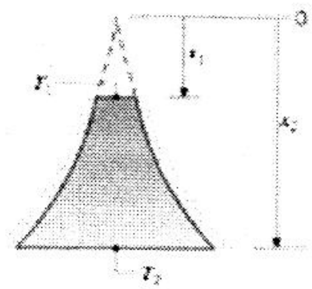
B. CHEM 3RD YEAR 1ST SEM EXAM 2017

PROCESS HEAT TRANSFER Time: Three Hours Full Marks: 100

Part- I
(50 marks for each part)
Use separate answer scripts for each part

Answer __any two__ questions.
Assume any missing data.
Write all assumptions clearly.

1. **(a)** A truncated solid cone is of circular cross section, and its diameter is related to the axial coordinate by an expression of the form $D = ax^{3/2}$, where a=1.0 m $^{-1/2}$. The sides are well insulated, while the top surface of the cone at x_1 is maintained at T_1 and the bottom surface at x_2 is maintained at T_2. (i) Obtain an expression for the temperature distribution $T(x)$. (ii) What is the rate of heat transfer across the cone if it is constructed of pure aluminum with x_1= 0.075 m, T_1 =100 C, x_2 = 0.225 m, and T_2 = 20°C?



(b) Derive an expression for critical thickness of insulation? How do you decide the thickness of insulation for electrical wires and steam pipes? **[15+10]**

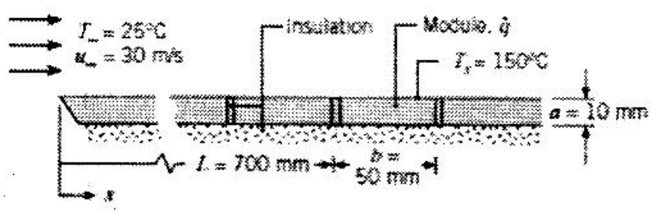
2. **(a)** Sketch the boiling curve and identify key regimes and features. What is the critical heat flux? What is the Leidenfrost point?

(b) How does dropwise condensation differ from film condensation? Which mode of condensation is characterized by larger heat transfer rates?

(c) A flat plate of width 1 m is maintained at a uniform surface temperature of T_s=150°C by using independently controlled, heat-generating rectangular modules of thickness a=10 mm and length b=50 mm. Each module is insulated from its neighbors, as well as on its back side. Atmospheric air at 25°C flows over the plate at a velocity of 30 m/s. The

thermophysical properties of the module are k=5.2 W/m.K, c_p=320 J/kg.K, and ρ=2300 kg/m^3. For air: k = 0.0308 W/m.K, ν = 22.02 ×10-6 m^2/s, Pr = 0.698.
(i) Find the required power generation, $\dot{q}$ (W/m^3), in a module positioned at a distance 700 mm from the leading edge.

(ii) Find the maximum temperature T_{max} in the heat generating module.



$$Nu_x = \frac{h_x x}{k} = 0.0296 Re_x^{4/5} Pr^{1/3}$$

[6+4+15]

3. **(a)** Derive an expression of log mean temperature difference (LMTD) for parallelflow heat exchanger. Explain the temperature profile of hot and cold fluid and LMTD for (i) condensing vapor, (ii) evaporating liquid and (iii) counterflow heat exchanger with equivalent fluid heat capacities.

(b) It is desired to heat 9820 lb/hr of cold benzene from 80 to 120°F using hot toluene which is cooled from 160 to 100°F. The specific gravities at 68°F are 0.88 and 0.87, respectively. The other fluid properties are given below. A fouling factor of 0.001 should be provided for each stream. A number of 20-ft hairpins of 2 by 1¼ in. IPS pipe are available. How many hairpins are required?

For Annulus: D_2=0.1725ft; D_1=0.138ft For Inner pipe: D=0.115ft
For 1¼ in. IPS standard pipe there are 0.435 ft^2 of external surface per foot length.

Since the temperature ranges and temperature differences are moderate. The coefficients may accordingly be evaluated from properties at the arithmetic mean, and the value of $(\mu/\mu_w)^{0.14}$ may be assumed equal to 1.0. **[10+15]**

Properties	Toluene	Benzene
c (BTU/ (lb)(°F))	0.44	0.425
μ (lb/ft.hr)	0.99	1.21
j_H	167	236
k (BTU/ (hr)(ft^2)(°F/ft))	0.085	0.091

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B. CHEM 3RD YEAR 1ST. SEM. EXAM.-2017

PROCESS HEAT TRANSFER **Time : 3 hrs** **Full Marks : 50**

Part-II (Use separate answer scripts for each part)

Answer Question no. 1 and any three from the rest

To the point answer is encouraged and assume any missing data

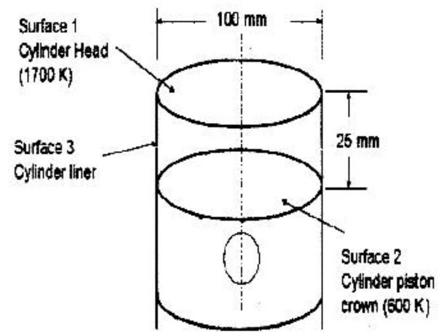
<u>Do remember that your mind will answer all questions if you learn to relax</u>

1.(a) Find out all relevant view factors for the schematic given(F_{12} = 0.6) (6)

(b) The cylinder head can be considered as black body with T_1 = 1700K and emissivity of the piston crown is ϵ_2 =0.75. Apply a grey body analysis to the piston crown (surface 2) and show that the radiosity is given by:

$J_2 = 42.5*10^{-9} T_2^4 + 71035 + 0.1J3$ (6)

(c) Similar analysis applied to cylinder liner gives J3 = 107210 + 0.222 J2. If the surface temperature of the crown is 600K, then calculate the radiative heat flux on to the crown. (4)



2. (a) An evaporator is used to concentrate 4536 kg/h of a 10% solution of NaOH in water entering at 50 °C to a product of 40% solids. The pressure of the saturated steam used is 172.4 kPa and the pressure in the vapor space of the evaporator is 11.7 kPa. The overall heat-transfer coefficient is 1560 $W/m^2.K$. Calculate the steam economy in kg vaporized/kg steam used, and the heating surface area in m^2. (10)

Given: BP of pure water at 11.7 kPa= $50^{O}C$; λ=2214 kJ/kg; H_V= 2660 kJ/kg for the superheated vapor.

(b) You have been asked to vaporize 1 kg of water in a single effect evaporator. How much steam should you use and why? (2)

3. (a) Steam at 320 °C flows in a cast iron pipe [k = 80 W/ m.°C] whose inner and outer diameter are D_1 = 5 cm and D_2 = 5.5 cm, respectively. The pipe is covered with a 3.0 cm- thick glass wool insulation [k = 0.05 W/ m.°C]. Heat is lost to the surroundings at 5°C by convection and radiation, with a combined heat transfer coefficient of h_2= 18 W/m^2 . °C. Taking the heat transfer coefficient inside the pipe to be h_1 = 60 W/m^2 K, determine the rate of heat loss from the steam per unit length of the pipe. Also determine the temperature drop across the pipe shell and the insulation. (10)

(b) Explain the process of heating soup on the stove. Start with the heat given off by the stove's element and proceed from there, step-by-step, until the soup is boiling. (2)

4. (a) Water is flowing through the tubes in a boiler. The overall heat transfer coefficient of this boiler based on the inner surface area is to be determined. (10)

The properties of water are given as:

K= 0.682 $W/m^{O}C$ kinematic viscosity = $0.268*10^{-6}$ m^2/s; Pr = 1.58

V_{av} = 3.5m/s; D_h=0.01 m; D_i=0.01 m; D_o= 0.014 m; L = 5 m; K = 14.2$W/m^{O}C$; h_o = 8400 $W/m^2.^{O}C$; Fouling Factor = 0.0005 m^2 .°C/W.

(b) State the basis of consideration of Rohsenow correction in film condensation? (2)

5. Write short notes on (any three): (i) Reynolds Analogy; (ii) Thermal boundary layer; (iii) Leidenfrost effect (iv) Radiation Shield, (v) Steam jet Ejector (12)