NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
BACHELOR OF SCIENCE HONOURS DEGREE
END OF FIRST SEMESTER EXAMINATIONS – FEBRUARY 2010
TRANSPORT PHENOMENA – SCH 2108
TIME: 3 HOURS

INSTRUCTIONS TO CANDIDATES

Answer *all questions* in Section A and *only 3* in Section B. Total marks are 100.

$R = 82.06$ atm $cm^3 gmol^{-1} K^{-1}$. also $R = 8.314 Jmol^{-1}K^{-1}$

SECTION A

1. (a) Define the following terms:

   (i) Shear stress
   (ii) Dimensional homogeneity
   (iii) Dimensionless number (6 marks)

   (b) With the aid of a sketch diagram, explain the relationship between absolute pressure, gauge pressure and atmospheric pressure. (4 marks)

2. (a) State the Buckingham PI theorem. (2 marks)

   (b) Derive the continuity equation of an incompressible fluid. Use diagrams where possible. (8 marks)

3. (a) Using suitable examples, what is the difference between a dimension, a value and a unit? (4 marks)

   (b) What is Pascal's Paradox? Give a practical application of Pascal's Paradox. (2 marks)

   (c) List four limitations of the Bernoulli equation. (4 marks)

4. (a) In a plant you have purchased out of the United States, the following designations are used for values on the equipment. What does each designation stand for:

(i) psi (1 mark)
(ii) psig (1 mark)
(iii) psia (1 mark)

(b) State the general equation for rate of transport. (2 marks)

5. A cork slab 10 cm thick has one face at -12°C and the other face at 21°C. If the mean thermal conductivity of cork in this temperature range is 0.042 J m^{-1} s^{-1} $°C^{-1}$, what is the rate of heat transfer through 1 m^2 of wall? (5 marks)

SECTION B (Answer Any Three Questions)

6. (a) Define the following heat transfer situations as conduction, convection, radiation, or a combination of the three. Please also clearly state what two objects the mode of heat transfer is between and the direction of heat transfer.

i) The sun shines brightly on a car, making the black upholstery very hot.
ii) A small 4" fan is installed in the back of a computer to help cool the electronics.
iii) Potatoes are boiled in water.
iv) A turkey is being roasted in the oven.
v) An ice cube is placed on a metal tray and left out of the freezer.
(5 marks)

(b) Derive the Bernoulli's equation. (12 marks)

(c) What does each term represent in the Bernoulli Equation. (3 marks)

2. (a) With the aid of a diagram, describe Reynolds experiment which showed the relationship between the velocity of a fluid and the nature of flow.
(10 marks)

(b) At high speeds, fluids tend to flow in an unsteady and violent manner.

i. What is the term used in fluid mechanics to describe the type of flow described above (b)? (2 marks)

ii. Draw the velocity profile that will result from the flow pattern described under (b). (3 marks)

iii. State the critical Reynolds region. Explain the significance of the region.
(5 marks)

3. (a) A cold store has a wall comprising 11 cm of brick on the outside, then 7.5 cm of concrete and then 10 cm of cork. The mean temperature within the store is maintained at -18°C and the mean temperature of the outside surface of the wall is 18°C.

(i) Calculate the rate of heat transfer through the wall. The appropriate thermal conductivities are for brick, concrete and cork, respectively 0.69, 0.76 and 0.043 J m^{-1} s^{-1} $°C^{-1}$.
(6 marks)

(ii) Determine also the temperature at the interfaces between the concrete and cork layers, and the brick and concrete layers.
(12 marks)

(b) Sketch a temperature versus distance graph for a counter-current heat exchanger.
(2 marks)

4. (a) Viscosity of a fluid can be measured using a number of techniques. With the aid of a diagram explain how viscosity can be measured using a falling ball.
(7 marks)

(b) Write down the formulae of the following indicating the meaning of the symbols:

(i) Reynolds number (3 marks)

(ii) Nusselt number (3 marks)

(c) Milk is flowing into a pipe cooler and passes through a tube of 2.5 cm internal diameter at a rate of 0.4 kg s^{-1}. Its initial temperature is 49°C and it is wished to cool it to 18°C using a stirred bath of constant 10°C water round the pipe. What length of pipe would be required? Assume an overall coefficient of heat transfer from the bath to the milk of 900 J m^{-2} s^{-1} $°C^{-1}$, and that the specific heat of milk is 3890 J kg^{-1} $°C^{-1}$.
(7 marks)

END OF QUESTION PAPER!!!