NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2018-2019

MA3006 – FLUID MECHANICS

November/December 2018 | Time Allowed: $2^1/_2$ hours

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **SIX (6)** pages including **ONE (1)** page of Moody Diagram.

2. Answer **ALL** questions.

3. All questions carry equal marks.

4. This is a **CLOSED BOOK** examination. Graph paper will be provided separately to be attached to the answer sheet.

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1. Figure 1 shows two water jets from two nozzles impacting on a vertical plate from both directions. The exit diameters of nozzles 1 and 2 are 0.01 m and 0.012 m respectively. The water velocities at nozzles 1 and 2 are 15 m/s and 12 m/s respectively and the water jets are discharged into the atmosphere. The vertical plate has a top slanting edge inclined at 30° to the horizontal as shown in Figure 1. Upon impact on the plate, the water splits equally along the plate for both water jets, i.e., half of the water flows upwards whilst the other half flows downwards on each side of the plate. The density of water is 1000 kg/m^3. The flow can be assumed to be frictionless in the atmosphere and along the plate and changes in height can be neglected.

   (a) Determine the magnitude and direction of the horizontal force F required to hold the plate stationary and the mass of the plate that can be sustained by the water jets.
   (10 marks)

   (b) If the plate moves horizontally to the right at a velocity of 2 m/s as indicated in Figure 1, determine the magnitude and direction of the horizontal force F that is applied and the mass of the plate that the water jets can now sustain.
   (10 marks)

   (c) If no horizontal force is applied, determine the mass flow rate of water at nozzle 2 so that the plate is stationary. State any assumption.
   (5 marks)

Note: Figure 1 appears on page 2.

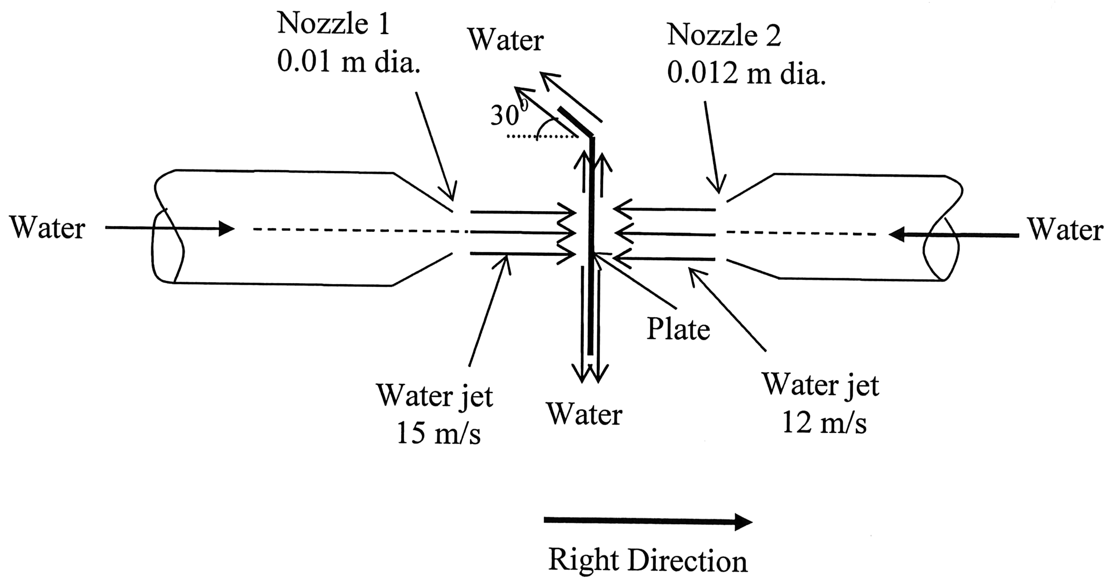


Figure 1

2 (a) The power P required to drive a ship propeller depends on the ship speed V, the propeller diameter D, the propeller rotational speed ω, the dynamic viscosity of seawater μ and the density of seawater ρ.

(i) Using dimensional analysis with suitable repeating variables, derive the standard dimensionless groups and write down their functional relationship.

(9 marks)

(ii) A 1:2 scale model of a ship propeller is tested in a flowing water channel. The torque of the model propeller is measured and found to be 6 kNm. If the rotational speed of the prototype propeller is 300 revolutions per minute and using suitable dimensionless groups derived in part 2(a)(i) above, determine the rotational speed of the model propeller to achieve dynamic similarity between the prototype and model propellers. Determine also the power to drive the prototype propeller. You can assume the physical properties of seawater and water to be the same.

(6 marks)

(b) Water enters through the base of a lawn sprinkler which has two rotating arms. The area of each nozzle is 50×10^{-6} m^2. Water then exits equally through each nozzle which is inclined horizontally at an angle of 60° to the tangential direction as shown in the plan view of the sprinkler in Figure 2. The radius from the axis of rotation to the centreline of each nozzle is 0.6 m. The density of water is 1000 kg/m^3.

(i) The sprinkler rotates freely at a constant speed of 150 revolutions per minute when no resisting torque is applied to the arms. Determine the volume flow rate of water.

(4 marks)

(ii) Determine the resisting torque that is applied to the arms if the sprinkler is rotating at a constant speed of 100 revolutions per minute. The water flow rate remains the same as in part 2(b)(i) above.

(6 marks)

Note: Figure 2 appears on page 3.

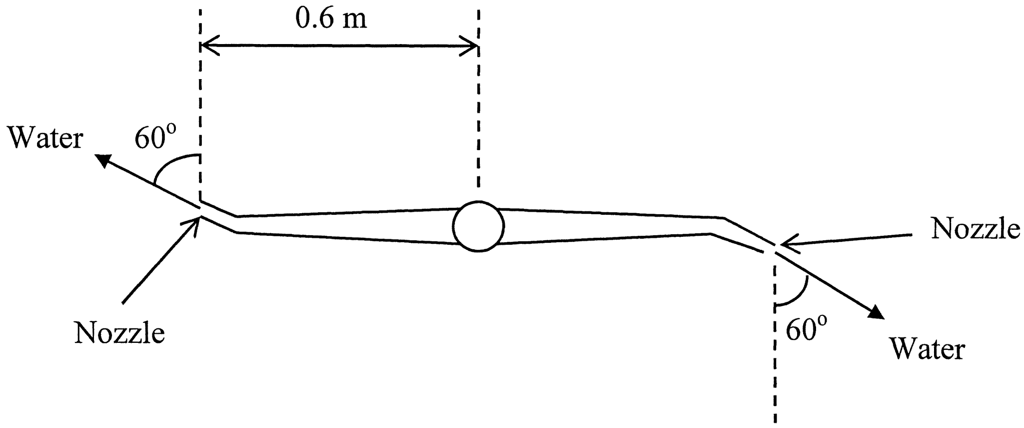


Figure 2

3 (a) Water flows through a 12 cm diameter horizontal pipe. The internal surface of the pipe is smooth. If the maximum flow rate in the pipe is maintained at 0.06 m^3/s.

(i) What is the maximum pressure drop over a distance of 8 m?

(ii) If flow in the pipe is reduced to laminar flow, what is the maximum pressure drop per metre length?

All minor losses may be neglected.
For laminar flow, friction factor, f = 64/Re.
For turbulent flow, friction factor, $f = 0.316/Re^{0.25}$
where Re = Reynolds Number.
Density of water = 1000 kg/m^3.
Dynamic viscosity of water = 0.001 Ns/m^2.

(10 marks)

(b) Figure 3 shows pressurized water flows through a horizontal piping system, comprising of a 100 mm diameter pipe, followed by a 50 mm diameter pipe connected by a reducer in series to feed a pump 15 m downstream. The velocity in the 50 mm diameter pipe is 3.5 m/s. Upstream pressure at point 1 is 50 kPa. Assuming that flow is wholly turbulent in both pipes, determine

(i) the distance l_2 where pressure in the pipe at point 2 is zero.

(ii) the pressure at the pump suction.

(iii) Sketch the energy grade line and hydraulic grade line from point 1 to the pump suction, and, indicate clearly the change in velocity head before and after the contraction section, as well as location where pressure in the pipe is zero.

Moody Chart is provided on page 6.

(15 marks)

Note: Figure 3 appears on page 4.

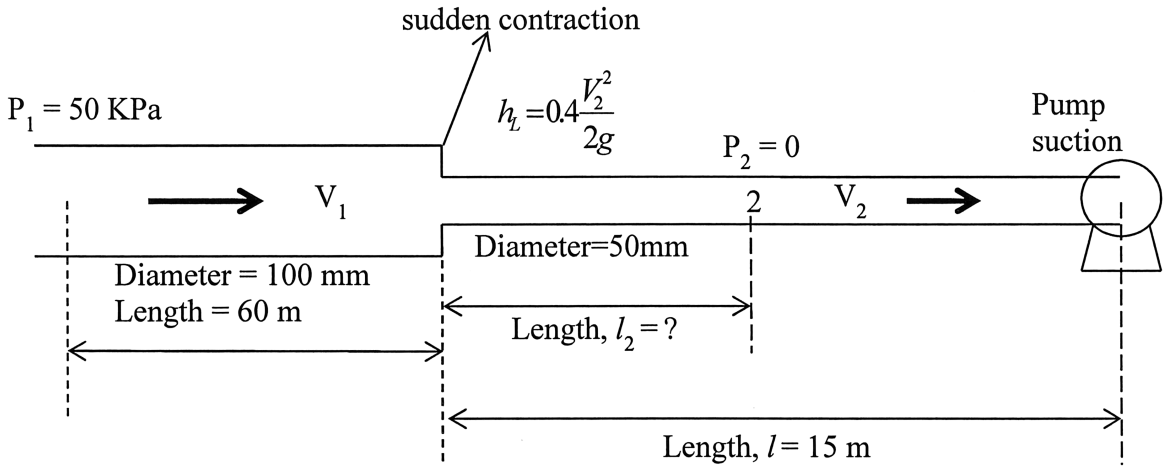


Figure 3

4. Water is pumped from a lake to a storage tank as shown in Figure 4. The highest level of the lake is 2 m below the pump centre line. The characteristic of the centrifugal pump is given in Graph A

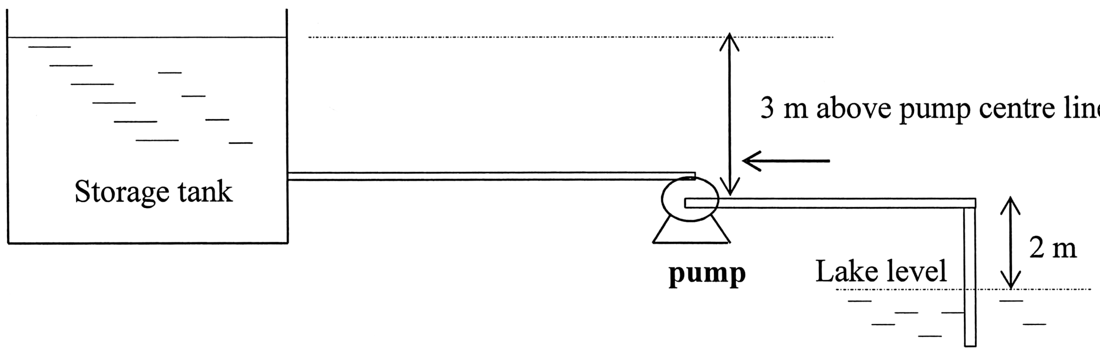


Figure 4

The overall length of the suction piping system is 15m while the discharge piping system is 45m. Both pipes have the same diameter of 0.15 m and the same frictional factor of 0.01. The overall minor loss for the suction pipe is $K_{suction}$ = 1.0 and for the discharge pipe is $K_{discharge}$ = 1.5.

(a) Determine the power required by the pump. (8 marks)

(b) What is the lowest level of the lake allowable so that cavitation can be avoided? (5 marks)

(c) If a second identical pump is added to the system in Parallel, determine the total Q and H. What is the power requirement for one pump operating? (6 marks)

Note: Question 4 continues on page 5.

(d) If a second identical pump is added to the system in Series, determine the total Q and H. What is the power requirement for one pump operating?

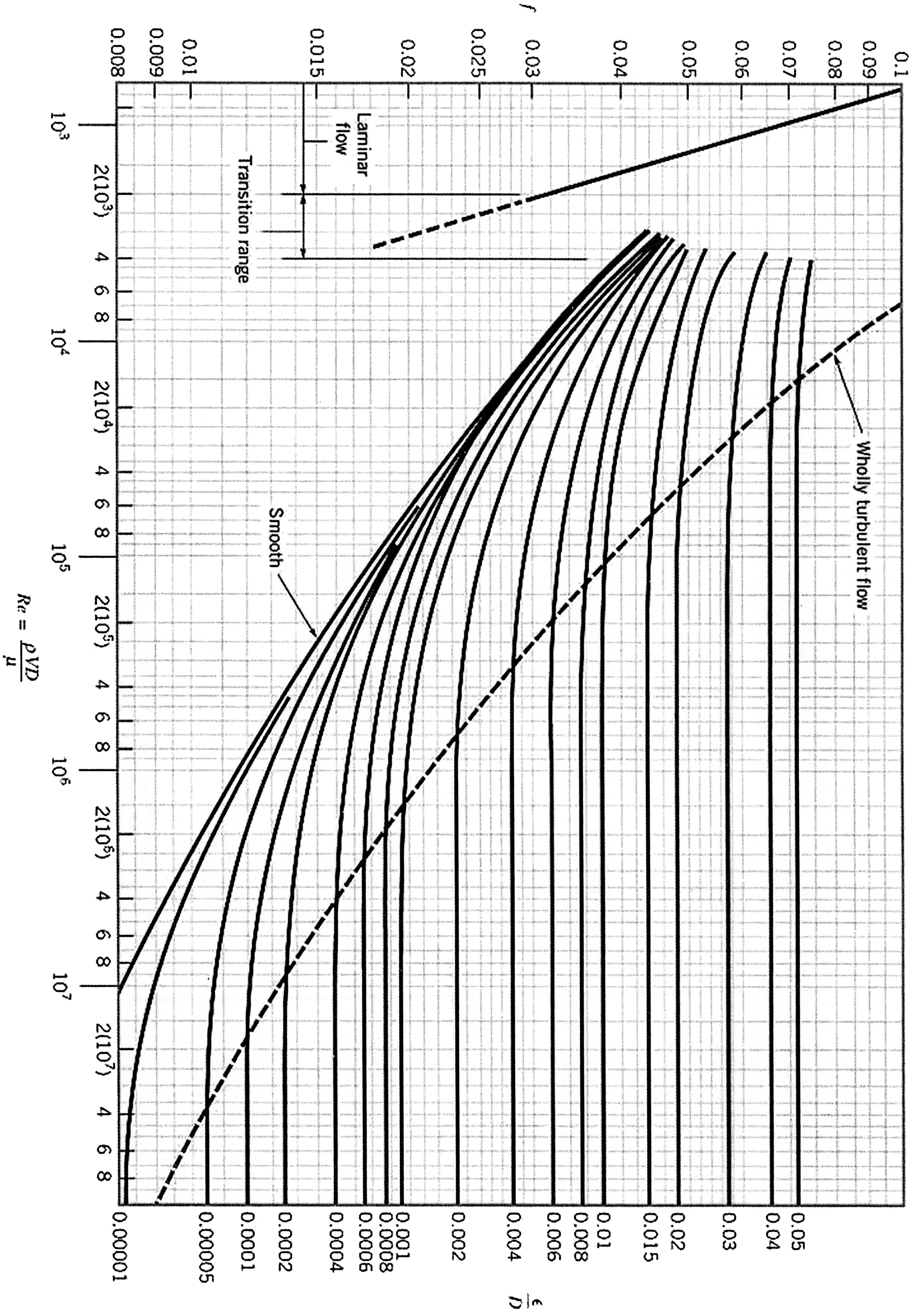
Density of water = 1000 kg/m^3
Water vapour pressure = 3 kPa
Atmospheric pressure = 1.0 bar

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

where P_s is pressure at pump suction
p_v is vapour pressure of fluid
V_s is velocity at pump suction

Note: Submit Graph A together with answer script.

(6 marks)


f
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
Laminar flow
Transition range
Wholly turbulent flow
Smooth
$Re = \frac{\rho V D}{\mu}$
10^3 2(10^3) 4 6 8 10^4 2(10^4) 4 6 8 10^5 2(10^5) 4 6 8 10^6 2(10^6) 4 6 8 10^7 2(10^7) 4 6 8
$\frac{\varepsilon}{D}$
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.00001

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.