ELIZADE UNIVERSITY, ILARA-MOKIN,
ONDO STATE, NIGERIA

DEPARTMENT OF MECHANICAL ENGINEERING

FIRST SEMESTER EXAMINATIONS

2019/2020 ACADEMIC SESSION

COURSE:	MEE 305 – Heat Transfer I (2 Units)
CLASS:	300 Level Mechanical Engineering
TIME ALLOWED:	2 Hours:15 Minutes
INSTRUCTIONS:	Answer **question No. 1** and any other **three questions**

Date: February, 2020

Question 1

(a) Explain the three modes of Heat transfer.

(b) State Fourier's law of conduction and mention three of its assumptions.

(c) A plane wall (thermal conductivity = 10.2 W/m°C) of 100 mm thickness and area 3 m^2 has steady surface temperature of 170 °C and 100 °C. Determine the rate of heat flow across the plane.

(d) Derive the general heat conduction equation for constant thermal conductivity in Cartesian Coordinates using the Fig. 1.

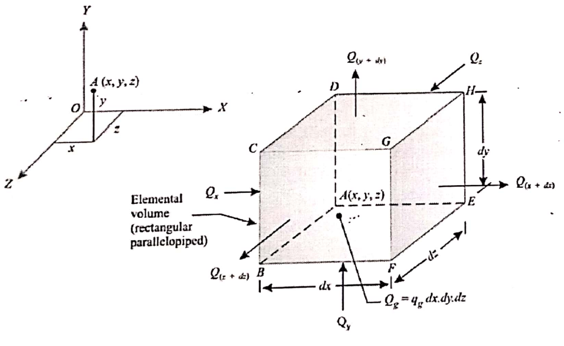

Fig. 1

Question 2

(a) Derive the equation for quantity of heat transferred for heat conduction through a composite plane wall shown in Fig. 2.

(b) A furnace wall consists of 200 mm layer of refractory bricks, 6mm layer of steel plate and a 100 mm layer of insulation bricks. The maximum temperature of the wall is 1150 °C on the furnace side and the minimum temperature is 40 °C on the outermost side of the wall. An accurate energy balance over the wall is 400 W/m^2. It is known that there is a thin layer of air between the layers of refractory bricks and steel plate. Thermal conductivities for the three layers are 1.52, 45 and 0.138 W/m°C, respectively. Find:

(i) To how many millimeters of insulation brick is the air layer equivalent?

(ii) What is the temperature of the outer surface of the steel plate? Ref. Fig. 3.

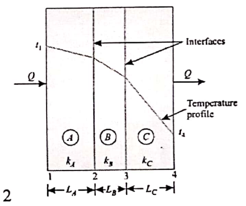

Fig. . 2

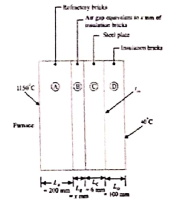

Fig. 3

Question 3

(a) Derive the equation for quantity of heat transferred for heat conduction through a composite cylindrical wall with convective heat transfer as shown in Fig. 4.

(b) A thick walled tube of stainless steel (18% Cr, 8% Ni, K=19 W/m°C) with 0.02 m inner diameter and 0.04 m outer diameter is covered with a 0.03 m layer of asbestos insulation (K=0.2 W/m°C) as shown in Figure 5. If the inside wall temperature of the pipes is maintained at 600 °C and the outside insulation is 100 °C. Calculate the heat loss per meter of length. Also calculate the tube interface temperature.

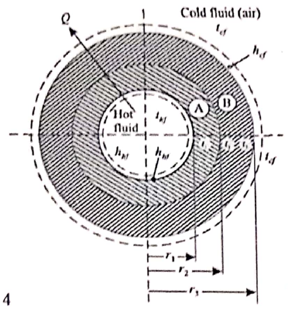

Fig. 4

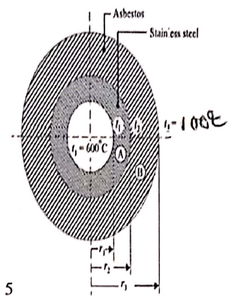

Fig. 5

Question 4

(a) Using Fig. 6, show that the overall heat transfer coefficient is

$$U = \frac{1}{\frac{1}{h_{hf}} + \frac{L}{k} + \frac{1}{h_{cf}}}$$

(b) A mild steel tank of wall thickness 12 mm contains water at 95°C as shown in Figure 7. The thermal conductivity of mild steel is 50 W/m°C, and the heat transfer coefficients for the inside and outside of the tank are 2850 and 10 W/m²°C, respectively. If the atmospheric temperature is 15°C, calculate:

(i) The rate of heat loss per m² of the tank surface area.

(ii) The temperature of the outside surface of the tank.

Question 5

(a) Show that the instantaneous heat flow rate for a transient heat conduction of a body which is placed suddenly in ambient air, is:

$$Q_i = -hA_s(t_i - t_a)\, e^{-B_i F_o}$$

(b) A 15 mm diameter mild steel sphere (k = 42 W/m°C) is exposed to cooling airflow at 20°C resulting in the convective coefficient h = 120 W/m²°C.

Determine the following:

(i) Time required to cool the sphere from 550 °C to 90 °C.

(ii) Instantaneous heat transfer rate 2 minutes after the start of the cooling.

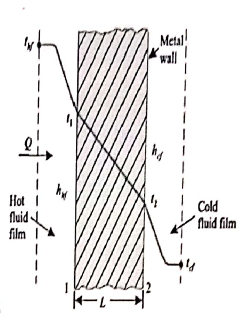

Fig. 6

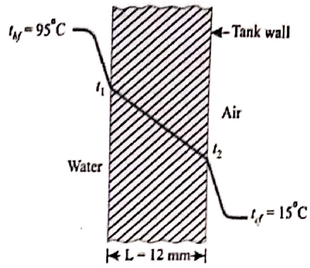

Fig. 7

Question 6

(a) What do you understand by "Critical Thickness of Insulation"?

(b) Show that the critical thickness of insulation for a cylinder and a sphere is "$r_2\ (= r_c) = \frac{k}{h_o}$" and "$r_2\ (= r_c) = \frac{2k}{h_o}$," respectively.

(c) A small electric heating appliance uses wire of 2 mm diameter with 0.8 mm thick insulation (k = 0.12 W/m°C). The heat transfer coefficient (h_o) on the insulated surface is 35 W/m²°C. Determine the critical thickness of insulation in this case and the percentage change in the heat transfer rate if the critical thickness is used, assuming the temperature difference between the surfaces of the wire and surrounding air remains unchanged.