NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2020-2021

MA3006 – FLUID MECHANICS

April/May 2021 Time Allowed: $2^{1}/_{2}$ hours

INSTRUCTIONS

1. This paper contains **SECTION A & SECTION B** and comprises **FIVE (5)** pages.
2. **COMPULSORY** to answer **ALL** questions in both sections.
3. All questions carry equal marks.
4. This is a **CLOSED-BOOK** examination.
5. Graph paper will be provided separately to be attached to the answer booklet.

SECTION A

1. Water in a horizontal pipe is discharged into the atmosphere through a nozzle flowmeter which is attached at the end of the pipe. The horizontal water jet then strikes a V-shaped vane as shown in Figure 1. The diameters of the horizontal pipe and nozzle exit are 0.03 m and 0.015 m, respectively. The static pressure upstream of the nozzle at point X is 65 kPa gauge pressure. The water flow rate at the nozzle exit is 0.002 m^3/s. The water jet, upon impact on the vane, splits equally along the vane, i.e., half of the water flows upwards whilst the other half flows downwards on each slanting side of the vane. The top slanting side is at 45° to the horizontal whilst the bottom slanting side is at 60° to the horizontal. The density of water is 1000 kg/m^3. The flow can be assumed to be frictionless in the atmosphere and along the vane sides. Changes in flow height along the vane can be neglected.

(a) Determine the discharge coefficient of the nozzle.

(7 marks)

(b) Determine the external horizontal force F required to hold the vane stationary and the mass of the vane that can be supported by the water jet. State any assumption.

(8 marks)

(c) If the vane moves at a constant velocity of 5 m/s to the left as indicated in Figure 1, determine the new external horizontal force F required and the new mass of the vane that can be supported by the water jet.

(10 marks)

Note: Figure 1 appears on page 2.

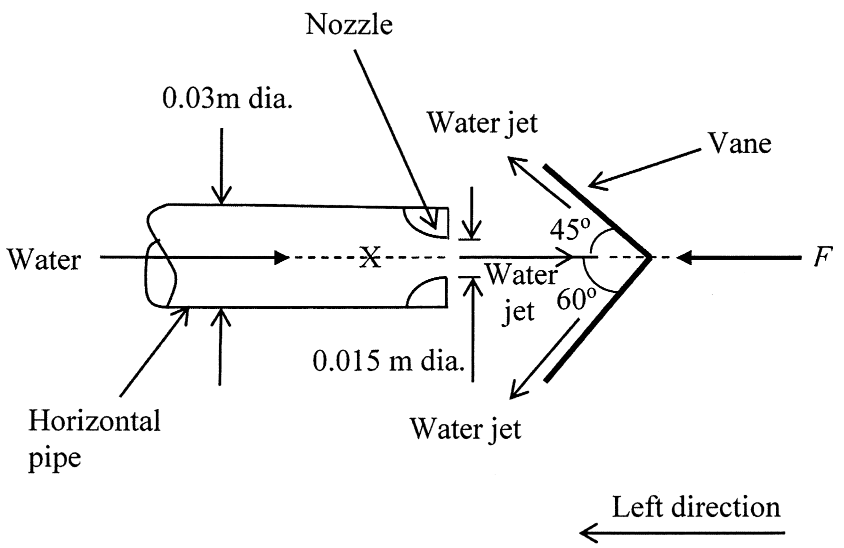


Figure 1

2 (a) The power P required to drive a fan depends on the fluid density ρ, the fluid dynamic viscosity μ, the volume flow rate Q, the impeller diameter D and the angular speed ω.

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

(10 marks)

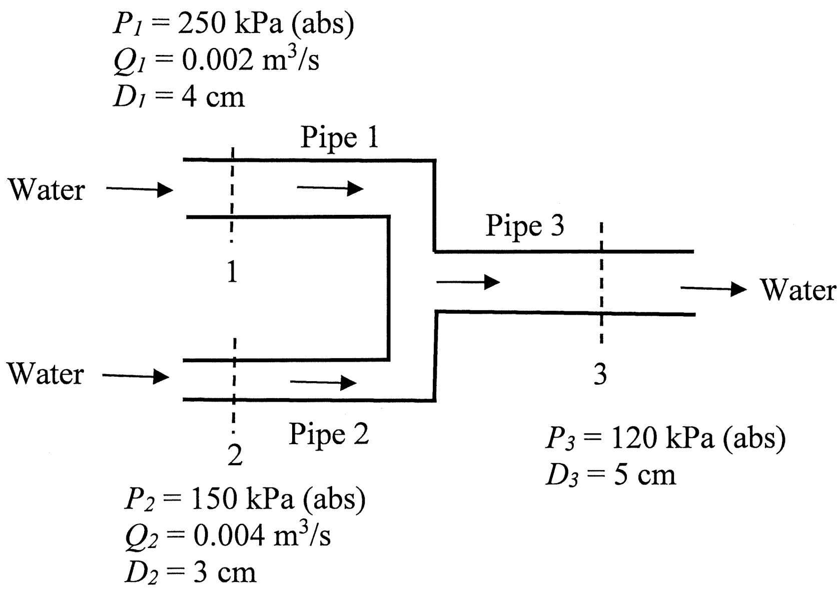
(ii) A prototype fan with an impeller diameter of 300 mm delivers air at a volume flow rate of 0.5 m^3/s and its rotational speed is 2,500 rpm. The torque to drive the fan is 12 Nm. If a geometrically similar model fan with an impeller diameter of 200 mm is used, determine the volume flow rate of air and torque of the model fan when it is operating at a rotational speed of 1,500 rpm. Dynamic similarity between the prototype fan and the model fan must be maintained.

(7 marks)

(b) Water flows in a branched pipe network consisting of two inlets and one outlet which are all at the same height, as shown in Figure 2. The pipe diameters and absolute pressures at sections 1, 2 and 3 are given as follows: $D_1 = 4$ cm, $P_1 = 250$ kPa (abs.), $D_2 = 3$ cm, $P_2 = 150$ kPa (abs.), $D_3 = 5$ cm, and $P_3 = 120$ kPa (abs.). The water flow rates in pipe 1 and pipe 2 are 0.002 m^3/s and 0.004 m^3/s, respectively. The frictional head losses in pipes 1 and 3 are $h_1 = 1.5\frac{V_1^2}{2g}$ and $h_3 = 3.0\frac{V_3^2}{2g}$ respectively, where V_1 and V_3 are the flow velocities in pipes 1 and 3, respectively. The density of water is 1000 kg/m^3. Determine the frictional head loss in pipe 2.

(8 marks)

Note: Figure 2 appears on page 3.



P_1 = 250 kPa (abs)
Q_1 = 0.002 m^3/s
D_1 = 4 cm
Pipe 1
Water
Water
1
Pipe 3
Water
3
Water
Pipe 2
2
P_3 = 120 kPa (abs)
D_3 = 5 cm
P_2 = 150 kPa (abs)
Q_2 = 0.004 m^3/s
D_2 = 3 cm

Figure 2

SECTION B

3 (a) Water is discharged from a tank to the atmosphere through a conical diffuser as shown in Figure 3. The diameters of the diffuser at the entrance and exit are 30 mm and 60 mm respectively.

The discharge flow rate is to be maintained constant at 0.003 m^3/s, determine

(i) The pressure head at the entrance to the conical diffuser

(ii) The elevation, H required.

(iii) Sketch the EGL and HGL of the system and indicate clearly entrance loss, diffuser loss and pressure head at the entrance to diffuser

The entrance and exit loss coefficients are 0.5 and 1.0 respectively. Losses in the diffuser is 0.88 $V^2/2g$ where V is the velocity entering the diffuser.
Losses in the short connection between diffuser and tank are to be neglected.

(15 marks)

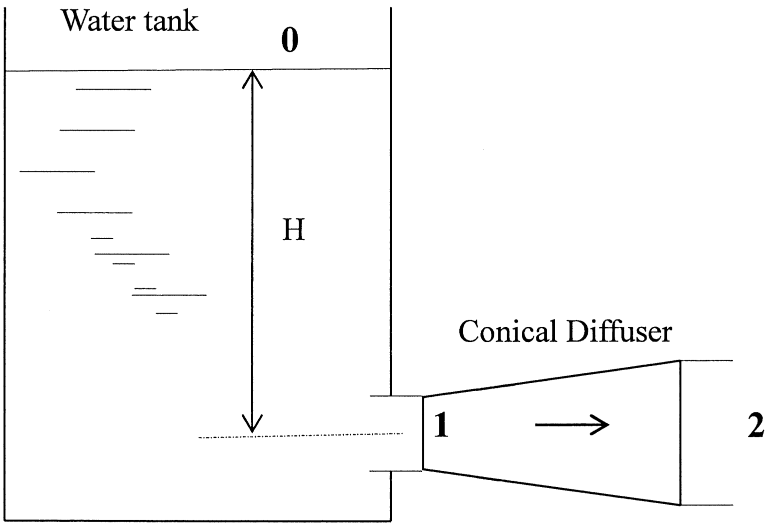


Figure 3

(b) Water flows down a vertical pipe and exits to the open atmosphere. The diameter of the pipe is 80 mm. If the flow in the pipe is to remain laminar, determine the limiting pressure and its corresponding flow rate at a location 8 m above the pipe exit. The density and dynamic viscosity of water is 1000 kg/m^3 and 1.307×10^{-3} Ns/m^2 respectively.

There is puncture in the pipe (about 1.5 mm diameter) located at 2 m above the pipe exit. Determine the water leakage at this point (if any).

(10 marks)

4. A centrifugal pump delivers fresh water from a well to a storage tank as shown in Figure 4. At the start of the operation, the suction level of the well is 1 m below the pump centre line. The pump and system characteristics are given in the Graph.

(a) What is the shut-off head of the pump?

(b) From the given system characteristics, what should be the level H (m)?

(c) What is the operating point and determine the power of the pump?

(12 marks)

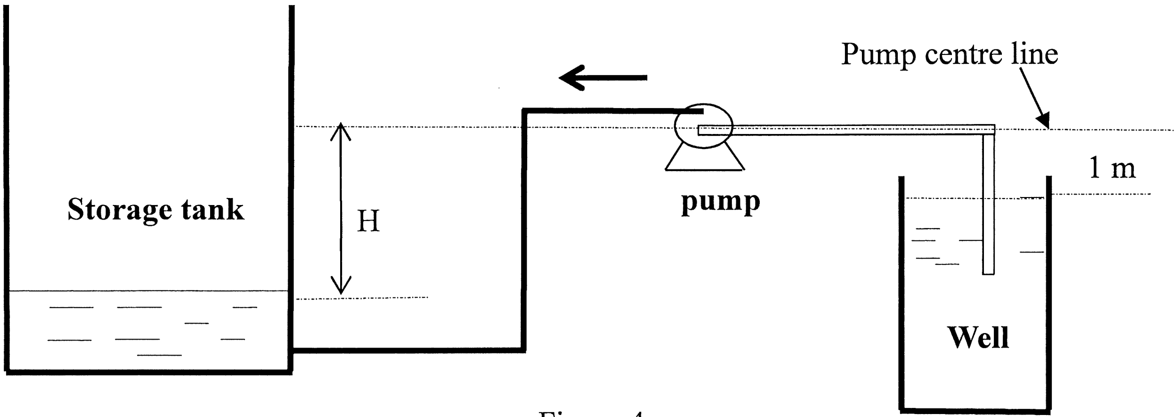


Figure 4

After operating the pump for sometime, the water level in the well drops to 2.0 m below the pump suction line. If the level in the tank has risen to 1 m above the pump centre line,

(d) Will the pump continue to operate and why?

(e) If an identical pump is added to the system, determine the combined pump head and flow rate.

(f) What is the power required by **one** of the two pumps.

(g) Will cavitation occur when the two pumps are operating?

Head loss in suction pipe, (up to pump suction) is 7 m.

(13 marks)

Density of water = 1000 kg/m^3
Water vapour pressure = 2.7 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 paper together with answer script.

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.