7. (a) Consider a cold plate maintained at uniform temperature, Tw, is placed vertically in a saturated vapour at Tv (Tw < Tv). The condensate film that is generated over the plate is flowing downward due to gravity. Derive an expression for the thickness of the condensate film at a distance x from the top of the plate.

   (b) What is nucleate boiling?

   (c) Define view factor.

**8 + 2 + 2 = 12**

## Group - E

8. (a) Water with a flow rate of 0.05 kg/s enters an automobile radiator at 400 K and leaves at 330 K. The water is cooled by air in cross flow which enters at 0.75 kg/s and leaves at 300 K. If the overall heat transfer coefficient is 200 W/m$^2$.K, what is the required heat transfer surface area?

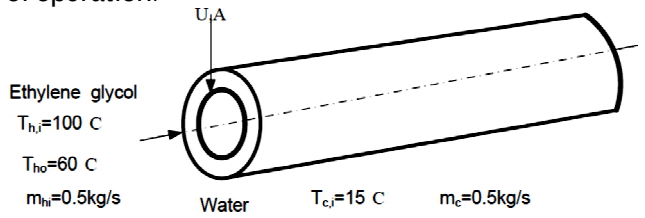
   (b) Why LMTD is important parameter to design a shell-tube heat exchanger? Define LMTD correction factor and it's importance.

**7 + (2 + 3) = 12**

9. (a) Water at 225 kg/h is to be heated from 35 to 95°C by means of a concentric tube heat exchanger. Oil at 225 kg/h and 210°C, with a specific heat of 2095 J/kg.K, is to be used as the hot fluid. If the overall heat transfer coefficient based on the outer diameter of the inner tube if 550 W/m$^2$.K, determine the length of the exchanger if the outer diameter is 100mm.

   (b) What do you mean by forward feed and backward feed evaporator?

   (c) A concentric tube heat exchanger uses water, which is available at 15°C, to cool ethylene glycol from100 to 60°C. The water and glycol flow rates are each 0.5 kg/s. Determine the maximum possible heat transfer rate and effectiveness of the exchanger. Determine which is preferred, a parallel–flow or counter flow mode of operation? Known: Inlet temperatures and flow rate for a concentric tube heat exchanger. Find: (i) Maximum possible heat transfer rate and effectiveness, (ii) Preferred mode of operation.




**5 +(2 + 5) = 12**





# PROCESS HEAT TRANSFER
# (CHEN 2201)

**Time Allotted : 3 hrs** **Full Marks : 70**

***Figures out of the right margin indicate full marks.***

***Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.***

***Candidates are required to give answer in their own words as far as practicable.***

## Group – A
## (Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

   (i) For the same inlet and exit temperatures of two fluids, the LMTD for counter flow is always
   (a) smaller than LMTD for parallel flow
   (b) greater than LMTD for parallel flow
   (c) same as LMTD for parallel flow
   (d) unpredictable.

   (ii) What is lumped heat capacity analysis?
   (a) the analysis of a system in which it is assumed to be at no uniform temperature
   (b) the analysis of a system in which it is assumed to be at uniform temperature
   (c) the analysis of a system in which it is assumed to be at either uniform or no uniform temperature
   (d) none of the above.

   (iii) Critical thickness of insulation on a spherical surface is given by
   (a) k/h (b) h/2k (c) 2k/h (d) h/k
   where, k is the thermal conductivity of insulation and h is convective heat transfer coefficient.

   (iv) Which of the following temperature difference is safer than other to consider in designing of heat exchangers?
   (a) Arithmetic Mean Temperature Difference ($\Delta T_{am}$)
   (b) Logarithmic Mean Temperature Difference (LMTD)
   (c) Both have nothing to do with safety
   (d) Other.

(v) In transient heat conduction, the two significant dimensionless parameters are
(a) Reynolds number and Prandlt number
(b) Biot number and Fourier number
(c) Reynolds number and Biot number
(d) Fourier number and Biot number.

(vi) The ratio of kinematic viscosity to thermal diffusivity is known as
(a) Prandlt number (b) Nusselt number
(c) Peclet number (d) Schimdt number.

(vii) Dropwise condensation occurs on
(a) clean surface (b) polished surface
(c) rough and contaminated surface (d) black surface.

(viii) In wien's displacement law, the value of $\lambda_{max}$ T is
(a) 2898 micron K (b) 5200 micron $^oR$
(c) both (a) & (b) (d) 300 micron $^oR$.

(ix) In sub-cooled boiling, temperature of the liquid mass is
(a) below of its boiling point (b) at its boiling point
(c) above atmospheric pressure (d) above boiling point.

(x) The Grashof number in natural convection plays same role as
(a) Prandtl number (Pr) in forced convection
(b) Reynolds number (Re) in forced convection
(c) Nusselt number (Nu) in forced convection
(d) None of the above.

## Group - B

2. (a) Derive the expression for the temperature profile and rate of heat loss from an infinitely long fin attached with a flat plate using neat schematic diagram. State any assumptions required.

(b) Show that the fin efficiency drops with increase in its length. What would you recommend to improve fin effectiveness?

**6 + 6 = 12**

3. (a) A furnace wall is made up of three layers of thickness 250 mm, 100 mm, and 150 mm with thermal conductivities of 1.65, K, and 9.2 W/m $^oC$, respectively. The inside is exposed to gases at 1550 $^oC$ and the inner surface is at 1050 $^oC$ with convection co-efficient 25 W/m$^2$ $^oC$. The outside air temperature is 25 $^oC$ with convection co-efficient 12 W/m$^2$ $^oC$. Find the value of K and all surface temperature.

(b) What is critical insulation thickness? Derive an expression for critical insulation radius on a cylindrical surface in terms of thermal





conductivity of the insulating material and film co-efficient on outer surface of insulation.

**6 +(2 + 4) = 12**

## Group - C

4. (a) An Engine oil at the rate of 0.5 kg/s are pumped through a cylindrical tube having 25 mm dia. The inlet temperature of engine oil is 298k. If the surface temperature of the tube is maintained at 373K, then calculate.
(i) outlet temperature of engine oil for 50 m long tube
(ii) LMTD and compare arithmetic mean temperature at entry and outlet for 50 m long tube.
The physical properties of oil's are, $C_p$ = 2035 J/kgk, $\mu$ = 0.0836 Ns/m$^2$, k = 0.141 W/mK, Pr = 1205, $\mu_w$ = 0.1041 Ns/m$^2$.

(b) Explain the behaviour of heat transfer coefficient for an electrically heated rod placed vertically in a room.

**8 + 4 = 12**

5. (a) Establish Reynold's analogy with the help of Newton's law of viscosity and Fourier's law of conduction.

(b) Two air streams are separated by a 1 m long thin flat plate. Stream 1 flow over the plate with a velocity of 60 m/s at a high temperature of 473 K. Stream 2 flow below the plate with a velocity of 10 m/s at a low temperature of 298 K. Calculate the heat flux between the two streams of air at the midpoint of the plate. Air properties are :
Kinematic viscosities of stream 1 and 2 are $20.92 \times 10^{-6}$ and $15.89 \times 10^{-6}$ m$^2$/s respectively. Thermal conductivities of stream 1 and 2 are 0.03 and 0.0263 W/mk respectively. Prandlt numbers for both the streams are 0.7.

**4 + 8 = 12**

## Group - D

6. (a) What are the assumptions made during the derivation of Nusselt's equation for heat transfer condensing the vapor (film type condensation) over a vertical tube?

(b) Prove that the rate of radiations heat transfer between two large parallel planes with one radiation shield is half of the radiation heat transfer between them in absence of radiation shield.

(c) How do you differentiate the gray body from black body?

**4 + 6 + 2 = 12**