NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
END OF SEMESTER TWO EXAMINATIONS – MAY 2005
TRANSPORT PHENOMENA – SCH 2108
TIME: 3 HOURS

INSTRUCTION TO CANDIDATES

Answer **four** questions only. Total marks are 100.

SECTION A

1. (a) A commonly used equation for determining the volume rate flow, Q, of a liquid through an orifice located in the inside of a tank is $Q = 0.61A_0\rho(2gh)^{1/2}$; where Ao is the area of the orifice, g is the acceleration of gravity, and h is the height of the liquid above the orifice. Investigate the dimensional homogeneity of this formula. (10marks)

   (b) Water flows at 3000 and 4000cm/s through a 50mm pipe and is metered by means of an orifice. Suggest a suitable size of orifice if the pressure difference is to be measured with a simple water manometer. What is the approximate pressure difference recorded at the maximum flowrate? $Q = C_DA_0\rho(2[P_1-P_2]/1-[Ao/A_1]^2)^{1/2}$;
   Take h = 1m;ρ=1000kg/m^3 (15marks)

2. (a) Develop three fundamental laws required for the analysis of heat transfer processes. (15marks)

   (b) Name and explain the three supplementary principles required in the analysis of all heat transfer processes. (10marks)

3. (a) The composition of air is often given in terms of only the two principal species in the gas mixture; oxygen, $y_{O2} = 0.21$; nitrogen,$y_{N2} = 0.79$. Determine the mass fraction of both oxygen and nitrogen and the mean molecular weight of the air when it is maintained at 278K and 1 atm ($1.013x10^5$ kPa). The molecular weight of oxygen is 0.032kg/mol and of nitrogen is 0.028kg/mol. To calculate mean molecular weight use the ideal gas law. (15marks)

   (b) Determine the diffusivity for carbon monoxide through a gas mixture in which the mole fractions of each of each component are:

   $y_{O2} = 0.225$
   $y_{N2} = 0.680$
   $y_{CO} = 0.095$.

   The gas mixture is at 298K and 2.25atm total pressure.

Where $D_{CO\text{-}N2} = 0.192\times10^{-4} m^2/s$ at 273K, 1 atm and $D_{CO\text{-}O2} = 0.197\times10^{-4} m^2/s$ at 288K,1atm

$$D_{AB}(C1)/D_{AB}(C2) = (T_1/T_2)^{3/2}(P_2/P_1)$$ (10marks)

4. (a) In a hot combustion chamber, oxygen diffuses through an air film to a carbon surface where it reacts according to the following equation:
$3C + 2O_2 \rightarrow 2CO + CO_2$, use a fully labelled diagram to answer the question.

(i) With the assumption that the carbon surface is flat, reduce the general differential equation for mass transfer to write the specific differential equation that describes this steady state process.

(ii) Write Fick's law in terms of only oxygen. (16marks)

(b) In a cylindrical nuclear fuel rod which contains fissionable material, the rate of production of neutron is proportional to the concentration. Use one of the general differential equations for mass transfer to write the differential equation which describes the mass transfer process. (9marks)

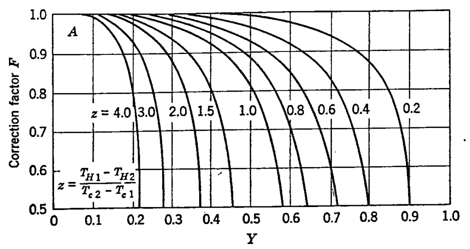
5 (a) Light lubricating oil (Cp = 2196J/kg.K) is cooled by allowing it to exchange energy with water in a small heat exchanger. The oil enters and leaves the heat exchanger at 373K and 355K, respectively, and flows at a rate of 0.65kg/s. Water at 285K is available in sufficient quantity to allow 0.205kg/s to be used for cooling purposes. Determine the required heat transfer area for (a) counter flow,

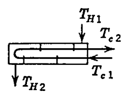
(b) Parallel flow operations. The overall heat transfer coefficient is $255 W/m^2.K$ (15marks)

(c) In the oil-water energy transfer described in (b) compare the result obtained with the result that would be obtained if the heat exchanger were

(i) Cross-flow, water mixed,
(ii) shell-and-tube with four tube side passes, oil being the tube-side fluid. (10marks)

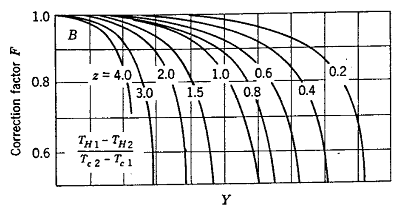
End of question Paper!!!

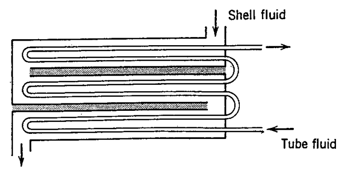




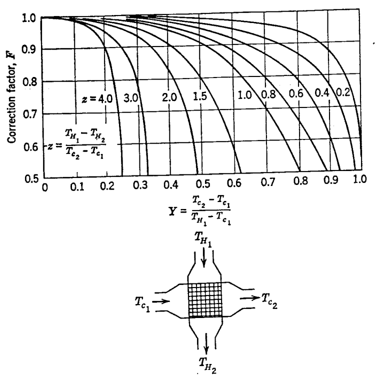
Correction Factor Plot for Exchanger with One Shell Pass and Two, Four, or any Multiple of Tube Passes

(a)

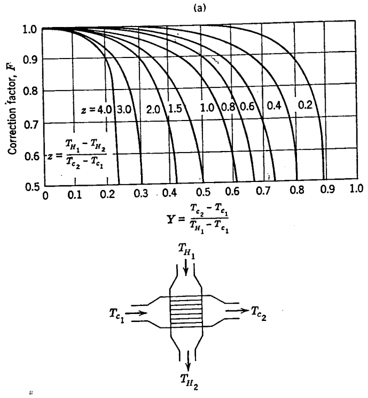




(b)


Correction factor, F
1.0
0.9
0.8
0.7
0.6
0.5
z = 4.0
3.0
2.0
1.5
1.0
0.8
0.6
0.4
0.2
z = (T_H1 − T_H2)/(T_c2 − T_c1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Y = (T_c2 − T_c1)/(T_H1 − T_c1)
T_H1
T_c1
T_c2
T_H2

(a)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0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Y = (T_c2 − T_c1)/(T_H1 − T_c1)
T_H1
T_c1
T_c2
T_H2