Faculty of Engineering Sciences

UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

DEPARTMENT OF FOOD PROCESS ENGINEERING

B.Sc FIRST SEMESTER FINAL EXAMINATION, 2012/2013

FPEN 301: HEAT TRANSFER (3 Credits)

Time Allowed: ~~3~~ 2 HOURS

Answer Section A and Three (3) Questions from Section B

SECTION A

1.

i. Define convection heat transfer while distinguishing between forced convection and natural convection.

ii. What are the factors upon which heat transfer by forced convection depends?

iii. Define Nusselt number (Nu) and state what it represents in heat transfer.

iv. Define the Prandtl number (Pr) and what is the significance of the following (i) Pr = 1, (ii) Pr >> 1 and (iii) Pr << 1

v. Assuming the fluid properties remain constant, explain why for a fluid flowing over a flat plate the heat transfer in a direction parallel to the longer side of the plate is higher than that in a direction parallel to the shorter side of the plate.

SECTION B

2. (a) What is the area density of a heat exchanger?

(b) What is LMTD and define it for counter flow and parallel flow in a heat exchanger.

(c) What is the effectiveness of a heat exchanger?

(d) A heat exchanger is used to cool vegetable oil (C_p = 2.52 kJ/kg K) being distilled at the rate of 2000 kg/hr from 100°C to 30°C by using cold water (C_p = 4.20 kJ/kg K) entering at 20°C. If the overall heat transfer coefficient of the counter flow heat exchanger being used for the cooling is 1.5 kW/m^2 K. Calculate:

(i) the water flow rate,

(ii) the surface area required and

(iii) the effectiveness of the heat exchanger using the NTU method.

Assume the exit temperature of the cooling water is 80°C.

3. To reduce energy cost a food process engineer in a small-scale food processing plant has undertaking an energy optimization project. Among others, the engineer is preheating process water with process fluid which has to be cooled from 80°C to 30°C. The process engineer intends to use a simple double pipe counter flow heat exchanger. The process water has a flow rate of 3 kg/sec.

   i. Calculate the heat transfer area if the flow rate of the process fluid is 90 kg/min and the overall heat transfer coefficient of the heat exchanger is 500 $W/m^2.\ ^{\circ}C$.
   ii. Determine the length of the heat exchanger if the inner pipe carrying the process fluid has an inside diameter of 5 cm.

   Assume the specific heat capacities of water and the process fluid are 4.18 kJ/kg °C and 4.5 kJ/kg °C respectively.

4. A cold storage room has a composite wall made of three layers of different materials namely fire burnt bricks, cork and cement. The outer layer of the composite wall is made of ordinary fire burnt bricks of thickness 200 mm, the middle layer of cork, 100 mm thick and a cement inner layer of 60 mm thick. The inner temperature of the cold room is -20°C and the outside temperature is 30°C. The thermal conductivities of the three layers are - brick 7.1×10^{-1} W/m °C, cork 4.25×10^{-2} W/m °C and cement 7.25×10^{-1} W/m °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,
   (c) the percentages of the total heat transfer resistance offered by the individual layers, and
   (d) if the process engineer desires to reduce the heat transfer further by 25% of the present value determine the additional thickness of cork required.

5. A cylindrical chimney has a height of 20 metres and carries hot flue gases from a combustion chamber in a steam plant. The chimney has an inside diameter of 1.0 m and an inner layer of fireclay bricks (k = 1.5 W/m °C) of 0.30 m thickness. The outer layer is 0.15 m of a special refractory brick (k = 0.90 W/m °C). The brickwork is enclosed in an outer steel cover which has a temperature of 50°C. If the inside temperature of the cylindrical duct is 300°C and the thickness of the steel cover is small such that the thermal resistance of the steel cover can be ignored. Calculate:

   (a) the rate of heat loss per metre of the cylindrical chimney
   (b) the interface temperature between the two ceramic layers
   (c) the fraction of total resistance offered by the special refractory brick and the fireclay brick.