UNIVERSITY OF GHANA

BSC ENGINEERING FIRST SEMESTER EXAMINATIONS: 2018/2019

DEPARTMENT OF FOOD PROCESS ENGINEERING

FPEN 301: HEAT TRANSFER (2 CREDITS)

INSTRUCTIONS:
ANSWER ALL QUESTIONS IN SECTION A AND THREE (3) QUESTIONS IN SECTION B

TIME ALLOWED: TWO (2) HOURS

SECTION A (ANSWER ALL QUESTIONS)

1.

a. Define (i) thermal conductivity and (ii) heat transfer coefficient and explain their significance in heat transfer.
b. Describe the mechanisms of heat transfer? How are they distinguished from each other?
c. Provide the relevant laws for each of the mechanisms of heat transfer. It is important to define the parameters for each law.
d. Describe (i) forced convection and (ii) natural convection.

e. What are the factors upon which heat transfer by forced convection depend?
f. Define Nusselt number (Nu) and state what it represents in heat transfer.
g. Define Prandtl number (Pr) and state the significance of the following:

   (i) Pr = 1, (ii) Pr >> 1 and (iii) Pr << 1

h. Define Grashof number and state what it represents in heat transfer
i. For the heat transfer rate $Q = UA_s\Delta T_{lm}$ for a heat exchanger define the terms in the relation. How do you calculate ΔT_{lm} for (1) parallel-flow and (2) counter-flow heat exchanger?
j. Define the area density of a heat exchanger,
k. Define the effectiveness of a heat exchanger.
l. Natural convection on a surface depends on which factors?

SECTION B (ANSWER THREE (3) QUESTIONS)

2. A reactor's wall has a thickness of 40 cm and is made of an inner layer of fire brick (k_1 = 0.85 W/m K) and an insulator layer (k_2 = 0.15 W/m K). The reactor temperature is maintained at 1327 °C while the ambient temperature is 27 °C.
   Calculate:
   a. the thickness of the fire brick layer and the insulation layer which gives the minimum heat loss.
   b. the heat loss if the insulation material has a maximum temperature of 1177 °C
   c. would an additional insulation material be necessary if the heat loss is unacceptable?

3. An engineer intends to use a simple double pipe counter flow heat exchanger to preheat process water with process fluid which has to be cooled from 90°C to 40°C. The flow rate of process water is 3 kg/s.
   a. Calculate the heat transfer area if the flow rate of the process fluid is 6000 kg/h and the overall heat transfer coefficient of the heat exchanger is 1000 W/m^2.°C.
   b. 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 $C_{p,\ water}$ = 4.20 kJ/kg °C and $C_{p,\ fluid}$ = 4.5 kJ/kg °C respectively.

4. A cold storage facility has a wall made of three layers of different materials namely - fire burnt bricks, cork and cement. The composite wall has an outer layer made of ordinary fire burnt bricks of thickness 25 cm, a middle layer of cork, 10 cm thick and a cement inner layer of 10 cm 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 7.0 x 10^{-1} W/m °C, cork 4.3 x 10^{-2} W/m °C and cement 10.0 x 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. the additional thickness of cork that should be provided to make the heat transfer a 30% less than the present value.

5. A water-to-water counter-flow heat exchanger has the following specifications. Hot water enters at 95°C while cold water enters at 20°C. The exit temperature of hot water is 15°C greater than that of cold water, and the mass flow rate of hot water is 50 percent greater than that of cold water. The product of heat transfer surface area and the overall heat transfer coefficient is 1.500 kW/m^2.°C. Sketch the heat exchanger and determine:
   a. the outlet temperature of the cold water;
   b. the effectiveness of the heat exchanger;
   c. the mass flow rate of the cold water; and
   d. the heat transfer rate.

   Assume the specific heat, (Cp) of both cold and hot water to be 4.180 kJ/kg.°C