NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2021-2022

MA3006 – FLUID MECHANICS

November/December 2021 Time Allowed: $2^1/_2$ hours

INSTRUCTIONS

1. This paper contains **SECTION A & SECTION B** and comprises **SIX (6)** pages.
2. **COMPULSORY** to answer **ALL** questions in both sections.
3. All questions carry equal marks.
4. This is a **CLOSED BOOK** examination.

SECTION A

1. A bend-nozzle is secured to an inclined pipe as shown in Figure 1. Water enters the bend-nozzle at 0.5 kg/s. The inlet diameter and exit diameter of the nozzle are 8 mm and 6 mm respectively. Angle θ of the nozzle is 60 degree and the water jet leaves the nozzle horizontally and strike a vertical plate. Assume frictionless flow and negligible height difference between inlet and exit of nozzle, determine :

(a) the resultant force and direction to secure the nozzle at the flange. (10 marks)

(b) the force to hold the plate stationary (5 marks)

(c) the power required to move the plate towards the jet at 3 m/s (5 marks)

(d) If the plate is inclined at $\alpha = 60°$, find the force and direction to hold the plate stationary (5 marks)

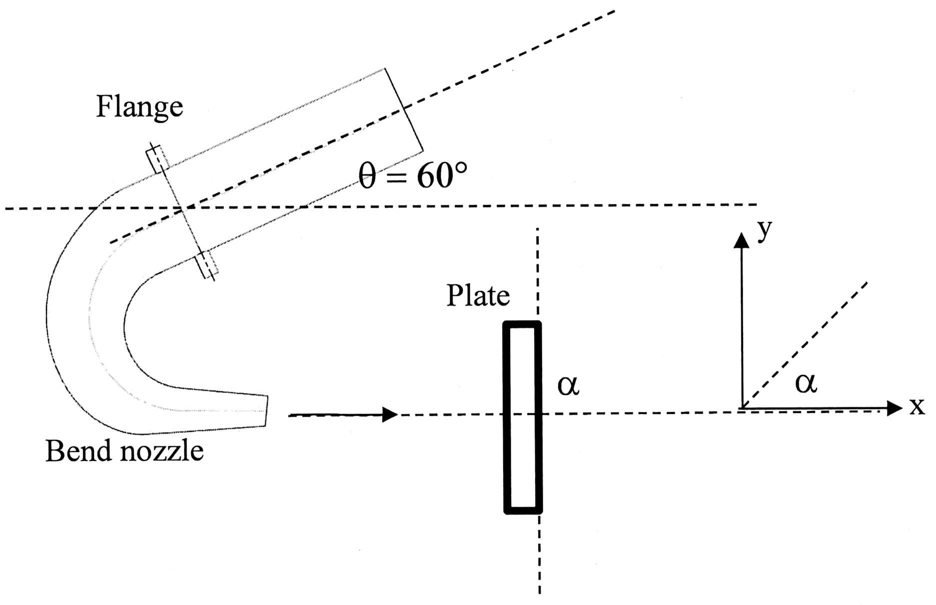

Figure 1

2 (a) Water is to be pumped out from an underground catchment tank by a pump via a parallel piping system as in Figure 2. At section 1, 2 and 3 in the piping system, the following information are given:

	Section-1	Section-2	Section-3
diameter *mm*	150	60	80
Pressure *kPa*	50	500	300
Velocity *m/s*	3	4	
Elevation *m*	-3	3	0.5

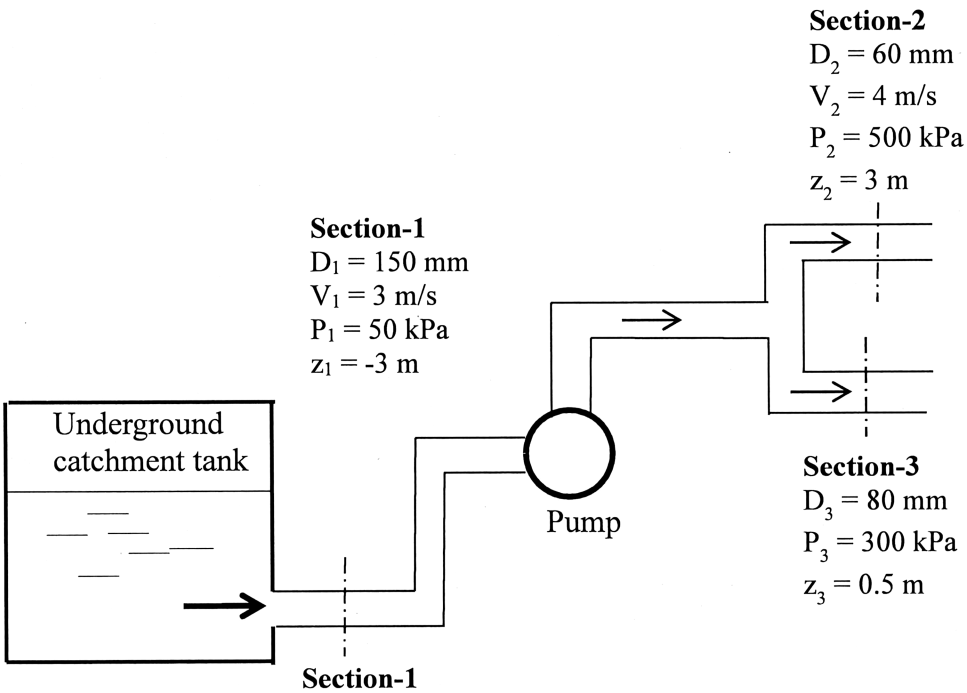

Figure 2

The power loss due to pipe friction and minor losses between section-1 to section-2 and section-3 is 600 W. The efficiency of the pump is 70%.
Determine the pump input power required.

(12 marks)

Note: Question 2 continues on page 3.

(b) The pressure rise across a pump is a function of the fluid density ρ, the fluid dynamic viscosity μ, the impeller diameter D, the rotational speed ω and the volume flow rate Q.

(i) Using dimensional analysis, derive dimensionless groups for the pump. Use ρ, ω, and D as repeating variables

(6 marks)

(ii) A pump with an impeller diameter of 400 mm delivers water at a flow rate of 0.25 m^3/s and its power input is 6 kW. The pressure rise across the pump is 3.5 $\times 10^5$ Pa. A geometrical similar model pump with an impeller diameter of 200 mm is used to deliver water. Determine the flow rate and the pressure rise across the model pump.
Note: Dynamic similarity between the prototype and model pump is to be maintained.

(4 marks)

(iii) Derive the dimensionless group for power coefficient of a pump.

(3 marks)

SECTION B

3 (a) A liquid of density 1200 kg/m^3 and dynamic viscosity 0.04 Ns/m^2 flows through a horizontal pipe of diameter 0.05 m and length 10 m as shown in Figure 3. The density of the manometer fluid is 400 kg/m^3.

(i) Given that the average flow velocity is 1.2 m/s, determine the Reynolds number, the pressure drop across the pipe and the manometer height h.

(ii) If the flow is inviscid and the average flow velocity is 1.2 m/s, determine the manometer height h.

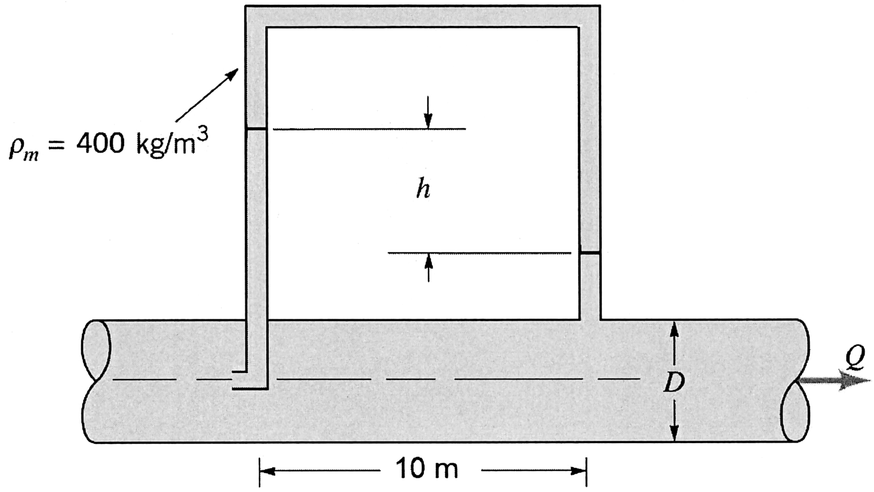

Figure 3

(15 marks)

(b) Water flows from reservoir A to another reservoir B through pipes 1, 2 and 3 as shown in Figure 4. The elevations of the free surface of reservoirs A and B are 40 m and 0 m respectively. It is noted that the total losses of each pipe can be represented by kQ^2 where k is the overall loss coefficient and Q is the flow rate in that pipe. The values of k of each pipe are given below:

Description	k
Pipe 1	400
Pipe 2	k_2
Pipe 3	100

Given that the flow rate in pipe 3 is twice that in pipe 2, determine the value of k_2 and the flow rate through each pipe. The density of water is 1000 kg/m^3 and the dynamic viscosity of water is 0.001 N.s/ m^2.

Note: Figure 4 appears on page 5.

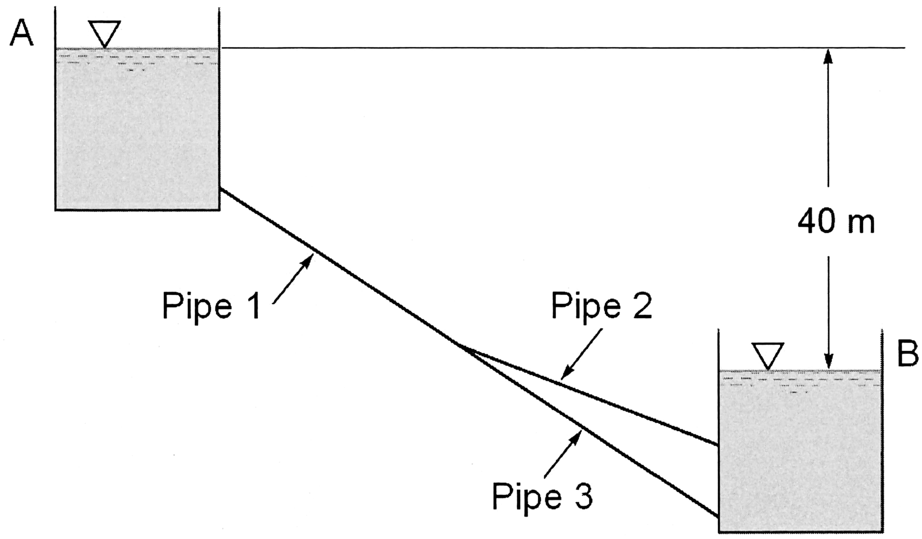

Figure 4

(10 marks)

4 (a) Figure 5 shows water is pumped from a reservoir A to the top of a building C through pipes 1 and 2. The elevations of the free surface of reservoir A, points B and C are 0 m, 2 m and 100 m respectively. The pump to be used in this arrangement has a pump characteristics of:

$$Hp = 100 - 800\,Q^2$$

You are asked to advise if 2 identical pumps in parallel or 2 identical pumps in series be used so that water can be delivered from A to C. Determine the system demand curve, the flow rate delivered and the head delivered by one single pump. You may make use of the following information:

Description	Diameter (m)	Length (m)	Friction factor	ΣK_L
Pipe 1	0.2	10	0.02	1
Pipe 2	0.2	110	0.02	9

Note: Question 4 continues on page 6.
Figure 5 appears on page 6.

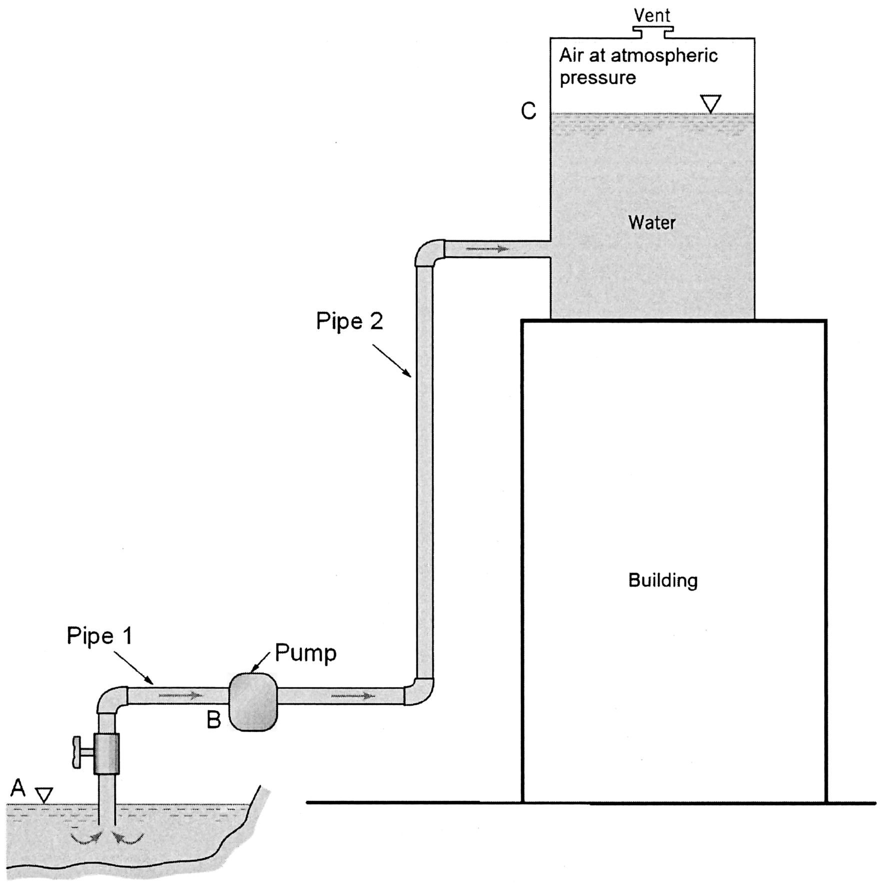

Figure 5

(15 marks)

(b) The $NPSH_R$ of the pump in part (a) is given by:

$$NPSH_R = A + 50Q^2$$

Where A is a constant.

Given that the system is operating at the flow rate obtained in part (a), determine the NPSH available of the 2 pumps used in the system. You may assume that the 2 pumps are placed close to each other. If both pumps are not operating under cavitating condition, what is the maximum value of A?

The density of water is 1000 kg/m^3. The atmospheric pressure is 100 kPa and the vapour pressure of water is 2340 Pa and NPSH available is defined as:

$$\text{NPSH}_A = \frac{\text{P}_s - \text{p}_v}{\rho g} + \frac{V_s^2}{2g}$$

(10 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.