UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER
SPECIAL/SUPPLIMENTARY EXAMINATIONS

FOR THE DEGREE OF
B.SC RENEWABLE ENERGY AND BIOFUELS TECHNOLOGY

COURSE CODE: REN 322

COURSE TITLE: HEAT AND MASS TRANSFER

DURATION: 2 HOURS

DATE: 9/8/2023 **TIME: 2:00-4:00PM**

INSTRUCTIONS TO CANDIDATES

(i) Answer Question 1 (Compulsory) and any other TWO questions
(ii) All symbols have their usual meaning
(iii) Use steam tables provided

QUESTION ONE (Compulsory) - 30 MARKS

a) State Fourier's law of conduction of heat.

(5 Marks)

b) Explain the implication of the Grashof number with regard to fluid flow.

(4 Marks)

c) Give the differences between the following.

i) Radiosity

(2 Marks)

ii) Irradiation

(2 Marks)

d) What is heat transfer by convection?

(3 Marks)

e) Explain briefly the differences between the following types of heat exchangers

(i) Recuperative

(2 Marks)

(ii) Regenerative

(3 Marks)

f) Draw a well labeled diagram to show the temperature distribution in a counter-flow heat exchanger

(5 Marks)

g) Define LMTD

(4 Marks)

QUESTION TWO – 20 MARKS

A furnace wall consists of 125mm wide refractory brick, an air gap, and 125mm wide insulating fire brick. The outside wall is covered with a16mm thickness of plaster. The inner surface of the wall is at 1100^0C and the room temperature is 25^0C. The heat transfer coefficient from the outside wall surface to the air in the room is $17W/m^2K$, and the resistance to heat flow of the air gap is 0.16K/W. The thermal conductivities of the refractory brick, insulating fire brick, and plaster are 1.6, 0.3, and 0.14 W/mK respectively.

Calculate:

a) The rate at which heat is lost per m^2 of the wall surface.

(12 Marks)

b) Each interface temperature of the wall.

(6 Marks)

c) The temperature of the outside surface of the wall.

(2 Marks)

QUESTION THREE – 20 MARKS

Calculate the heat transfer coefficient for water flowing through a 25mm diameter tube at a mass flow rate of 1.8 kg/s when the mean bulk temperature is 42^0C.
For turbulent flow of a liquid, take:

$$Nu = Re^{0.8}Pr^{0.4}$$

(20 Marks)

QUESTION FOUR – 20 MARKS

In a chemical plant, a solution of density 1100 kg/m^3 and a specific heat of 4.6 kJ/kgK is to be heated from 65^0C to 100^0C; the flow of solution required is 11.8 kg/s. It is desired to use a tubular heat exchanger, the solution flowing at about 1.2 m/s in a 25mm bore iron tubes, and being heated by wet steam at 115^0C. The length of the tubes must not exceed 3.5 m. The inside and outside heat transfer coefficients are 5 and 10 kW/m^{2}K, respectively. The thermal resistance of the iron tube is negligible.

Estimate the:

a) number of tubes required

b) number of tube passes required **(8 Marks)**

(12 Marks)

QUESTION FIVE – 20 MARKS

A single pass shell and tube counter-flow heat exchanger uses waste gas on the shell side to heat a liquid in the tubes. The waste gas enters at a temperature of 400°C with a mass flow rate of 40kg/s. The water enters at a temperature of 100°C with a mass flow rate of 3kg/s.
Assuming that the velocity is not to exceed 1m/s, use the data provided below to calculate:

a) The required number of tubes.

(9 Marks)

b) The effectiveness of the heat exchanger.

(9 Marks)

c) The exit temperature of the water.

(2 Marks)

DATA

- Tube inside diameter = 10mm. Tube outside diameter = 12.5mm.
- Tube length = 4m. Density of liquid = 500kg/m^3
- Specific heat capacity of waste gas = 1.04kJ/kgK.
- Specific heat capacity of liquid = 1.5kJ/kgK.
- Coefficient of heat transfer of the shell side = 0.26kW/m^{2}K.
- Coefficient of heat transfer of the tube side = 0.58kW/m^{2}K.