ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE, NIGERIA

DEPARTMENT OF MECHANICAL ENGINEERING

FIRST SEMESTER EXAMINATIONS

2020/2021 ACADEMIC SESSION

HOD'S SIGNATURE

COURSE: MEE 305 – Heat Transfer (2 Units)

CLASS: 300 Level Mechanical Engineering

TIME ALLOWED: 2 Hours:15 Minutes

INSTRUCTIONS: Answer **question No. 1** and any other **three questions**

Date: March, 2021

Question 1

(a) What is conduction heat transfer and how does it differs from convection and radiative heat transfer?

(b) State Fourier's law of conduction and explain why the negative sign in Fourier law of conduction?

(c) Derive the general heat conduction equation for constant thermal conductivity in Cartesian Coordinates using the Fig. 1 and **write out Laplace Equation**

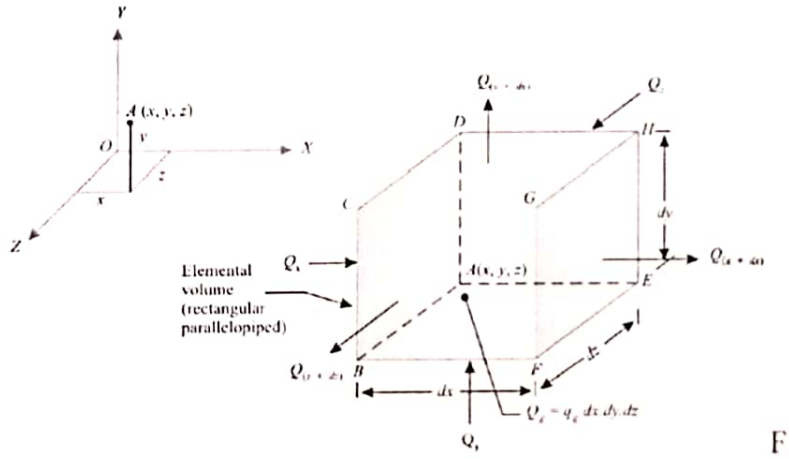

Fig. 1

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?

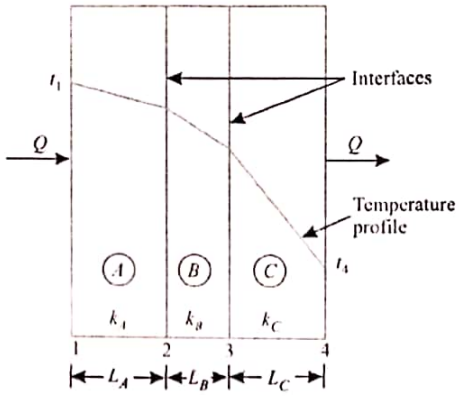

Fig. 2

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. 3.

(b) A steam pipe (k = 45 W/m°C) having 70 mm inside diameter and 85 mm outside diameter is lagged with two insulation layers; the layer in contact with the pipe is 35 mm asbestos (k = 0.15 W/m°C) and it is covered with 25 mm thick magnesia insulation (k = 0.075 W/m°C). The heat transfer coefficients for the inside and outside surfaces are 200 W/m^2 °C and 6.5 W/m^2 °C, respectively. If the temperature of steam is 350°C and the ambient temperature is 30 °C, calculate the steady loss of heat for 50 m length of the pipe.

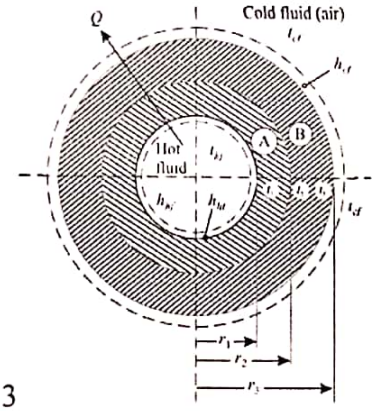

Fig. 3

Question 4

(a) Using Fig. 4 show that the overall heat transfer coefficient is

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

(b) A cold storage room has walls made of 220 mm of brick on the outside, 90 mm of plastic foam, and finally 16 mm of wood on the inside. The outside and inside air tempearatures

are 25 °C and -3 °C respectively. If the inside and outside heat transfer coefficients are respectively 30 and 11 W/m°C, and the thermal conductivities of brick, foam and wood are 0.99, 0.022 and 0.17 W/m°C, respectively determine

(i) The rate of heat removal by refrigeration, if the total wall area is 85 m^2.

(ii) The temperature of the inside surface of the brick.

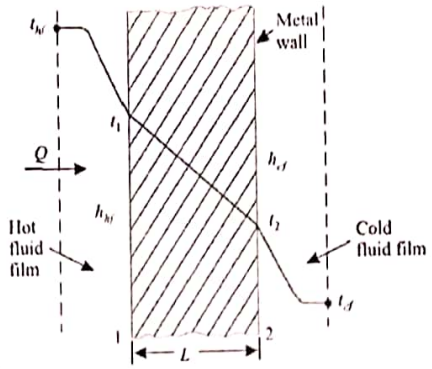

Fig. 4

Question 5

(a) Derive the **temperature distribution** for Newtonian heating or cooling for a transient heat conduction of a body which is placed suddenly in ambient air as shown in Figure 5, and show that the instantaneous rate of flow (Q) is:

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

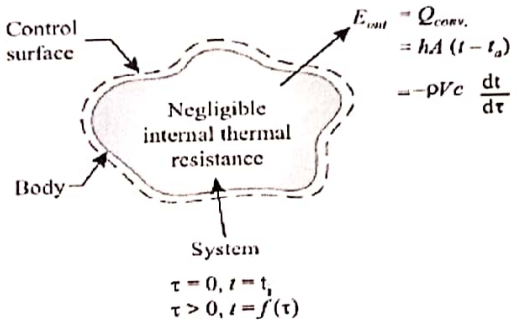

Fig. 5

(b) An aluminium alloy plate of 400 mm x 400 mm x 4 mm size at 200°C is suddenly quenched into liquid oxygen at -183°C. Determine the time required for the plate to reach a temperature of -70 °C. Assume h = 20000kJ/m^2 °C, Cp = 0.8 kJ/kg °C, and ρ = 3000 kg/m^3

Question 6

(a) Explain the phenomenon "Critical Thickness of Insulation".

(b) Show that the critical thickness of insulation for a cylinder and a sphere is "$r_2 (= r_c) = \frac{k}{h_0}$" and "$r_2 (= r_c) = \frac{2k}{h_0}$," respectively.

(c) A wire of 6.5 mm diameter at a temperature of 60 °C is to be insulated by a materials having thermal conductivity of 0.174 W/m°C. Convection heat transfer coefficient is 8.72 W/m^2°C. The ambient temperature is 20°C. For maximum heat loss, what is the minimum thickness of insulation and heat loss per meter length?