Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	FLUID MECHANICS
COURSE CODE	:	BBM 30103
PROGRAMME CODE	:	BBA/ BBD/ BBG
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **FIVE (5)** QUESTIONS OUT OF SIX 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 **SIX (6)** PAGES

Q1 Fluid mechanics plays a major part in the design and analysis of aircraft, boats, submarines, rockets, jet engines, wind turbines, biomedical devices, cooling systems for electronic components, and transportation systems for moving water, crude oil, and natural gas.

(a) Define the fluid mechanics and state three sub-disciplines under fluid mechanics' field.

(5 marks)

(b) Nutrients dissolved in water are carried to upper parts of plants by tiny tubes partly because of the capillary effect as shown in **Figure Q1(b)**. Determine how high the water solution will rise in a tree in a 0.0026 mm diameter tube because of the capillary effect. Treat the solution as water at 20°C ($\sigma_s = 0.073$ N/m) with a contact angle of 15°.

(7 marks)

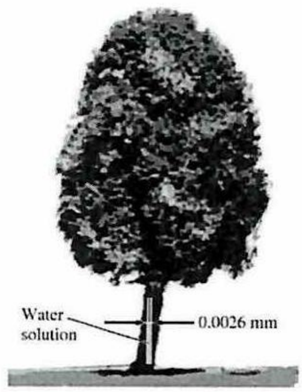

Figure Q1(b)

(c) A thin plate moves between two parallel, horizontal, stationary flat surfaces at a constant velocity of 5 m/s as shown in **Figure Q1(c)**. The two stationary surfaces are spaced 4 cm apart, and the medium between them is filled with SAE 30 oil whose kinematic viscosity is 4.2×10^{-4} m^2/s and specific gravity is 0.912. The part of the plate immersed in oil at any given time is 2 m long and 0.5 m wide. If the plate moves through the mid-plane between the surfaces, determine.

(i) The force required to maintain this motion.

(4 marks)

(ii) The force required to maintain this motion if the plate was 1 cm from the bottom surface (h_2) and 3 cm from the top surface (h_1).

(4 marks)

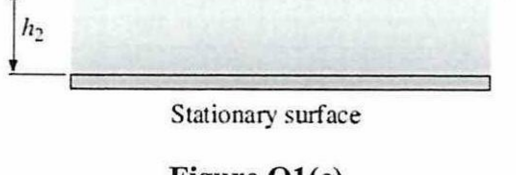

Figure Q1(c)

Q2 The pressure at a point in a fluid at rest, or in motion, is independent of direction as long as there are no shearing stresses present. This important result is known as Pascal's law, named in honor of Blaise Pascal, a French mathematician who made important contributions in the field of hydrostatics.

(a) Define pressure and list 3 different pressure units that are frequently used.

(5 marks)

(b) For the inclined-tube manometer of **Figure Q2(b)** the pressure in pipe A is 4000 Pascals. The fluid in both pipes A and B is water, and the gage fluid in the manometer has a specific gravity of 2.6. Calculate the pressure in pipe B if h_1 and h_2 is 7 cm, l_2 is 20 cm and θ is 30°.

(15 marks)

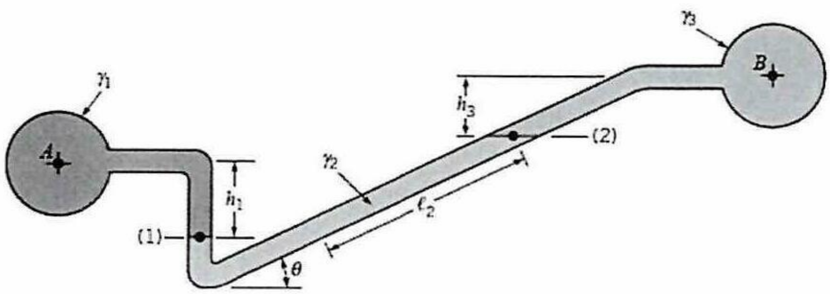

Figure Q2(b)

Q3 Archimedes' principle is a useful knowledge and significant in day-to-day life.

(a) Explain the Archimedes' principle by providing a suitable example.

(5 marks)

(b) The volume and the average density of an irregularly shaped body are to be determined by using a spring scale. The body weighs 7200 N in air and 4790 N in water. Determine the volume and the density of the body.

(7 marks)

(c) An open water tank is moved on a truck that is travelling along a horizontal road at 90 km/hr. If the truck slowly has a complete stop in 5 seconds, calculate the slope of the water surface during the period of constant deceleration?

(8 marks)

Q4 Bernoulli equation is among the famous equation used in Fluid Mechanics.

(a) Write the Bernoulli equation and list 3 limitations of the Bernoulli equation.

(7 marks)

(b) Water (assumed inviscid and incompressible) flows steadily in the vertical variable area pipe shown in **Figure Q4.**

(i) If the pressure in each of the gages reads 50 kPa, show that the flow rate can be expressed as

$$Q = A_2\sqrt{\frac{2g(z_1 - z_2)}{(1 - A_2^2/A_1^2)}}$$

(8 marks)

(ii) Determine the flowrate, Q.

(5 marks)

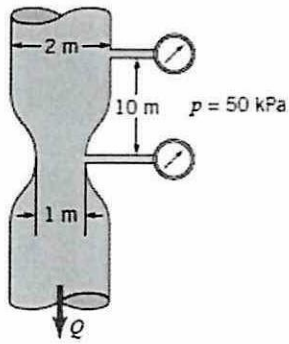

Figure Q4

Q5 Momentum equation is commonly used to calculate the forces induced by the flow such as the reaction forces acting on support systems or connectors.

(a) A 0.75 m^3 rigid tank initially contains air whose density is 1.18 kg/m^3. The tank is connected to a high-pressure supply line through a valve. The valve is opened, and air is allowed to enter the tank until the density in the tank rises to 4.95 kg/m^3. Determine the mass of air that has entered the tank.

(5 marks)

(b) Water flow steadily at a rate of 0.16 m^3/s is deflected downward by an angled elbow as shown in **Figure Q5(b)**. Determine the force acting on the flanges of the elbow when D, d, h, and volume is given by 30 cm, 10 cm, 50 cm and 0.03 m3, respectively. Assume that the weight of the elbow material, the weight of the water in the elbow and the frictional effects are neglected.

(15 marks)

Area = 0.015 m^2

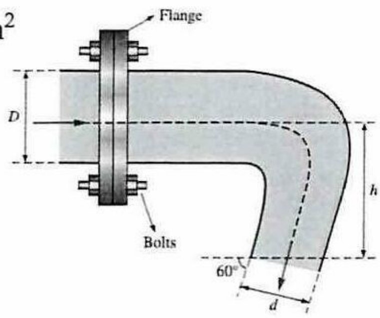

Figure Q5(b)

Q6 Dimensional analysis is useful technique to generate nondimensionless parameters that help in the design of experiments and in the reporting of experimental results. Use **Table Q6** to answer the following questions.

(a) The drag coefficient is a dimensionless representation of the frictional effect, also known as drag force, D_f experienced by an airplane wing as it moves through the air. The drag coefficient C_d is defined as

$$C_d = \frac{D_f}{\frac{1}{2}\rho V^2 A}$$

Given that the area, *A* and the velocity, *V*, verify that the drag coefficient C_d is dimensionless.

(5 marks)

Table Q6

No.	**Quantity**	**Unit**
1	Shear stress	N/m^2
2	Drag force	$kg.m/s^2$
3	Pipe Diameter	m
4	Roughness height	m
5	Viscosity	kg/m.s

(b) Consider the flow of an incompressible fluid of density ρ and viscosity μ through a long, horizontal section of a round pipe of diameter D. The velocity profile is sketched in **Figure Q6(b)**. V is the average speed across the pipe cross section, which by conservation of mass remains constant down the pipe. For a very long pipe, the flow eventually becomes hydrodynamically fully developed, which means that the velocity profile also remains uniform down the pipe. Because of frictional forces between the fluid and the pipe wall, there exists a shear stress τ_w on the inside pipe wall as sketched. The shear stress is also constant down the pipe in the fully developed region. We assume some constant average roughness height ε along the inside wall of the pipe. The only parameter that is not constant down the length of the pipe is the pressure, which must decrease (linearly) down the pipe to "push" the fluid through the pipe to overcome friction. Develop a nondimensional relationship between shear stress τ_w and the other parameters in the problem. Use ρ, V, and D as the repeating variables.

$$\tau_w = f(V, \varepsilon, \rho, \mu, D)$$

(15 marks)

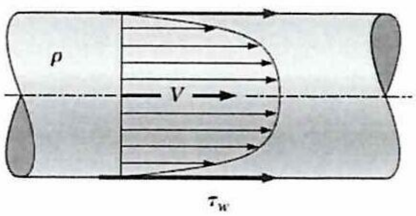

Figure Q6(b)

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