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INTERNATIONAL CENTRE FOR APPLIED SCIENCES

(Manipal University)

IV SEMESTER B.S. DEGREE EXAMINATION APRIL / MAY 2017

SUBJECT: HEAT TRANSFER OPERATION (CHM 242)

(BRANCH: CHEMICAL ENGINEERING)

Thursday, 04 May 2017

Time: 03 Hours **Max. Marks: 100**

- ✓ **Answer ANY FIVE full Questions.**
- ✓ **Missing data, if any, may be suitably assumed**

1A. Derive an expression for the rate of heat flow through a compound wall made of several resistances in series, stating the necessary assumptions

1B. The wall of cold storage consists of three layers- an outer layer of ordinary bricks 25cm thick, a middle layer of cork 10cm thick and an inner layer of cement 6cm thick, the thermal conductivities of the materials are brick: 0.7 cork: 0.043 and cement : 0.72 W/m oC. The temperature of the outer surface of the wall is 30°C, and the inner is -15°C. Calculate a) the steady state rate of heat gain per unit area of the wall b) the temperature at the interfaces of the composite wall and c) the percentage of the total heat transfer resistance offered by the individual layers, what additional thickness of cork should be provided to make the rate of heat transfer 30% less than the present value ?. **(10+10)**

2A. Explain i) Critical thickness of insulation ii) Optimum thickness of insulation
iii) Overall coefficient iv) Dirt Factor

2B. An ice-ball of initial diameter 0.06m is suspended in a room at 30°C. The ice melts by absorbing heat from the ambient, the surface heat transfer coefficient being 11.4 W/m^2 °C. The air in the room is essentially dry. If the shape of the ball remains unchanged, calculate the time required for reduction in its volume by 40%. The density of ice is 929 kg/m^3 and its latent heat of fusion is 3.35 x 10^5 J/kg. **(12+8)**

3A. Derive an expression for the heat flow through a rectangular fin stating all the necessary assumptions.

3B. A 3 inch schedule 40 carbon steel pipe (actual i.d = 78mm, wall thickness = 5.5mm) has eight longitudinal fins of 1.5mm thickness, each fin extends 30mm from the pipe wall, the thermal conductivity of the fin material is 45 W/m °C. If the wall temperature, the ambient temperature and the surface heat transfer co-efficient are 150°C, 28°C and 75 W/m^2 °C respectively. Calculate the percentage increase in the rate of heat transfer for the finned tube over the plain tube. **(12+8)**

4A. For forced convection, the heat transfer coefficient 'h' is observed to depend upon the following variables.

Velocity of the fluid V.

Viscosity of the fluid μ.

Specific heat of the fluid Cp.

Thermal conductivity of the fluid K.

Density of the fluid ρ .

Diameter of the pipe d.

Using the dimensional analysis obtain the following relationship Nu=f (Re, Pr).

4B. A 1 kW electric room heater has a coil of nichrom wire of diameter 0.574 mm and electrical resistance 4.167 ohm/m. if the temperature of the room remains constant at 21°C and the average heat transfer coefficient at the surface of the wire is 100 W/m^2 °C, calculate the time required for the heating coil, after it is switched on, to reach 63% of its steady state temperature rise. Assume that the wire itself offers negligible heat transfer resistance. The density of the material of the wire is 8920 kg/m^3, and its specific heat is 384 J /kg °C. **(10+10)**

5. Benzene from the condenser at the top of a distillation column is cooled at a rate of 1000 kg/h from 75°C to 50°C in a counter current double pipe heat exchanger, the construction of heat exchanger is a hairpin type with an effective length of 15 m, the inner tube of carbon steel 25 mm outer diameter 14 BWG, the outer pipe is schedule 40, 1-1/2 inch nb (nominal bore). Benzene flows through the annulus, water which flows through the inner tube, entering at 30°C and leaving at 40°C is the coolant.

a) Calculate the heat duty of the exchanger and the water flow rate

b) Calculate the individual film co-efficient and the overall co-efficient based on both inside and outside areas.

c) do you think that the tube wall have gathered scale and have been fouled ? if so estimate the fouling factor.

The following data are available

Inner tube: I.D -21mm, O.D – 25.4mm, wall thickness-2.2mm, thermal conductivity of the tube wall – 74.5 w/m.k

Outer pipe: I.D – 41mm. O.D – 48mm.

Thermo physical properties.

a) Benzene at the average temperature (62.5°C)

Specific heat – 1.88 KJ/kg °C, Viscosity – 0.37CP, Density – 860 kg/m^3, Thermal conductivity – 0.154 W/m.k

b) Water at average temperature (35oC)

Viscosity – 0.8CP, Thermal conductivity – 0.623 W/m.k, Specific heat – 4.183 KJ/kg.°C Density – 1000 kg/m^3. **(20)**

6A. Determine the individual thermal resistance to calculate overall heat transfer coefficient in a plane wall.

6B. A steam pipe of 97mm inner diameter and 114mm outer diameter (4 inch schedule 80) is required to carry high pressure saturate steam at 30bar absolute pressure, it is covered by a layer of mineral wool in order to reduce heat loss through an extra thick layer of insulation saves a lot of heat , it is expensive at the same time as a standard practice a design engineer usually allows the temperature at the outer surface of the insulation (also called the skin temperature) to remain at 15 – 20°C, above room temperature, in order to calculate the thickness of insulation of the above steam pipe, assume a skin temperature of 55°C, the ambient temperature is 30°C, thermal conductivity of mineral wool may be taken as 0.1 W/m °C and that of pipe material (carbon steel) as 43 W/m °C, the external air-film co-efficient for heat loss to the ambient is 8 W/m^2 °C. Calculate the thickness of insulation and the rate of heat loss per meter length of the pipe. **(10+10)**

7A. Derive an expression for unsteady state heat conduction. State its assumptions.

7B. Briefly discus the advantage of shell and tube heat exchanger over a double pipe heat exchanger. **(12+8)**

8A. Derive an expression for the net radiant energy transfer between two infinitely long parallel planes having different emissivity.

8B. Find out the heat transfer rate per unit area due to radiation between two infinitely long parallel planes. The first plane has an emissivity of 0.4 and is maintained at 473K. The emissivity of second plane is 0.2 and is maintained at 300K , if a radiation shield having e= 0.5 is introduced between the given planes, find the percentage reduction in heat transfer rate and the steady state temperature attained by the shield. **(10+10)**