UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	ADVANCE HEAT AND MASS TRANSFER
COURSE CODE	:	MDT 10103
PROGRAMME	:	MDM
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS. **OPEN BOOK EXAMINATION**.

THIS QUESTION PAPER CONSISTS OF **SIX** (**6**) PAGES

Q1 (a) Heat conduction in Series is heat passes through several consecutive layers of different materials. For example, in a cold store wall, heat might pass through brick, plaster, wood and cork. Support the heat conduction in Series by derive the Conduction Heat Equation as figure illustrated in **Figure Q1 (a)**. In this case, applied equation below to each layer.

$$q = kA\ \Delta T/x = (k/x)\ A\ \Delta T$$

(8 marks)

(b) Heat transfer in cold store wall of brick, concrete and cork A cold store has a wall comprising 11 cm of brick on the outside, then 7.5 cm of concrete and then 10cm of cork. The mean temperature within the store is maintained at –18ºC and the mean temperature of the outside surface of the wall is 18ºC. Calculate the rate of heat transfer through 1m2 of wall. The appropriate thermal conductivities are for brick, concrete and cork, respectively 0.69, 0.76 and 0.043 $Jm^{-1}s^{-1}{}^{o}C^{-1}$. Evaluate also the temperature at the interface between the concrete and the cork layers.

(12 marks)

Q2 (a) A businesswoman travelling cross-country in her car notices the temperature gauge on her dashboard is in the red and reads 150ºC. She pulls over and inspects her radiator fluid. She sees that there is no coolant in the radiator. Her car's engine is made of cast iron (specific heat = 0.460 kJ/kg-K) and she estimates that it is 200 kilograms. She wants to get the engine down to a safe temperature of 100ºC. She has a jug of water at 20ºC in her trunk. What volume of water does she need to put into the radiator? Value it. Assume that the water and engine exchange heat only with each other, not with the surrounding air or other mechanical parts.

(8 marks)

(b) The boiling temperature of oxigen at atmospheric pressure at sea level (1 atm pressure) is -183°C as shown in **Figure Q2(b)**. Therefore, oxigen is commonly used in low-temperature scientific studies, since the temperature of liquid oxigen in a tank open to the atmosphere will remain constant at -183°C until it is depleted. Any heat transfer to the tank will result in the evaporation of some liquid nitrogen, which has a heat of vaporization of 213 kJ/kg and a density of 1140 kg/m^3 at 1 atm.
Consider a 4-m-diameter spherical tank that is initially filled with liquid nitrogen at 1 atm and -183°C. The tank is exposed to 20°C ambient air and 40 km/h winds. The temperature of the thin-shelled spherical tank is observed to be almost the same as the temperature of the nitrogen inside. Disregarding any radiation heat exchange, determine the rate of evaporation of the liquid nitrogen in the tank as a result of heat transfer from the ambient air if the tank is

(i) not insulated,
(ii) insulated with 5-cm-thick fiberglass insulation (k = 0.035 W/m°C), and
(iii) insulated with 2-cm-thick superinsulation that has an effective thermal conductivity of 0.00005 W/m°C.

(12 marks)

Q3 (a) What is forced convection? How does it differ from natural convection? Is convection caused by winds forced or natural convection? Physically, what does the Grashof number represent? Support the answer by derivation on Grashof number and Rayleigh number.

(8 marks)

(b) A 1.5m diameter, 5m long cylindrical propane tank is initially filled with liquid propane, whose density is 581 kg/m^3. The tank is exposed to the ambient air at 25°C in calm weather. The outer surface of the tank is polished so that the radiation heat transfer is negligible. Now a crack develops at the top of the tank, and the pressure inside drops to 1 atm while the temperature drops to -42°C, which is the boiling temperature of propane at 1 atm. The heat of vaporization of propane at 1 atm is 425 kJ/kg. The propane is slowly vaporized as a result of the heat transfer from the ambient air into the tank, and the propane vapor escapes the tank at -42°C through the crack. Assuming the propane tank to be at about the same temperature as the propane inside at all times, define how long it will take for the tank to empty if it is not insulated.

(12 marks)

4 (a) Consider a 20-cm-diameter spherical ball at 800 K suspended in air as shown in **Figure Q4(a)**. Assuming the ball closely approximates a blackbody, determine

(i) the total blackbody emissive power,
(ii) the total amount of radiation emitted by the ball in 5 min, and
(iii) the spectral blackbody emissive power at a wavelength of 3 mm.

(8 marks)

(b) A jet of liquid metal at 2000C pours from a crucible. It is 3 mmm in diameter. Along cylinder radiation shield, 5 cm diameter, surrounds the jet through an angle of 330° slit in it. The jet and the shield radiate as black bodies. They sit in a room at 30°C, ant the shield has a temperature of 700°C. Calculate

(i) the net heat transfer from the jet to the room through the slit
(ii) from the jet to the shield
(iii)from the inside of the shield to the room

(12 marks)

Q5 (a) Flik's law of diffusion for mass diffusion phenomenon states that the rate of diffusion of a chemical species at a location in a gas mixture (or liquid or solid solution) is proportional to the concentration gradient of the species at that location. Summarized these two (2) common way to expressed concentration of a species.

(i) Mass Basis

(ii) Mole Basis

(8 marks)

(b) At Low temperatures, carbon oxidizes (burns) in through the surface reaction

$$C + O_2 \text{----------}\rightarrow CO_2.$$

Figure Q5(b) shows the carbon-air interface in a coordinate system that moves into the stationary carbon at the same speed that the carbon burns away as though the observer were seated on the moving interface. Oxygen flows toward the carbon surface and carbon dioxide flows away, with a net flow of carbon through interface. If the system is at steady state and if separate analysis shows that carbon is consumed at the rate of 0.00241 kg/m2s, find the mass and mole fluxes through an imaginary surface , s, that stays close to the gas side of the interface. For this case, concentrations at the s-surface turn out to be $m_{O2,s}$ =0.20, $m_{CO2,s}$ =0.052 and ρ_s =0.29 kg/m^3.

(12 marks)

- END OF QUESTIONS -

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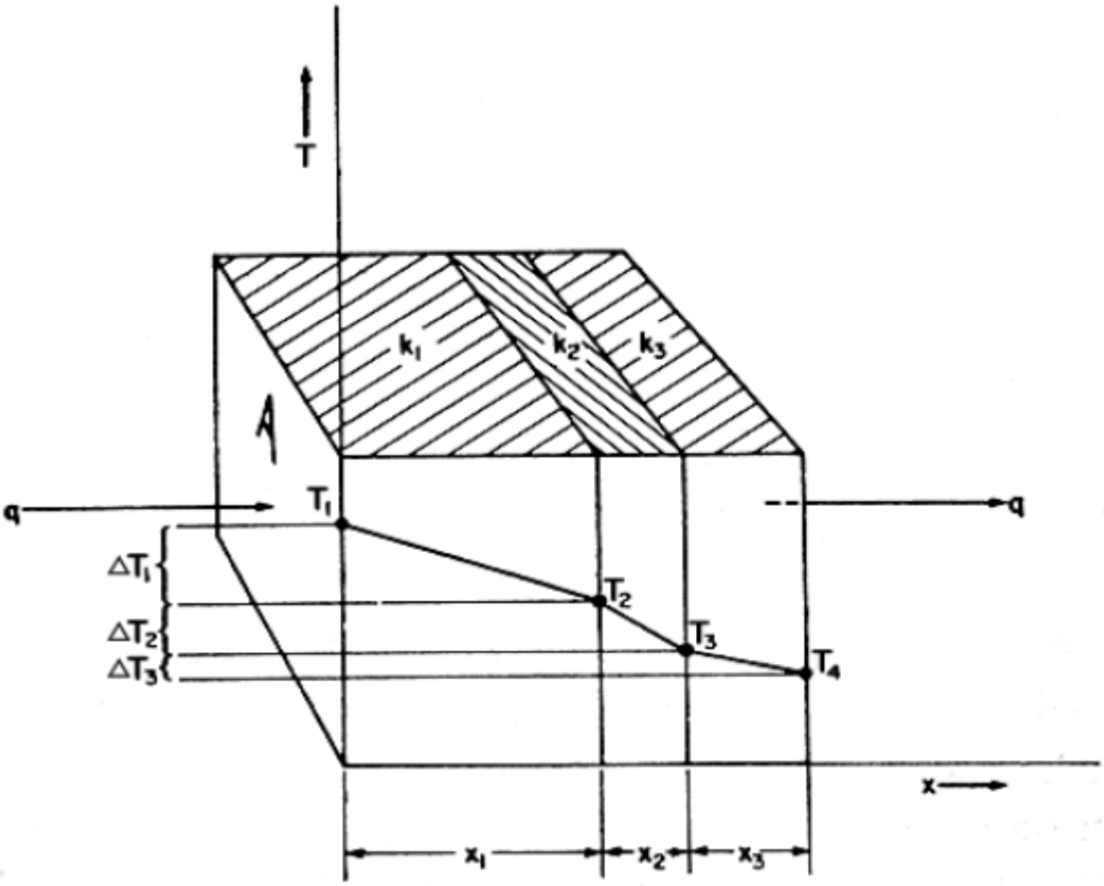

$$q = \frac{A \Delta T_1 k_1}{x_1} = \frac{A \Delta T_2 k_2}{x_2} = \frac{A \Delta T_3 k_3}{x_3}$$

Figure Q1(a): The heat conduction in Series

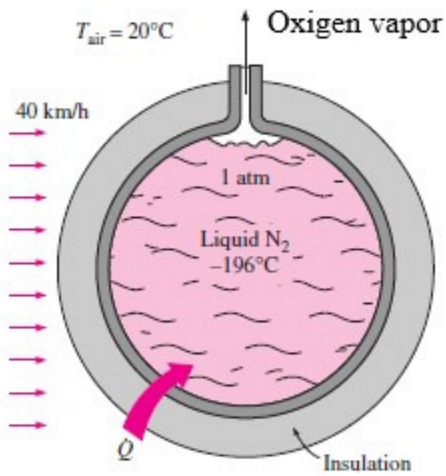

Figure Q2(b): The boiling temperature of oxigen at atmospheric pressure at sea level

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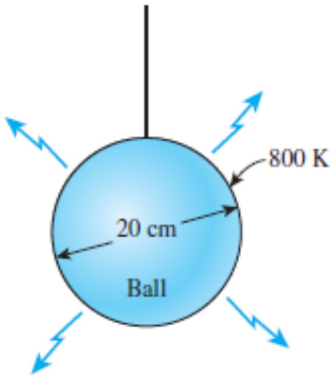

Figure Q4(a): 20-cm-diameter spherical ball at 800 K suspended in air

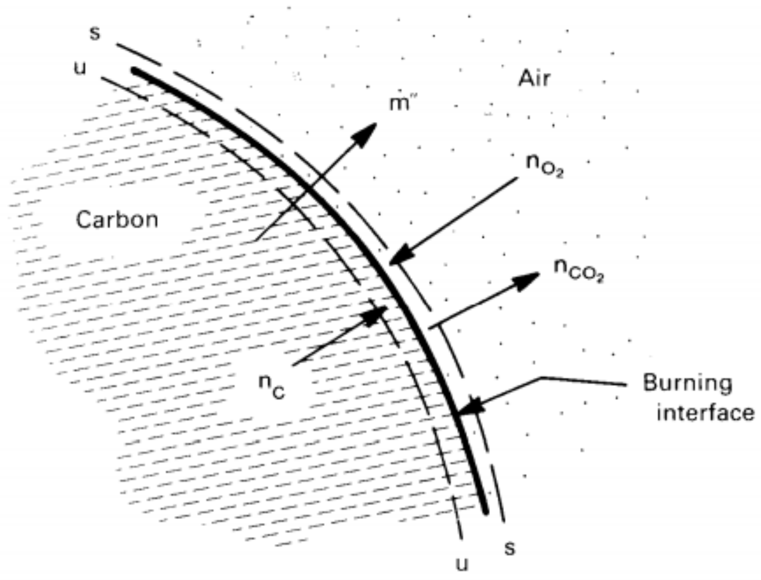

Figure Q5(b): The carbon-air interface in a coordinate system