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#### MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

**FACULTY OF ENGINEERING, APPLIED SCIENCES AND TECHNOLOGY**

**DEPARTMENT: METALLURGICAL ENGINEERING**

**MODULE: HEAT TRANSFER AND MASS TRANSFER**

**CODE: ENGM 211**

**SESSIONAL EXAMINATIONS**

**DECEMBER 2023**

**DURATION: 3 HOURS**

**EXAMINER: MS MT MAJAHA**

## **INSTRUCTIONS**

1. *Answer*  ***Question 1*** *in Section A**and any other* ***three*** *in Section B*
2. *Total marks 100*

***ADDITIONAL MATERIALS***

*Scientific calculator*

**SECTION A: ANSWER ALL QUESTIONS**

**QUESTION 1**

1. State and explain the three modes of heat transfer. [10]
2. What are the differences between heat transfer and thermodynamics? [4]
3. A spherical shaped vessel of 1.4 m diameter is 90mm thick. Find the rate of heat leakage, if the temperature difference of the inner and outer surfaces is 220°C. Thermal conductivity of the material of the sphere is 0.083 W/m°C. [6]
4. The coating on a plate is cured by exposure to an infrared lamp providing a uniform irradiation of 2000 W/m2. It absorbs 80% of the irradiation and has an emissivity of 0.50. It is exposed to an air flow and large surroundings for which temperatures are 20 ᵒC and 30 ᵒC respectively. If the convection coefficient between the plate and the ambient air is 15 W/m2K, what is the temperature of the plate? [15]
5. A carbon steel plate (thermal conductivity = 45 W/mᵒC) 600 mm x 900 mm x 25 mm is maintained at 310 ᵒC. Air at 15 ᵒC blows over the hot plate. If the convection heat transfer co-efficient is 22 W/m2ᵒC and 250W is lost from the plate surface by radiation, calculate the inside plate temperature. [5]

**SECTION B: ANSWER ANY THREE QUESTIONS**

**QUESTION 2**

1. Discuss the effects of various parameters on the thermal conductivity of solids. [5]
2. A standard cast iron pipe (inner diameter = 50 mm and outer diameter = 55 mm) is insulated with magnesium insulation (k = 0.02 W/m°C). Temperature at the interphase between the pipe and insulation is 300°C. The allowable heat loss through the pipe is 600 W/m length of pipe and for safety, the temperature of the outside surface must not exceed 100°C. Determine;

i .Minimum thickness of insulation required

ii. The temperature of inside surface of pipe given that its thermal conductivity is 20W/m°C. [15]

**QUESTION 3**

1. Calculate the rate of cooling of an aluminium plate (1.5 m by 1.5 m) at 580K when it is suspended horizontally in stagnant air at 300K. The heat transfer coefficient is estimated using the following correlation

*Nu L = (Gr L)1/3Pr1/3*

Where *GrL =( L3p2ɡβΔT)/µ2*

The properties of air evaluated at the film temperature of 440K are

*p =* 0.8021kg/m3 ; *Cp =* 1.0197 x 103 J/kgK ; µ = 2.4453 X 10-5 Pas; *k =* 3.6427 x 10-2 W/mK ; β =2.2681 x 10-3 K-1 ; g = 9.81 m/s [20]

**QUESTION 4**

1. Discuss on the modes of mass transfer. [10]
2. A steel rectangular container having walls 20 mm thick is used to store gaseous hydrogen at elevated pressure. The molar concentrations of hydrogen in the steel at the inside and outside surfaces are 1.2 kg mole/m3 and zero respectively. Assuming the diffusion coefficient for hydrogen in steel as 0.248 x 10-12 m2/s, calculate the molar diffusion flux for hydrogen through the steel. [10]

**QUESTION 5**

1. State Fick’s law of mass diffusion. [5]
2. Hydrogen gas at 25 °C and 2.5 atmosphere flows through a rubber tubing of 12mm inside radius and 24mm outside radius. The binary diffusion coefficient of hydrogen is 2.1 x 10-8 m2/s and the solubility of hydrogen is 0.055 m3 of hydrogen per m3 of rubber at 1 atmosphere. If the gas constant for hydrogen is 4160 J/kgK and the concentration of hydrogen at the outer surface of tubing is negligible, calculate the diffusion flux rate of hydrogen per meter length of rubber tubing. [15]

**END OF EXAMINATION**