NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2022-2023

MA3006 – FLUID MECHANICS

November/December 2022 Time Allowed: $2^1/_2$ hours

INSTRUCTIONS

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

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1. A horizontal water jet strikes a plate with mass flow rate m_1 and velocity V_1 as shown in Figure 1. Upon striking the plate, the jet is split into two streams, mass flow rate m_2 flowing upwards and m_3 flowing downwards, with velocity V_2 and V_3 respectively. The exit diameter of the jet nozzle is 30 mm and its corresponding velocity is 8 m/s

(a) When θ is 90°, what is the force required to hold the plate stationary? (5 marks)

(b) When θ is 90° and the plate is moving horizontally towards the jet at 3 m/s, what is the power required?

(7 marks)

(c) Derive an expression for m_2 and m_3 in terms of m_1 and angle θ. (10 marks)

(d) Determine mass flow rate m_2 and m_3 when θ is 60°. (3 marks)

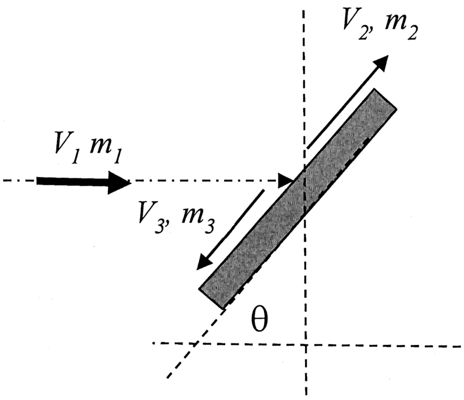

Figure 1

2 (a) The pressure rise across a centrifugal pump depends on the rotational speed ω, impeller diameter D, volume flow rate Q, the density ρ of the fluid and the dynamic viscosity μ of the fluid. Using dimensional analysis, establish suitable dimensionless group for a centrifugal pump. You may take ρ ω and D as repeating variables.

Hence, combine the head and flow coefficient to derive
(i) power coefficient
(ii) a dimensionless parameter that is independent of the impeller diameter.

(13 marks)

(b) Figure 2 shows water from Lake A and Lake B merge to feed a hydraulic turbine downstream. At point-1 below Lake A, water flows along a 1.0 m diameter pipe at 6 m^3/s and the gauge pressure p_1 is 50 kPa taken at an elevation 45 m. The total head loss along pipe-1 is 8 m.

At point-2 below Lake B, water enters a 0.8 m diameter pipe at 3 m^3/s and the gauge pressure p_2 is 90 kPa measured at an elevation 95 m. The total head loss along pipe-2 is 5 m.

The total head loss along pipe-3 is 4 m and the diameter of this section is 1.2 m, Water exits the turbine via a 1.5 m diameter pipe and a pressure of –30 kPa (negative) is recorded at an elevation 5 m. Turbine efficiency is 90%.

Determine
(i) Energy loss in pipe-1, pipe-2 and pipe-3
(ii) Power developed by the turbine for useful work
(iii) Overall efficiency of power generation

(12 marks)

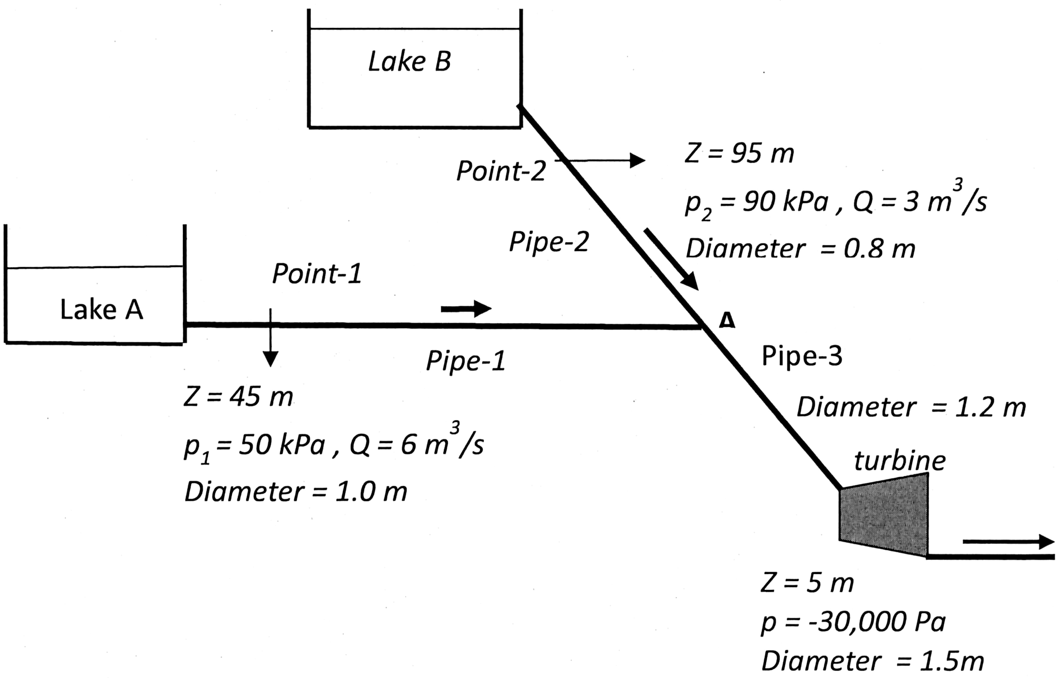

Figure 2

3 (a) Two students, A and B, conducted the same experiment to determine the friction factor and pressure drop of a liquid flowing upward in a smooth vertical pipe of diameter 25 mm and length 10 m at a Reynolds number of 2000. The density of the liquid is 800 kg/m^3 and its dynamic viscosity is 0.008 N.s/m^2. Student A considered the flow to be laminar while student B assumed that the flow to be turbulent. Determine the friction factor and pressure drop obtained by the two students and discuss your results.

You may make use of the following information:

Laminar flow : $f = 64/Re$

Turbulent flow in smooth pipe : $f = 0.316/Re^{0.25}$

(8 marks)

(b) Water flows from a pressurised closed tank A to an open reservoir C as shown in Figure 3. The elevations of the free surface of A and C are 20 m and 40 m respectively.

(i) Determine the air pressure (gauge) in the closed tank A if the flow velocity in the pipes is 2.5 m/s.

(ii) Sketch the EGL and HGL from A to C, taking into considerations of all minor losses (entry, valve and exit losses). What is the implication if the HGL line intersects the pipeline?

(iii) After several months of operation, corrosion resulted in a small hole at point B. To avoid air from entering the hole at B, what is the maximum height of the point B? You may assume that the flow velocity in the pipes is 2.5 m/s. You may ignore the minor losses at the point B.

(iv) The hole at point B is sealed. Given that the height of B is that obtained in part (iii) and the fluid velocity is 2.5 m/s, will cavitation occur at point B?

You may make use of the following information.

Description	Diameter (m)	Length (m)	Friction factor
Pipe 1	0.1	20	0.02
Pipe 2	0.1	80	0.02
Pipe 3	0.1	50	0.02

Entry loss coefficient = 0.5, valve loss coefficient = 7.5, Exit loss coefficient =1.0. The density of water is 1000 kg/m^3 and the dynamic viscosity of water is 0.001 N.s/ m^2. The atmospheric pressure is 100 kPa and the vapour pressure of water is 2340 Pa.

(17 marks)

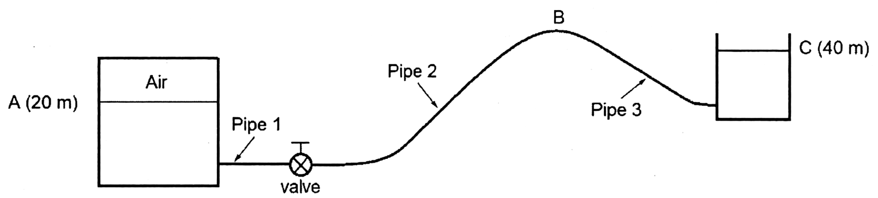

Figure 3

4 (a) A prototype pump of diameter D_p is designed to operate on planet X where the gravitational acceleration is 4 m/s^2. The pump delivers a liquid of density 800 kg/m^3 and dynamic viscosity of 0.04 N.s/ m^2 at a volume flow rate of 1 m^3/s. The input shaft power is limited to 200 kW and its maximum rotational speed is 100 rad/s. The pump efficiency is 80 percent. A geometrically similar model pump of diameter D_m/ D_p ratio of 0.5 is tested on earth where the gravitational acceleration is 10 m/s^2. The liquid tested in the model has a density of 1000 kg/m^3 and dynamic viscosity of 0.01 N.s/m^2 .

Assuming complete dynamic similarity between the model and the prototype,

(i) Determine the prototype pump head.

(ii) What is the rotational speed of the model pump?

(iii) What is the flow rate and pump head in the model pump?

(iv) What is the model input shaft power?

$$C_Q = \frac{Q}{\omega D^3}, \qquad C_H = \frac{g\,h_p}{\omega^2 D^2} \quad \text{and} \quad C_P = \frac{\dot{W}_{shaft}}{\rho \omega^3 D^5}$$

(15 marks)

(b) A pump delivers water from an open tank A to an open reservoir B via a pipeline of diameter 0.2 m and length 500 m. The system demand curve is given as : E=16 + 150Q^2

And the pump characteristics is given as: H_p= 80-106Q^2

(i) What is the difference in elevation between the free surface of tank A and that of reservoir B?

(ii) Determine the operating flow rate and the pump head.

(iii) On a particular day, a valve in the pipeline is partially closed such that the flow rate is now 0.2 m^3/s, determine the expression for the new system demand curve assuming that the same pump is being used.

(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.