ENCH 403 – Heat Transfer
Mid-Term Examination (Fall 2014)

Question #1

This question consists of three (3) *Multiple Choice* questions. Choose only one answer in each case.

(A) Two long pipelines are parallel to each other and are buried deep in the ground. Both pipelines are 5.0-km long and their centre-lines are 30 cm apart. Their diameters and surface temperatures are 20 cm & 15 cm and 10°C & –10°C, respectively. The ground thermal conductivity is 1.2 W/(m K). The steady-state rate of heat transfer between the two pipelines is approximately:

(a)) 330 W	(b) 105 kW	(c) 330 kW	(d) 621 kW	(e) none of these

(B) A spherical vessel is used for storing liquid oxygen. Its (outer) diameter is 1.5 m. The vessel is covered with a 10-cm thick layer of insulation, whose thermal conductivity is 0.02 W/(m K). The temperature at the inner surface of the insulation is –180ºC. The insulated vessel is exposed to air at 10ºC, with a heat transfer coefficient of 5.0 W/(m^2 K). The steady-state temperature at the outer (exposed) surface of the insulation is approximately:

(a) –135ºC	(b) –13.5ºC	(c) –3.5ºC	(d) 3.5ºC	(e) none of these

(C) A long metal rod, 2.0 cm in diameter, is initially at a uniform temperature of 100ºC. The average properties of the metal are: density = 4.9 g/cm^3, specific heat capacity = 0.52 kJ/(kg K), and thermal conductivity = 100 W/(m K). It is suddenly exposed to an air stream at a uniform temperature of 20ºC, with a heat transfer coefficient of 50 W/(m^2K). The time required for the rod to reach an average temperature of 26ºC is approximately:

(a) 44 s	(b) 66 s	(c) 440 s	(d) 660 s	(e) none of these

Correct Answers are: ***(c); (d); (d)***

Question #2

In a heat-transfer experiment, air flowed at a uniform velocity over a square plate, 3.0 m × 3.0 m, made of a new material. The plate and air temperatures were held at 40ºC and 14ºC, respectively. The local heat transfer coefficient [h_x, in W/(m^2 K)] was found to vary with the distance from the leading edge of the plate [x, in m], as follows: [$h_x = 10.0\ x^{-0.25}$]. Calculate the following at steady state: (i) the heat flux at a distance of 1.5 m from the leading edge of the plate and (ii) the rate of heat loss from the entire plate.

Ans.: (i) 235 W/m^2; (ii) 2.37 kW

Question #3

An insulated pipeline carries hot water. Its outside diameter is 8.0 cm. The temperature at the outer surface is 44°C. The insulated pipeline is placed horizontally in air (at 10°C and 90 kPa). Calculate the steady-state rate of heat loss per unit pipe length, when: (i) there is a 20-km/h wind blowing across the pipe and (ii) there is no wind.

Ans.: (i) 253 W/m (Eq. 6-17); (ii) 49 W/m (C = 0.53) or 45 W/m (C = 0.48), 51 W/m (Table 7-2)

Question #4

Part (a): A laboratory experiment was used to study heat transfer to a liquid flowing through a tube, which is 2.5 cm in diameter and 5.0 m long. The specific heat capacity and flow rate of the liquid are 3.0 kJ/(kg K) and 1.0 kg/s, respectively. The flow has been confirmed to be under turbulent conditions (i.e., $Re > 4000$). The tube-wall temperature is 50°C. The liquid inlet and outlet temperatures are 20°C and 30°C, respectively. Use these data to estimate: (i) the average heat transfer coefficient and (ii) the rate of heat transfer.

Part (b): We wish to utilize the above laboratory measurements for predicting the rate of heat transfer in a larger tube, which is 5.0 cm in diameter and 10.0 m long. Its tube-wall temperature is also 50°C. This larger tube is to be used for the same liquid, at the same Reynolds number and at the same inlet temperature, as in Part (a). All liquid properties can be assumed to be the same as in the experiment. [Hint: For fully-developed turbulent flow, any one of Equations 6-4 and 6-5 could be used to compare the heat transfer coefficients for the two cases.]

Calculate (for the larger tube at steady state): (i) the liquid mass rate, (ii) the average heat transfer coefficient, (iii) the liquid outlet temperature, and (iv) the rate of heat transfer.

Ans.: (a) 30 kW, 3060 W/(m^2 K); (b) 2.0 kg/s, 1530 W/(m^2 K), 30ºC, 60 kW