UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

SCHOOL OF ENGINEERING
DISCIPLINE OF CHEMICAL ENGINEERING
HOWARD COLLEGE CAMPUS

TEST: OCTOBER 2019

COURSE AND CODE: EXPERIMENTAL TECHNIQUES AND MEASUREMENTS (ENCH2ET)

DURATION: 3 HOURS

TOTAL MARKS: 100

INTERNAL EXAMINERS: MR EM OBWAKA
MR N BRIJMOHAN

INTERNAL MODERATOR: DR S MOODLEY

EXTERNAL EXAMINER: DR FT MHLANGA

INSTRUCTIONS:

1. This question paper consists of two sections: Section A (Questions 1 – 4) and Section B (Questions 5 – 6).
2. Two Booklets have been provided. **ANSWER ANY 3 QUESTIONS FROM SECTION A IN BOOKLET A; AND ALL QUESTIONS FROM SECTION B IN BOOKLET B.**
3. Any programmable or non-programmable calculator may be used provided it has been cleared of any information that would subvert the purpose of the test.
4. Calculations must be shown in sufficient detail to illustrate your understanding of the procedure.
5. Factors for unit conversions and the gas constant in various units are provided on page 7.

SECTION A

QUESTION 1

a) The diameter of a Venturi meter is 50 mm at the inlet and 10 mm at the throat. Oil of density 900 kg/m^3 and dynamic viscosity 1×10^{-3} Pa.s flows through it, and a differential pressure head of 80 mm is produced. Given $C_d = 0.92$, determine the flow rate in kg/s.

Formulae:

$$Q = C_d A_1 \sqrt{\frac{2\Delta P}{\rho(\frac{A_1}{A_2} - 1)}}$$

$$\Delta P = \rho g \Delta h$$

(7)

b) Determine the Reynolds number at the inlet and classify the flow regime.

(5)

c) What is the significance of the coefficient of discharge C_d?

(3)

d) What are the relative advantages and disadvantages of using a Venturi meter instead of an Orifice plate?

(5)

TOTAL /20/

QUESTION 2

The manufacturer of an air conditioner claims an Energy Efficiency Ratio (EER) of 16 (Btu/h)/W for one of its units. This performance ratio is for the operating conditions when the evaporator saturation temperature is -5°C and the condenser saturation temperature is 45°C. This unit operates on the normal vapor compression refrigeration cycle and uses R-22 as the working fluid. Selected data for R-22 are provided in Table 2.1 below.

Table 2.1: R-22 Data

T (°C)	P_{sat} (kPa)	h_f (kJ/kg)	h_g (kJ/kg)
-5	421.2	38.76	248.1
45	1728	101	261.9

a) Sketch and fully label the hardware (component cycle) and the T-S diagram for this air conditioner.

(8)

b) Determine the heat absorbed by the refrigerant in the evaporator per unit mass of R-22, in kJ/kg.

(4)

c) Determine the work input to the compressor and the heat rejected in the condenser per unit mass of R-22, in kJ/kg.

(8)

Additional information:

$$1\text{W} = 3.412 \text{ Btu/h}$$

$$COP_R(EER) = \frac{Q_{Evap}}{W_{in}}$$

TOTAL /20/

QUESTION 3

An evaporator is required to concentrate a glycerol-water solution from 10% to 30% at the rate of 250 kg of feed per hour. The pressure in the evaporator is 77 kPa (absolute), and steam is available at 200 kPa (gauge). The temperature of the feed is 18°C and the boiling point of the solution at 77 kPa (absolute) is 91°C. The specific heat of the solution is the same as that for water, that is, 4186 J/kg.°C, and the condensing temperature of steam at 200 kPa (gauge) is 134°C with latent heat of 2164 kJ/kg. The condensing temperature of the solution at 77 kPa (absolute) is 91°C with latent heat of 2281 kJ/kg.

a) Calculate the mass of water evaporated in kg/h.

(7)

b) Determine the quantity of steam required per hour.

(10)

c) How can the energy requirements of the unit be reduced?

(3)

TOTAL /20/

QUESTION 4

a) What are the common causes of fouling in a heat exchanger, and how does fouling affect heat transfer and pressure drop?

(4)

b) How is the thermal resistance due to fouling in a heat exchanger accounted for, and how do the fluid velocity and temperature affect fouling?

(4)

c) With the aid of sketched temperature profiles for a counter flow system, explain why the log mean temperature difference is used to determine the heat transfer rate.

(4)

d) A test is conducted to determine the overall heat transfer coefficient in a shell-and-tube oil-to-water heat exchanger that has 24 tubes of internal diameter 1.2 cm and length 2 m in a single shell. Cold water (C_p = 4180 J/kg.°C) enters the tubes at 20°C at a rate of 5 kg/s and leaves at 55°C. Oil (C_p = 2150 J/kg.°C) flows through the shell and is cooled from 120°C to 45°C. Determine the overall heat transfer coefficient U_i of this heat exchanger based on the inner surface area of the tubes.

Formulae:

$$Q = \dot{m}C_p\Delta T$$

$$A = N\pi DL$$

$$Q = UA\Delta T_{LM}$$

(8)

TOTAL /20/

SECTION B

QUESTION 5

A group of students obtained the following results from a static calibration experiment:

Table 5.1: Increasing Temperature Data

Thermometer Temperature (K)	Resistance (Ω)	RTD temperature (K)
273.15	100	273.15
283.15	103.8	282.89
293.15	107.6	292.15
303.15	111.6	301.29
313.15	115.3	312.53
323.15	119.2	322.64
333.15	123	332.53
343.15	126.3	341.12
353.15	129.6	349.76

Table 5.2: Decreasing Temperature Data

Thermometer Temperature (K)	Resistance (Ω)	RTD Temperature (K)
353.15	131.3	354.21
343.15	126.2	340.86
333.15	122.3	330.68
323.15	118.9	321.87
313.15	115.2	312.27
303.15	113.4	307.62
293.15	107.7	292.92
283.15	103.7	282.64
273.15	100.2	273.66

a) Determine the percentage accuracy at 303.15 K for increasing temperatures (4)

b) Calculate the precision of RTD decreasing temperature measurements (7)

c) Determine the maximum hysteresis as a percentage of full-scale deflection (determine this from a table of calculations not a graph) (9)

TOTAL /20/

QUESTION 6

The water in a tank is pressurized by air, and the pressure is measured by a multi-fluid manometer as shown in Figure 6.1. The tank is located on a mountain at an altitude of 1400 m where the atmospheric pressure is 85.6 kPa. Take the densities of water, oil, and mercury to be 1000 kg/m^3, 850 kg/m^3, and 13600 kg/m^3, respectively.

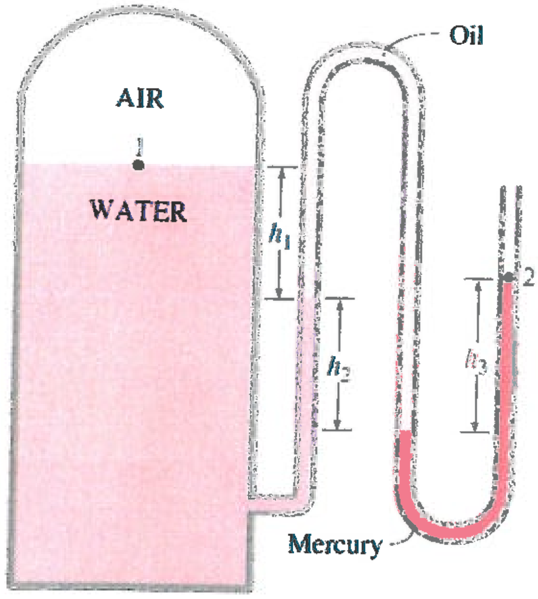

Figure 6.1: Measuring Pressure with a Multi-Fluid Manometer

a) State two assumptions necessary for calculation to be possible.

(4)

b) Determine the air pressure in the tank if $h_1 = 0.1$ m, $h_2 = 0.2$ m, and $h_3 = 0.35$ m.

(12)

c) Provide an advantage and a disadvantage of using mercury with reference to water in a manometer

(4)

TOTAL /20/

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5 × 10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 liters = 10^6 cm^3 = 10^6 ml = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 liters = 28 317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482 × 10^5 dynes
Pressure	1 atm = 1.01325 × 10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars = 1.01325 × 10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778 × 10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486 × 10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f s = 9.486 × 10^{-4} Btu/s = 1.341 × 10^{-3} hp

THE GAS CONSTANT

8.314 m^3·Pa/mol·K
0.08314 liter·bar/mol·K
0.08206 liter·atm/mol·K
62.36 liter·mm Hg/mol·K
0.7302 ft^3·atm/lb-mole·°R
10.73 ft^3·psia/lb-mole·°R

8.314 J/mol·K
1.987 cal/mol·K
1.987 Btu/lb-mole·°R

$$T(^oK) = T(^oC) + 273.15$$
$$T(^oR) = T(^oF) + 459.67$$
$$T(^oF) = 1.8\,(T^oC) + 32$$
$$T(^oR) = 1.8\,T(K)$$

$$\frac{1.8°F}{1°C}, \frac{1.8°R}{1K}, \frac{1°F}{1°R}, \frac{1°C}{1K}$$