MURANG'A UNIVERSITY OF TECHNOLOGY

SCHOOL OF PURE, APPLIED AND HEALTH SCIENCES

DEPARTMENT OF PHYSICAL AND BIOLOGICAL SCIENCES

UNIVERSITY ORDINARY EXAMINATION

2021/2022 ACADEMIC YEAR

THIRD YEAR **FIRST** SEMESTER EXAMINATION FOR, BACHELOR OF SCIENCE IN INDUSTRIAL CHEMISTRY

ACH315: FLUID FLOW, HEAT AND MASS TRANSFER

DURATION: 2 HOURS

Instructions to candidates:

1. Answer question One and Any Other Two questions.
2. Mobile phones are not allowed in the examination room.
3. You are not allowed to write on this examination question paper.

SECTION A: ANSWER ALL QUESTIONS IN THIS SECTION

QUESTION ONE (30 MARKS)

Useful constants

Specific heat of water, C_w=4187 J/kg ºC

Boltzmann's constant, B= 1.38 x10^{-23} J/K

Stefan- Boltzmann Constant, $\sigma = 5.67 \times 10^{-8}$ Wm-^{2}K^{-4}

1 atm = 101300 Pa

Gas constant, R= 8.314 J/K mol

Density of water ρ = 1000 kg/m^3

Gravity strength g = 9.8 N/Kg

Latent heat of vaporization of water Lz = 2430 KJ/kg

1. a). Define coefficient of viscosity and hence write its dimensional formula. (3 marks)

b) Liquids have a constant density while gases don't. Explain. (2 marks)

c) Show that the pressure due to static liquid column is directly proportional to the column height. (4 marks)

d) Calculate the Reynolds number, R_e for oil flowing in a circular pipe. The diameter of the pipe is 50 mm, the density of the oil is 920 kg/m^3, the volumetric oil flow rate is 56 L/min and the dynamic viscosity of the oil is 40 x 10^{-3} pa.S. (3 marks)

e) A garden hose has an inside diameter of 12 mm, and water flows through it at 2.5m/s.

i) What nozzle diameter is needed for the water to emerge at 10m/s? (2 marks)

ii) At what rate does water leave the nozzle in litres/second? (1 mark)

f) Explain two mechanisms which heat transfer through conduction is accomplished. (2 marks)

g) i) State Graham's law of diffusion. (1 mark)

ii) From a certain apparatus, the diffusion rate of hydrogen - atomic number = 1 and mass number = 2 – has an average of 28.7 cm^3/S; the diffusion of another gas under the same conditions is measured to have an average rate of 7.2 cm^3/S. Calculate the atomic mass of the gas. (3 marks)

h) Calculate the difference in level between mercury surfaces inside the tube of radius r = 20 mm and outside. (The surface tension of mercury, r = 5.47 x 10^{-2} N/m and density ρ = 13600 kg/m^3 and angle of contact of mercury with clean glass Θ = 130º). (3 marks)

i) A mass of 12 g of ice at 0ºC were added to100 g of water at 30ºC. The final temperature was 20º C. Calculate the specific heat latent heat of the ice. (3 marks)

j) Helium, He gas is contained in a pipe at a temperature of 298 K and 1 atm total pressure which is constant throughout. Calculate the concentration of the gas in Kgmol/m^3 (3marks)

SECTION B – ANSWER ANY TWO QUESTIONS IN THIS SECTION

QUESTION TWO (20 MARKS)

a). Define the following terms as they are applied in mass transfer. (6 marks)

i) Adsorption (1 marks)

ii) Humidification (1 mark)

iii) Distillation (1 mark)

iv) Extraction (1 mark)

v) Leaching (1 mark)

b) State the first law of diffusion. (4 marks)

c) A mixture of He and N_2 gas contained in a pipe at a temperature of 298K and 1 atm total pressure which is constant throughout. At one end of the pipe at point 1, the partial pressure of He is P_{A1} = 0.6 atm and at the other end of the pipe which is 0.2 m from end one has a partial pressure P_{A2}= 0.2 atm. Calculate the flux of Heat steady state if coefficient of diffusion D_{AB} = 0.687 x 10^{-4} m^2/s of the He – N_2 mixture. (7 marks)

d) A pure nitrogen carrier gas flows parallel to a surface f area A= 0.6m^2 of a liquid acetone in an open tank. The acetone temperature is maintained at 290 K. If the average mass transfer coefficient, K_c for the acetone into the nitrogen stream is 0.0324 m/s, determine the total rate of acetone released in the units of kg.mol/s given that acetone exerts a vapour pressure of $161 mmHg$ or 2.148 x 10^4 pa. (7 marks)

QUESTION THREE (20 MARKS)

a). State

i) Pascal's principle (1 mark)

ii) Archimede's principle (1 mark)

iii) A hydraulic lift has pistons with diameters 8 cm and 36 cm respectively. If a force of 825N is exerted at the input piston, what maximum mass can be lifted by the output piston[2]. (3 marks)

b) A businessman purchases a "gold" crown at a black market. After he gets home, he hangs it from a spring scale and finds its weight to be 7.84 N. He then weights the crown while immersed in water and now the scale read 6.86 N. Given that the density of pure gold $\rho_{gold} = 19.3 \times 10^3$ kg/m^3, determine whether the crown was made of pure gold? (5 marks)

c) Water flows at a velocity of 5 m/s through a hose pipe whose inner diameter is 20 mm.

i) find the rate of water though the hose pipe in litres per minutes. (2 marks

ii) Find the force needed to hold the nozzle. (3 marks)

d) Water flows inside a horizontal pipe of non-uniform cross-section area. It is observed that pressure of 10 mmHg exists at a point where the velocity is 20 m/s. Find the pressure in mmHg at the point where the velocity is 20 m/s. (5 marks)

QUESTION FOUR (20 MARKS)

a). i) Define the term heat capacity and state the SI unit. (2 marks)

ii) A block of metal of mass 0.2kg and temperature 100 º C is placed in water of mass 0.4 kg and temperature 20 ºC. If the final temperature of water is 24 ºC, calculate the specific heat capacity of the metal. (Neglect heat absorbed by the container) (3 marks)

b) The wall of a house, 7 m wide and 6 m high is made from 0.3 m, thick brick with conduction coefficient K= 0.6 W/mk. The surface temperature on the inside of the wall is 16 ºC and that on the outside is 6 ºC. Find the heat flux though the wall and the total rate of heat loss through the wall. (5marks)

c) An average person generates heat at the rate of 120 W when at rest. At what rate must water evaporate from his body to completely get rid of this energy? (6 marks)

d) During one cycle, heat engine extracts 2.0×10^3J of energy from a hot reservoir and transfers 1.5×10^3 J to a cold reservoir.

i. Find the thermal efficiency of the engine. (2 marks)
ii. How much work does this engine do in one cycle? (1 mark)
iii. How much power does the engine generate if it goes through four cycles in 2.5 seconds? (2 marks)