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# INTERNATIONAL CENTRE FOR APPLIED SCIENCES

(Manipal University)

## IV SEMESTER B.S. DEGREE EXAMINATION – APRIL/ MAY 2017

**SUBJECT: HEAT AND MASS TRANSFER OPERATIONS IN BIOPROCESSING (BT 244)**

**(BRANCH: BIOTECHNOLOGY)**

**Thursday, 27 April 2017**

**Time: 3 Hours** **Max. Marks: 100**

- ✓ **Answer ANY FIVE full Questions.**
- ✓ **Missing data, if any, may be suitably assumed**

1A. A pipe carrying steam having an OD of 20cm runs in a large room, and is exposed to air at a temperature of 30°C. The pipe surface temperature is 200°C. Find the heat loss per meter length of the pipe by convection and radiation taking the emissivity of the pipe surface as 0.8.
Given $Nu = 0.53(Gr_D.Pr)^{1/4}$ , $\nu = 24.93\times10^{-6}$ m$^2$/s, k =33.06x10$^{-3}$W/mK and Pr = 0.687.

1B. State and explain Kirchoff's law of radiation.

1C. Explain the concept of contact resistance. **(10+5+5)**

2A. Air stream at 27°C is moving at 0.3m/s across a 100W electric bulb at 127°C . If the bulb is approximated by a 60mm diameter sphere, estimate the heat transfer rate.
Given physical properties K=0.03W/mK, Pr=0.697, $\nu$= 0.208x10$^{-6}$ m$^2$/s,Nu=0.37 $Re_d^{0.}$

2B. Assuming that a man can be represented by a cylinder 30cm in diameter and 1.7m high with a surface temperature of 30°C, calculate the heat he would loose while standingin a 36km/hr wind at 10°C. Given physical properties are : k= 0.0259 W/mK, $\nu$=15.00x10$^{-6}$m$^2$/s, Pr =0.707, Nu=0.027($Re^{0.805}$ x $Pr^{0.333}$)

2C. Explain the thermal boundary layer concept. **(8+8+4)**

3A. State the physical significance of Reynolds and Grashoff number.

3B.Perform a dimensional analysis for forced convection with the pertinent variables.

3C. Explain the two film theory of mass transfer **(4+6+10)**

4A. Explain the various regimes in forced convection boiling.

4B. Water heated to 80°C flows through 2.54cm ID and 2.88 cm OD steel (k=50W/mK). The tube is exposed to an environment which is known to provide an average convection heat transfer coefficient of $h_o$=30800W/m$^2$K on the outside of the tube. The water velocity is 50cm/s. Calculate the overall heat transfer coefficient based on the outer area of the pipe Given properties : $\rho$=974 kg/m$^3$, $\nu$=0.364 x10$^{-6}$ m$^2$/s, $c_p$=4180J/kg°C, k=0.668W/mK and Pr=2.20, Nu=0.023 $Re_d^{4/5}$ x $Pr^{0.4}$

4C. In a power plant steam is to be condensed at a temperature of 30°C with cooling water from a nearby lake which enters the tubes of the condenser at 14°C and leaves at 22°C. The surface area of the tube is 45m$^2$ and the overall heat transfer coefficient is 2100W/m$^2$K. Calculate the mass flow rate of cooling water and rate of condensation of steam in the condenser. Given $\lambda$=2430kJ/kg. **(6+8+6)**

5A. Explain the forward and backward feed systems in evaporators with a neat sketch

5B. A single-effect evaporator is used to concentrate 7 kg/s of a solution from 10 to 50 per cent solids. Steam is available at 205 kN/m$^2$ and evaporation takes place at 13.5 kN/m$^2$. If the overall coefficient of heat transfer is 3 kW/m$^2$K, estimate the heating surface required and the amount of steam used if the feed to the evaporator is at 294 K and the condensate leaves the heating space at 352.7 K. The specific heats of 10 and 50 per cent solutions are 3.76 and 3.14 kJ/kgK respectively. Assuming that the steam is dry and saturated at 205 kN/m$^2$, then from the Steam Tables, the steam temperature = 394 K at which the enthalpy of steam = 2530 kJ/kg and the enthalpy of condensate is 333.2kJ/kg. At 13.5 kN/m$^2$, water boils at 325 K .The total enthalpy of vapour at 325 K is 2594 kJ/kg. **(10+10)**

6A. Two large vessels are connected by a tube 5cm in diameter and 15cm in length. Vessel 1 contains 80% $N_2$ (A) and 20% $O_2$ (B); Vessel 2 contains 20% $N_2$ and 80% $O_2$. The temperature is 20°C and the pressure is 1 atm. Calculate (a) the steady state flux and the rate of transport of $N_2$ from vessel 1 to 2 (b) the steady state flux and the rate of transport of $O_2$ from vessel 1 to 2. Given $D_{AB} = 1.01 \times 10^{-5}$m$^2$/s.

6B. Explain the analogy between heat, mass and momentum transfer.

6C. In an experimental study of the absorption of ammonia by water in a wetted wall column, the value of $K_G$ was found to be 2.75 x $10^{-6}$kmol/m$^2$s(kPa). At one point in the column the composition of the gas and the liquid phase were 8 and 0.115mole % $NH_3$ respectively. The temperature was 300K and the total pressure was 1 atm. Eighty five percent of the total resistance to mass transfer was found to be in the gas phase. At 300K, ammonia water solutions follow Henry's law upto 5 mole % ammonia in the liquid, with m=1.64 when the total pressure is 1 atm. Calculate the individual film coefficients and the interfacial concentration.

**(5+5+10)**

7A. A gas diffuses through a plane plastic membrane which is 1mm in thickness. The concentration of the gas in the membrane is 0.02kmol/m$^3$ at the inner surface and 0.005kmol/m$^3$ at the outer surface. If the binary diffusion coefficient of the gas with respect to the plastic is $10^{-9}$m$^2$/s what is the diffusion flux of helium through the plastic. State the assumption.

7B. Explain the Fick's law of steady state diffusion.

7C. With an example explain the solid liquid and gas liquid mass transfer operations.

**(5+5+10)**

8A. With an example explain the process of diffusion of A through non diffusing B.

8B. Explain the terms molar concentration and mass density.

8C. A container containing a mixture of gases say oxygen and carbon dioxide is maintained at 21°C and 151.9kPa. The mean velocity of oxygen is 0.08m/s and that of carbon dioxide is -0.02m/s. If the molar fraction of oxygen is 0.4, calculate the mole fraction of carbon dioxide, the molecular weight of the mixture, molar concentration of carbon dioxide and oxygen, mass concentration of carbon dioxide and oxygen.

**(6+4+10)**