NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2018-2019

MA3006 – FLUID MECHANICS

April/May 2019 Time Allowed: $2^1/_2$ hours

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **SIX (6)** pages.
2. Answer **ALL** questions.
3. All questions carry equal marks.
4. This is a **CLOSED BOOK** examination.

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1 (a) A steady stream of water jet discharges from the nozzle with a uniform velocity of 10 m/s at angle 60^o as shown in Figure 1. The jet strikes a horizontal plate 2 m above the nozzle exit. Upon impact, part of the flow is guided towards the left while the remainder towards the right, and the plate is suspended in the air. The weight of the plate is 25 N. Assume frictionless flow along the plate and weight of water to be neglected.

(i) Write down the momentum equation for x and y direction.

(ii) Determine the diameter of the nozzle (at the exit).

(iii) Determine the mass flow rate A and B.

(12 marks)

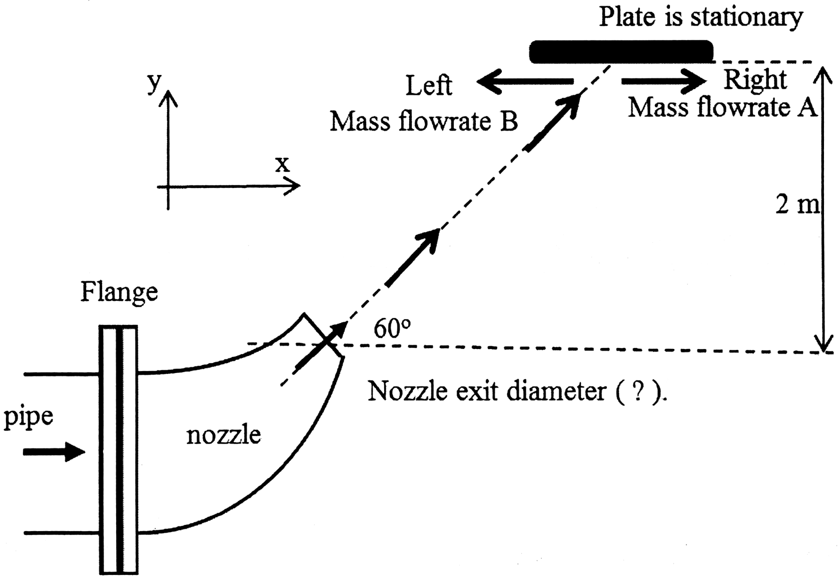

Figure 1

Note: Question 1 continues on page 2.

(b) Figure 2 shows a sprinkler system with 4 identical arms equally spaced. Water enters through the central collar and exits from the nozzles at radius 0.18 m. Each nozzle has a diameter of 0.008 m and water exits at an angle (θ) of 30 degree. The flow rate entering the sprinkler is 0.005 m^3/s

(i) develop an equation for the sprinkler torque and determine the angular speed ω when there is No resisting torque applied.

(ii) what is the torque required to reduce the angular speed to 10 radians per second.

(iii) with no resisting torque applied, show that when the nozzle exit angle (θ) is 90 degree, the sprinkler stops rotating.

(13 marks)

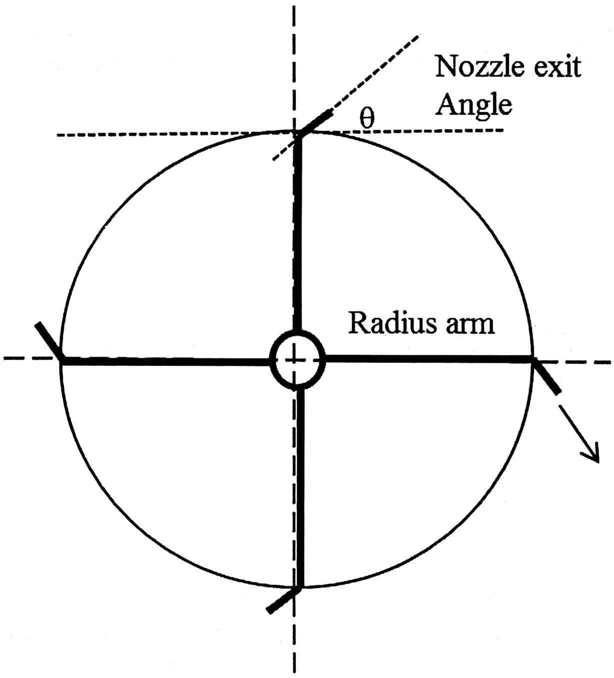

Figure 2

2 (a) An orifice plate is installed in a piping system to monitor the water flow rate. Develop a governing equation for volume flow rate as a function of pressure drop across the orifice plate and dimension of the orifice and pipe diameter.

The piping system carrying has a diameter of 80 mm with an orifice plate of diameter 48 mm is selected for monitoring volume flow rate. If the operating mass flow rate is 10 kg/s, determine the pressure difference across the orifice plate.

Dynamic viscosity of water, $\mu = 1.002 \times 10^{-3}$ Ns/m^2
Density of water, $\rho = 1000$ kg/m^3
Figure 3 shows the coefficient of discharge for an orifice plate.

(13 marks)

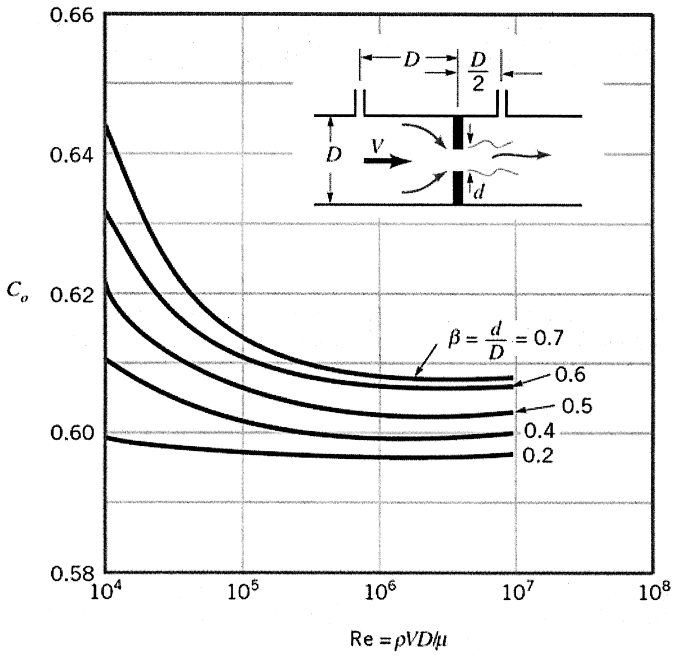

Figure 3

(b) A viscosity meter comprises of a rotating cylinder immersed in the testing fluid. The power W required to rotate the cylinder depends on diameter of the cylinder d, its length l, rotating speed ω, the fluid velocity V, the fluid density ρ and fluid dynamic viscosity μ.

Determine suitable dimensionless parameters relating to power W by using ρ, d, and ω as repeating variables.

(12 marks)

3 (a) A student conducted an experiment where a liquid of density 1200 kg/m^3 and dynamic viscosity 0.1 Ns/m^2 is passed through a horizontal pipe of diameter 0.1 m as shown in Figure 4. Given that the flow is laminar and the centerline velocity is 1 m/s, determine the length L if the manometer height is 0.2 m. The density of the manometer fluid is 1600 kg/m^3. Comment on the results obtained. If the flow is inviscid and the volume flow rate remains constant, do you expect the length L and the manometer height h to be different? Explain your answers. (You are not required to compute L and h).

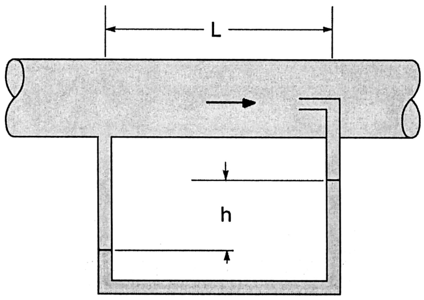

Figure 4

(12 marks)

(b) Water is pumped from reservoir A into reservoir B as shown in Figure 5 through smooth pipes 1 and 2. The elevations of the free surface of reservoirs A and B are equal and the pump characteristic is given as:

$$H_p = K - 2000Q^2 \quad \text{where } K \text{ is a constant}$$

If the volume flow rate into reservoir B is 0.02π m^3/s, determine the total frictional head loss and the constant K. You may make use of the following information:

Description	Diameter (m)	Length (m)	Friction factor	ΣK_L
Pipe 1	0.2	50	f	2
Pipe 2	0.2	400	f	5

For laminar flow, $f = 64/\text{Re}$

For turbulent flow in smooth pipe $f = 0.316/(\text{Re})^{0.25}$

The density of water is 1000 kg/m^3 and its dynamic viscosity is 0.001 Ns/m^2.

Sketch the EGL, taking into consideration of all frictional and minor losses. Indicate the location along the pipeline where cavitation is likely to occur and explain your answers.

If the pump is removed and the flow is inviscid, sketch the EGL for flow from A to B. Comment on your results.

Note: Figure 5 appears on page 5.

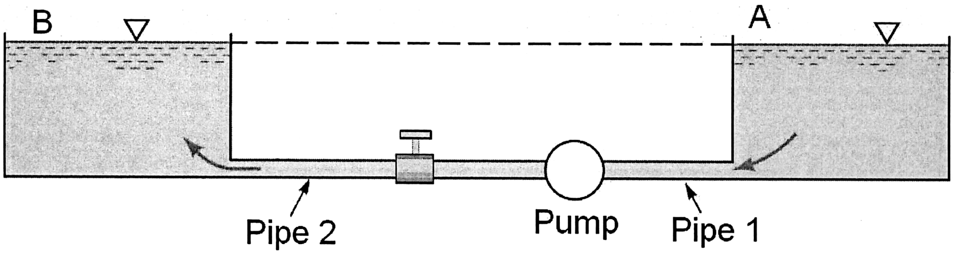

Figure 5

(13 marks)

4 (a) Water is pumped from reservoir A to reservoir B through a pipe of diameter D and length L. The diameter of the pump impeller is 0.5 m. The pump characteristic is given as:

$$H_p = 100 - 625Q^2$$

and its efficiency (in percent) is given as:

$$\eta = 600Q - 3750Q^3$$

Given that the system demand is $E = 60 + 500Q^2$

(i) Determine the difference in elevation between the free surfaces of reservoirs A and B.

(ii) If the rotational speed of the pump impeller is 2000 rpm, use Figure 6 to select the correct type of pump.

(iii) Determine the pump input power.

(iv) If 2 pumps are connected in parallel, determine the pump head, volume flow rate and the input power of each pump.

The pump specific speed N_s is given as $$N_s = \frac{\omega\sqrt{Q}}{(gh_p)^{3/4}}$$

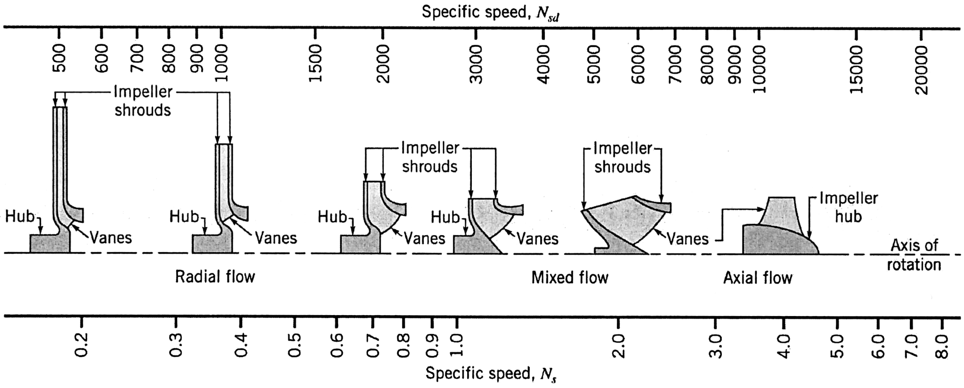

Figure 6

(13 marks)

Note: Question 4 continues on page 6.

(b) Water is drawn from a pond A to a tank B as shown in Figure 7. The volume flow rate is 0.1 m^3/s. The diameter of the suction pipe is 0.2 m and the head loss in the suction pipe is 2 m. Given that the NPSH required at this flow rate is 5 m, determine the minimum allowable pressure at the pump inlet and the maximum height of the pump above the free surface of the pond to avoid cavitation. The atmospheric pressure is 100kPa and the vapour pressure is 2340 Pa.

An identical pump with the same pipe network is to be installed at an altitude Z m above the sea level. The entire pipe network arrangement is the same as shown in Figure 7. The volume flow rate, head loss in the suction pipe and the NPSH required are assumed to remain constant. It is noticed that the maximum possible height of the pump above the free surface of the pond is reduced to 1.6 m. Determine the altitude Z where this pump network is installed. The atmospheric pressure at an altitude Z m is P_{atm} and the vapour pressure is 2340 Pa.

The density of water is 1000 kg/m^3. *NPSH* available is defined as

$$NPSH_A = \frac{P_s - p_v}{\rho g} + \frac{V_s^2}{2g}$$

The atmospheric pressure at an altitude Z m above the sea level is given by the expression below:

$$P_{atm} = 100\left[1 - \left(\frac{0.0065}{288}\right)Z\right]^{5.2586} \quad \text{kPa}$$

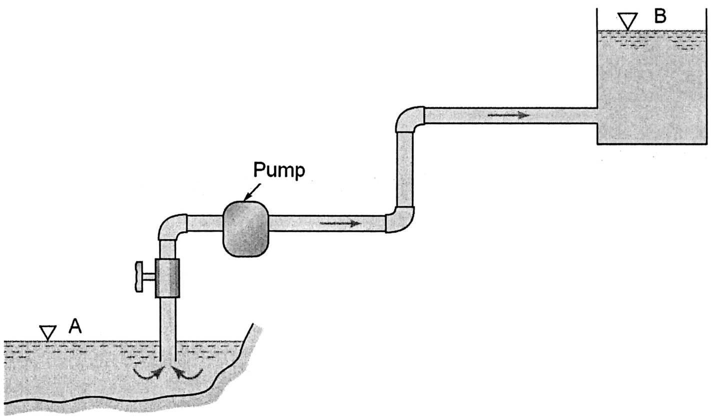

Figure 7

(12 marks)

END OF PAPER

MA3006 FLUID MECHANICS

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.