MACHAKOS UNIVERSITY

University Examinations for 2020/2021 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 407: HEAT TRANSFER

DATE: 9/8/2021 **TIME: 8.30-10.30 AM**

INSTRUCTIONS

Answer question ONE and any other TWO questions.

Tables are provided

QUESTION ONE (30 MARKS)

a) State and explain Fourier's law of conduction. Mention the assumptions on which it is based (3 marks)

b) Explain two mechanisms through which heat transfer by conduction takes place in solids (2 marks)

c) Derive an expression for the heat flow rate through a hollow sphere of inside radius r_1 and outside radius r_2, whose internal and external surfaces are maintained at temperatures t_1 and t_2 respectively. (5 marks)

d) A cold storage room has walls made of 200 mm of brick on the outside, 80 mm of plastic foam, and finally 20 mm of wood on the inside. The outside and inside air temperatures are 25°C and -3°C respectively. If the outside and inside convective heat transfer coefficients are respectively 10 and 30W/m^2°C , and the thermal conductivities of brick, foam and wood are 1.0, 0.02 and 0.17W/ m°C respectively. Determine:

i. Overall heat transfer coefficient (3 marks)

ii. The rate of heat removed by refrigeration if the total wall area is 100m^2 (2 marks)

iii. Outside and inside surface temperatures and mid-plane temperatures of composite wall (3 marks)

e) Outline FOUR applications of heat exchangers (2 marks)

f) Briefly explain the significance of following dimensionless numbers Nusslet number, Reynolds number, Grashof number and Prandtl number (4 marks)

g) A steam pipe 50 mm diameter and 2.5 m long has been placed horizontally and exposed to still air at 25°C. If the pipe wall temperature is 295°C, determine the rate of heat loss. The thermo physical properties of air at 160°C are k = 3.64 x 10-2 W/m-deg C, v = 30.09 x 10-6 m^2/s, Pr = 0.682. Use co relation $Nu = 0.53\ (Gr\ Pr)^{1/4}$ (5 marks)

h) Distinguish between a blackbody and a gray body in radiation heat transfer (1 mark)

QUESTION TWO (20 MARKS)

a) A steam main of 200mm outside diameter containing wet steam at 30bar is insulated with an inner layer of diatomaceous earth, 50mm thick, and an outer layer of magnesia, 35mm thick. Calculate the heat loss per m length of the pipe and the temperature of the outside surface of the lagging, when the room temperature is 22^0C. Neglect the thermal resistance of the pipe itself. Assume that the inside surface of the pipe is at the steam temperature and take the heat transfer coefficient for the outside surface of the lagging as 19W/m^2K. The thermal conductivities of diatomaceous earth and magnesia are 0.09, and 0.06W/mK, respectively. Take the saturation temperature of steam at 30bar as 234°C. Neglect radiation. (7 marks)

b) A spherical pressure vessel of 1m inside diameter is made of 20mm steel plate. The vessel is lagged with a 30mm thickness of vermiculite held in position by 15mm thick asbestos. Calculate the heat loss from the sphere when the inside surface is at 600^0C, and the room temperature is 20^0C. The heat transfer coefficient for the outside surface is 20W/m^2K, and the thermal conductivities of steel, vermiculite and asbestos are 48, 0.047, and 0.21W/mK, respectively. Neglect radiation. (7 marks)

c) Consider a composite structure shown in figure below. Conductivities of the layer are: k_1 = k_3 = 10 W/mK, k_2 = 16 W/mK, and k_4 = 46 W/mK. The convection coefficient on the right side of the composite is 30 W/m²K. Calculate the total resistance and the heat flow through the composite. (6 marks)

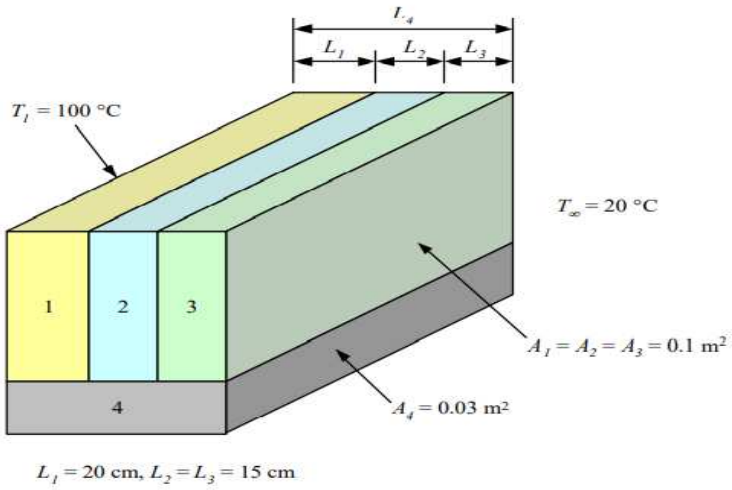

Figure 2 C

QUESTION THREE (20 MARKS)

a) With aid of sketches, discuss the following:

i. Parallel heat exchanger

ii. Counter flow heat exchanger (4 marks)

b) What do you mean by fouling factor and what are causes of fouling effect on heat exchanger design (3 marks)

c) A counter flow double pipe heat exchanger using super heated steam is used to heat water at the rate of 10500 kg/hr. The steam enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperature of water are 30°C and 80°C respectively.

If the overall heat transfer coefficient from steam to water is 814 W/m^2 K, calculate the heat transfer area. What would be the increase in area if the fluid flow were parallel? (6 marks)

d) 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 at a mass flowrate of 50kg/s. The liquid enters at 100°C at a mass flowrate of 3kg/s.

Assuming that the velocity of the liquid does not exceed 1m/s, calculate using the data below:

i. The required number of tubes

ii. The effectiveness of the heat exchanger

iii. The exit temperature of the liquid. Neglect the thermal resistance of the wall.

(7 marks)

Data:

Tube inside diameter 10mm

Tube outside diameter 12.7mm

Tube length = 4m

Specific heat of waste gas 1.04kJ/kgK

Specific heat of the liquid = 1.5kJ/kgK

Density of the liquid = 500kg/m^3

Heat transfer coefficient of shell side = 260W/m^2k

Heat transfer coefficient of the tube side = 580 W/m^2K

QUESTION FOUR (20 MARKS)

a) Differentiate between forced convection and natural convection giving examples (2 marks)

b) Calculate the heat transfer coefficient for water flowing through a 25mm diameter tube at a rate of 2.5kg/s when the bulk temperature is 60°C. For turbulent flow of the liquid take:

$$Nu = 0.03Re^{0.8}(Pr)^{0.6}$$

Where the characteristic dimension of length is the tube diameter and all properties are evaluated at mean bulk temperature. (7 marks)

c) Calculate the heat loss by natural convection per m length from a horizontal pipe of 150mm diameter, the surface of which is at 280°C. The room temperature is 18°C.

Take for horizontal pipe

$Nu = 0.527(Pr)^{0.5}(Pr + 0.952)^{-0.25}(Gr)^{0.25}$

Where properties are evaluated at surface temperature.

Take Grashof number as $Gr = 1.51 \times 10^6$ (6 marks)

d) A double pipe heat exchanger has an effectiveness of 0.5 when the flow is counter – current and the thermal capacity of one fluid is twice that of the other fluid. Calculate the effectiveness of the heat exchanger if the direction of flow of one of the fluids is reversed with the same mass flow rates as before. (5 marks)

QUESTION FIVE (20 MARKS)

a) Explain the following terms as used in radiation heat transfer

i. Emissive power

ii. Emissivity

iii. Kirchoff's law

iv. Stefan – Boltzman law

v. Absorbtivity

vi. Transmissivity (6 marks)

b) A body at 1300^{o}C in black surrounding at 650^{o}C has an emmisivity of 0.4 at 1300^{o}C and an emissivity of 0.7 at 650^{o}C. Calculate the rate of heat loss by radiation per m^2

i. When body is grey with $\varepsilon = 0.4$

ii. When body is not grey (4 marks)

c) Calculate the heat transferred per m^2 of surface area by radiation between two brick wall at a short distance apart when the temperature of the surfaces are 30^{o}C and 15^{o}C. The emissivity of the brick may be taken as 0.93 and the surfaces may be assumed to be grey. (4 marks)

d) Emissivities of two large parallel plates maintained at 800^{o}C and 300^{o}C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per square meter of the plates.

If a polished aluminium shield (ϵ = 0.05) is placed between them. Find the percentage of reduction in heat transfer. (6 marks)