UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	FLUID MECHANICS
COURSE CODE	:	BNJ 20203
PROGRAMME CODE	:	BNM/BNG
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) Energy equation of an ideal flow along a streamline can be represented as:

$$\frac{P}{\rho} + \frac{V^2}{2} + gz = C$$

Where C is a constant along a streamline. This equation is based on the assumption that no work or heat interaction between a fluid element and the surrounding take place. The sum of these three terms on the left-hand side of the equation represents the total mechanical energy per unit mass. Thus, based on your understanding, describe each term on the left-hand side of the equation.

(3 marks)

(b) State **TWO (2)** major assumptions used in the derivation of the Bernoulli equation.

(2 marks)

(c) A piping system has a 'Y' configuration for separating the flow. The diameter of the inlet leg is 14 cm and the diameter of the outlet legs are 10 cm and 12 cm. The velocity in the 10 cm leg is 20 m/s. The mass flow rate at the inlet is 230 kg/s. Given that the density of the water is 1000 kg/m^3, calculate the velocity out of the 8 cm pipe section.

(6 marks)

(d) A piezometer and a pitot tube are tapped into a horizontal water pipe to measure static and stagnation pressures as depicted in **Figure Q1.1**. For the water column heights, determine the velocity at the center of the pipe.

(6 marks)

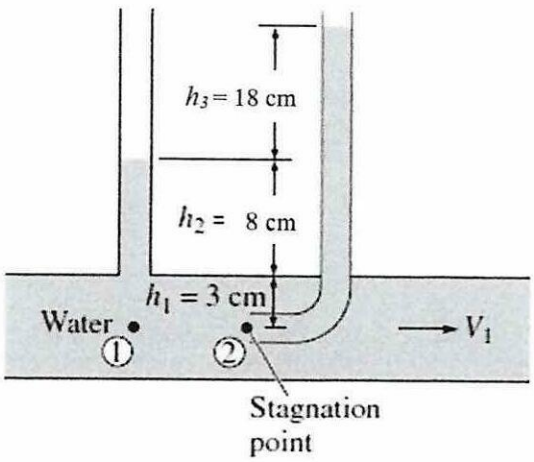

Figure Q1.1

(e) Estimate the volume flow rate (Q) that goes through a venturimeter as shown in **Figure Q1.2** if ideal conditions exist.

(8 marks)

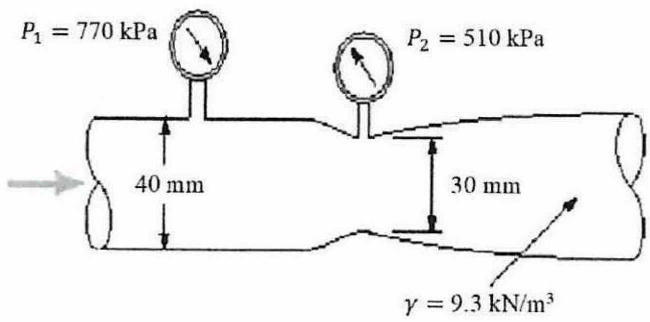

Figure Q1.2

Q2 (a) Define the conservation of momentum principle.

(2 marks)

(b) Based on the momentum principle, the total of the forces acting on an element of fluid is equal to the rate of change of momentum. Describe these forces that need to be taken into consideration.

(3 marks)

(c) A reducing right-angled bend lies in a horizontal plane as shown in **Figure Q2.1**. Water enters from the west with a velocity of 3 m/s and a pressure of 30 kPa, and it leaves toward the north. The diameter at the entrance is 500 mm and at the exit it is 400 mm. Neglecting any friction loss, resolve the magnitude and direction of the resultant force on the bend.

(12 marks)

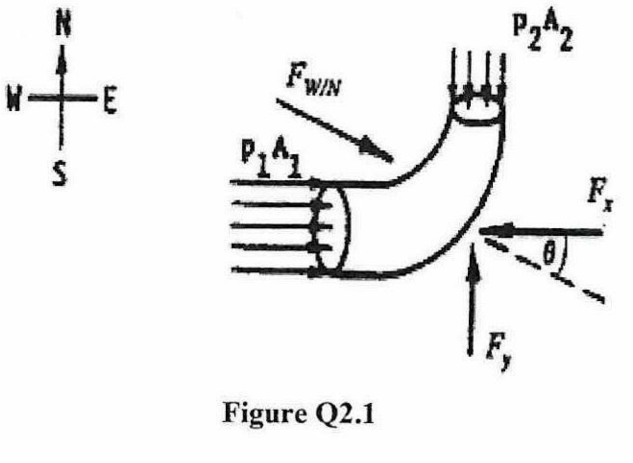

Figure Q2.1

(d) Water flows through a reducing 180° bend as shown in **Figure Q2.2**. Examine the magnitude of the force exerted on the bend in the x-direction (F_{RX}). Assume energy losses to be negligible.

(8 marks)

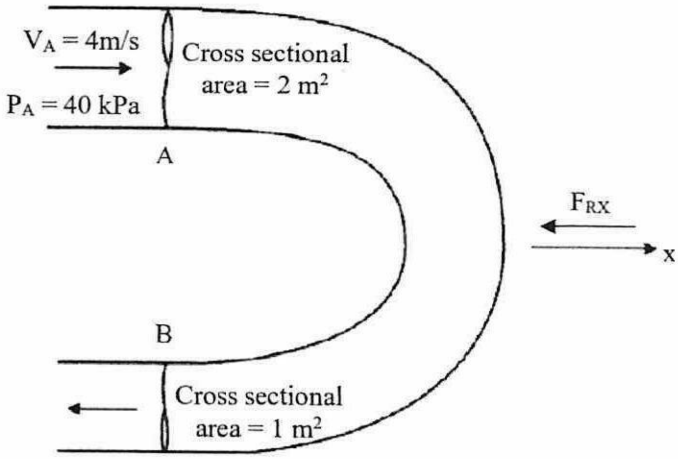

Figure Q2.2

Q3 (a) Explain the use of Reynolds number.

(2 marks)

(b) Oil flows in a pipe 40 mm bore with a Reynolds number of 550. The dynamic viscosity is 0.017 Ns/m^2 and the density of the oil is 950 kg/m^3. Based on the given information, estimate the velocity of the oil flow inside the pipe.

(2 marks)

(c) By referring to the Table of water properties and Moody diagram and as provided in **Table Q3.1** and **Figure Q3.1**, identify the friction factor if water at 40 °C is flowing at 120 m/s in an uncoated ductile steel pipe having an inside diameter of 22 mm. (Given that the roughness of the ductile steel pipe is equal to 5.6×10^{-5} m).

(6 marks)

Table Q3.1

Properties of Water (adapted from Potter and Wiggert (2001))

Temperature (°C)	Density, ρ (kg/m³)	Dynamic Viscosity, μ (Pa-s)	Kinematic Viscosity, ν (m²/s)	Surface Tension, Y (N/m)	Vapor Pressure, p_v (kPa)	Bulk Modulus, K (Pa)
0	999.9	1.792E-03	1.796E-06	0.0762	0.610	2.04E+09
5	1000.0	1.519E-03	1.519E-06	0.0754	0.872	2.06E+09
10	999.7	1.308E-03	1.308E-06	0.0748	1.13	2.11E+09
15	999.1	1.140E-03	1.141E-06	0.0741	1.60	2.14E+09
20	998.2	1.005E-03	1.007E-06	0.0736	2.34	2.20E+09
30	995.7	8.010E-04	8.040E-07	0.0718	4.24	2.23E+09
40	992.2	6.560E-04	6.610E-07	0.0701	7.38	2.27E+09
50	988.1	5.490E-04	5.560E-07	0.0682	12.3	2.30E+09
60	983.2	4.690E-04	4.770E-07	0.0668	19.9	2.28E+09
70	977.8	4.060E-03	4.150E-07	0.0650	31.2	2.25E+09
80	971.8	3.570E-04	3.670E-07	0.0630	47.3	2.21E+09
90	965.3	3.170E-04	3.280E-07	0.0612	70.1	2.16E+09
100	958.4	2.840E-04	2.960E-07	0.0594	101.3	2.07E+09

Reference: Potter, Wiggert, DC., Hondzo, M., and Shih, T.I.P. (2001) Fluid mechanics. Brooks/Cole Thomson Learning: Pacific Grove, California, USA.

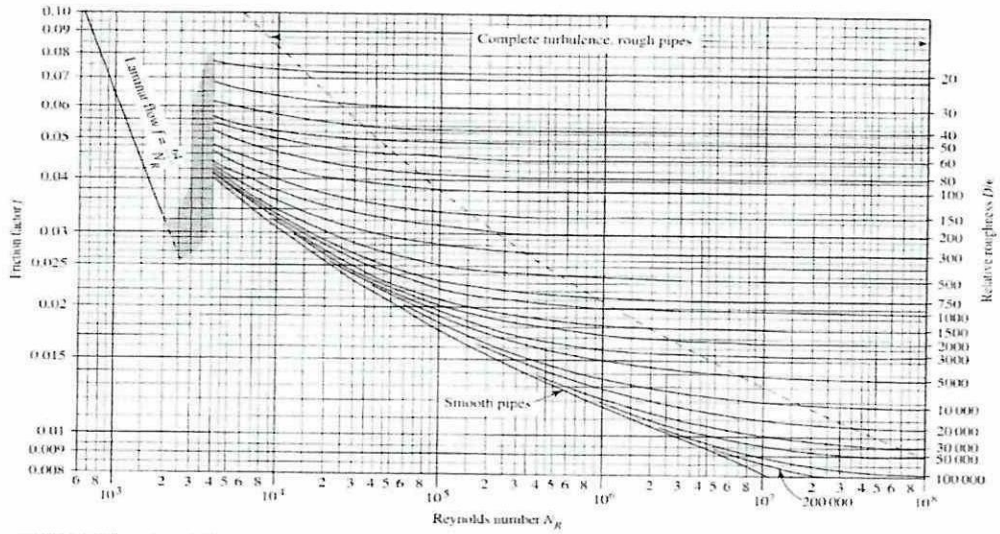

FIGURE 8.6 Moody's diagram. (Source: Pao, R. H. F. 1961. *Fluid Mechanics*. New York: John Wiley & Sons, p. 284)

Figure Q3.1

(d) Head losses are a common phenomenon in pipe systems. It can be divided into two categories and based on major losses and the minor losses. Describe **FOUR (4)** factors affecting losses in pipe systems.

(4 marks)

(e) **Figure Q3.2** shows the system using a device to pump a fluid from point A to point B. Given the volume flow rate, $Q = 0.014$ m^3/s, the fluid density, $\rho = 0.86$ kg/m^3 and the total head loss, $h_L = 1.86$ m, determine the energy added by the pump.

(5 marks)

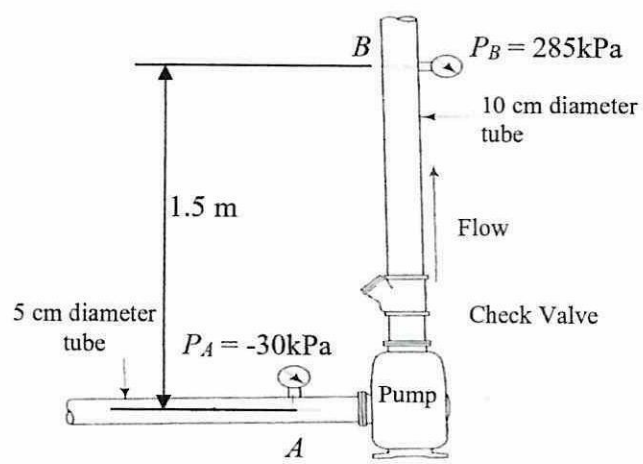

Figure Q3.2

(f) The system shown in **Figure Q3.3** contain major and minor losses due to friction, valves and pipe bends. Consider the water moving in the system is 0.002 m^3/s, estimate the total head loss in the system from position 1 to position 2.

(6 marks)

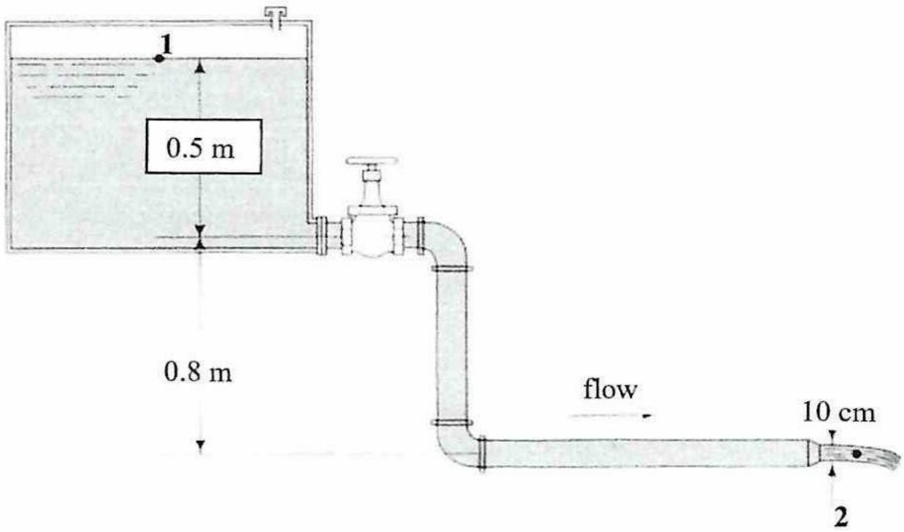

Figure Q3.3

Q4 (a) Differentiate net positive suction head (NPSH) and required net positive suction head ($NPSH_R$). Explain how these two quantities are used to ensure that cavitation does not occur in a pump.

(8 marks)

(b) By using the aid of diagram, explain the working principle of **TWO (2)** types positive-displacement pumps.

(6 marks)

(c) The performance data of a water pump follow the curve fit $H_{available} = H_0 - aV^2$, where the pump's shutoff head H_0 = 7.46 m, the coefficient a = 0.0453 m/(Lpm)^2. The pump is used to pump water from one large reservoir to another large reservoir at a higher elevation. The free surfaces of both reservoirs are exposed to atmospheric pressure. The system curve simplifies to $H_{required} = (z_2 - z_1) + bV^2$, where elevation difference $z_2 - z_1$ = 3.52 m, and coefficient b = 0.0261 m/(Lpm)^2.

(i) State **THREE (3)** assumptions and calculate the operating point of the pump ($V_{operating}$ and $H_{operating}$) in appropriate units Lpm and meters unit.

(8 marks)

(ii) If the pump is required to deliver 9 Lpm, justify **TWO (2)** parameters that need to be improved.

(3 marks)

- END OF QUESTION –

List of Formula

1. $$\gamma = \rho g$$

2. $$SG = \frac{\gamma}{\gamma_{water}}$$

3. $$2\pi R\sigma cos\theta = \rho g\pi R^2 h$$

4. $$F = PA = \rho gh.A$$

5. $$y_R = \frac{I_X}{y_c A} + y_c$$

6. $$h_R = \frac{I_X sin^2\theta}{h_c A} + h_c$$

7. $$W = F_B = \rho gV$$

8. $$\dot{m} = \rho\, A\, v = \rho Q$$

9. $$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P}{\rho g} + \frac{V_2^2}{2g} + z_2$$

10. $$\sum F = \dot{m}\,(v_2 - v_1)$$

11. $$h_L = K_L\left[\frac{V^2}{2g}\right]$$

12. $$h_L = f\frac{L}{D}\left[\frac{V^2}{2g}\right]$$

13. $$\dot{W}_{water\ horsepower} = \dot{m}gH = \rho g\dot{V}H$$

14. $$Re = \frac{\rho VD}{\mu} = \frac{VD}{v}$$