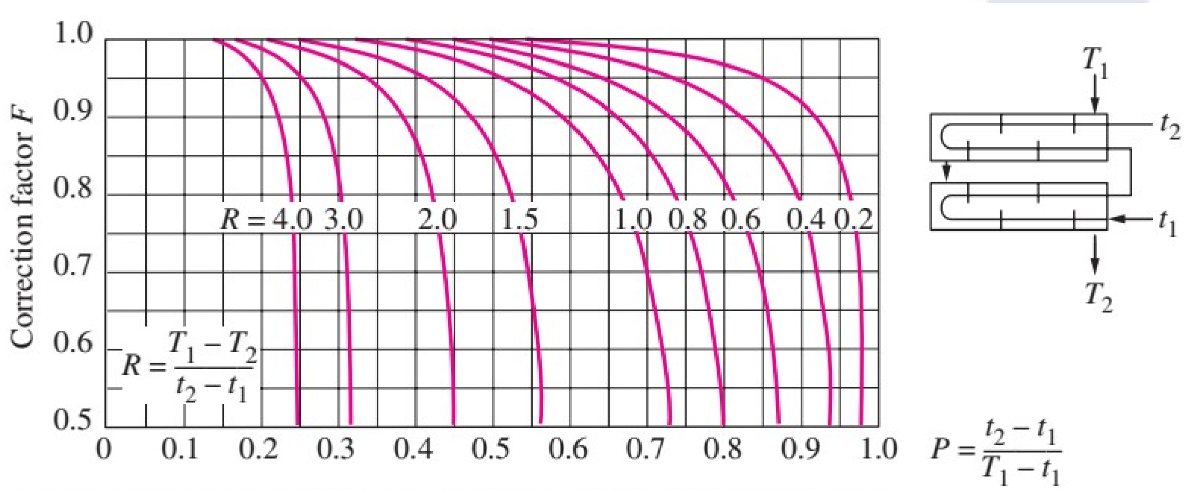
13. (CO4) A furnace is shaped like a long equilateral triangular duct. The width of each side is 1 m. The base surface has an emissivity of 0.7 and is maintained at a uniform temperature of 600 K. The heated left-side surface closely approximates a blackbody at 1000 K. The right-side surface is well insulated. Determine the rate at which heat must be supplied to the heated side externally per unit length of the duct in order to maintain these operating conditions.

(Or)

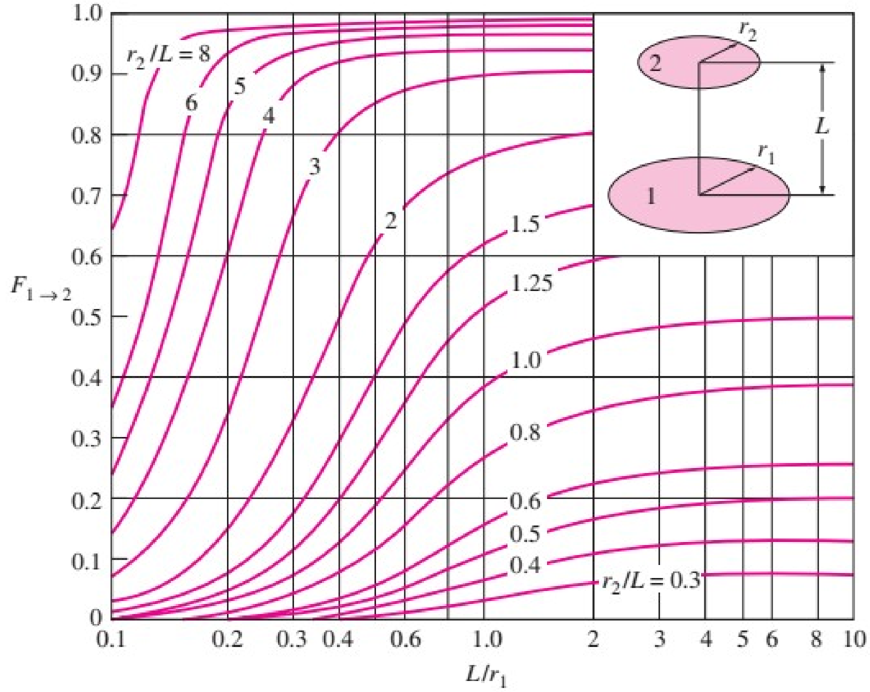
11. (CO5) (a) The partial pressure of diffusing vapour over a surface under steady state of mass transfer was measured and plotted against height above the surface. At the surface the partial pressure was 0.1 bar and in the free stream the partial pressure was 0.02 bar. The tangent to the concentration profile at the surface meets the x-axis at 2.2 mm. Determine the convective mass transfer coefficient D = 28.8 × 10–6 m2/s.

(CO5) (b) The outlet of a desert cooler is 28°C and 80% RH. In the inlet air the partial pressure of water vapour is 0.18 bar. Estimate the outside air temperature and the relative humidity. $D = 27.12 \times 10^{-6}$ m^2/s, $\alpha = 21.42 \times 10^{-6}$ m^2/s.

12. (CO3) A 2-shell passes and 4-tube passes heat exchanger is used to heat glycerin from 20°C to 50°C by hot water, which enters the thin-walled 2-cm-diameter tubes at 80°C and leaves at 40°C. The total length of the tubes in the heat exchanger is 60 m. The convection heat transfer coefficient is 25 $W/m^2{}^\circ C$ on the glycerin (shell) side and 160 $W/m^2{}^\circ C$ on the water (tube) side. Determine the rate of heat transfer in the heat exchanger (a) before any fouling occurs and (b) after fouling with a fouling factor of 0.0006 $m^2{}^\circ C/W$ occurs on the outer surfaces of the tubes.



Two-shell passes and 4, 8, 12, etc. (any multiple of 4), tube passes



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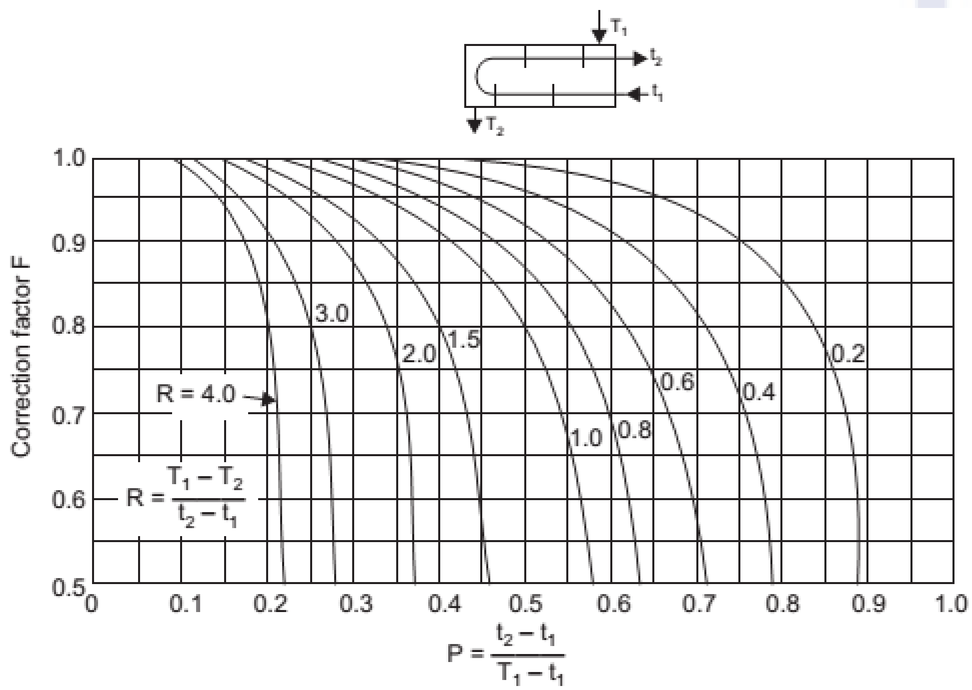

Correction factor F for shell-and-tube heat exchangers with one shell pass and any multiple of two tube passes (2, 4, 6, etc., tube passes).