NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2017-2018

MA3006 – FLUID MECHANICS

April/May 2018 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) Two steady streams of water jet strike a vertical plate as shown in Figure 1. The water jets exit the nozzles at 15 m/s. The diameter of each nozzle is 8 mm. Upon impact on the plate, 60% of the combined mass flow rate is directed downwards, the remaining upwards. Consider frictionless flow and effects of height of the nozzles are negligible.

(i) Determine the resultant force F to hold the plate stationary, when Nozzle 1 and Nozzle 2 are both operating.

(ii) Only Nozzle 1 is operating and upon impact, the water jet divides equally in the upwards and downwards direction. If the plate moves horizontally at a speed of 0.5 m/s (in the same direction as the water jet), determine the force F acting on the plate.

(15 marks)

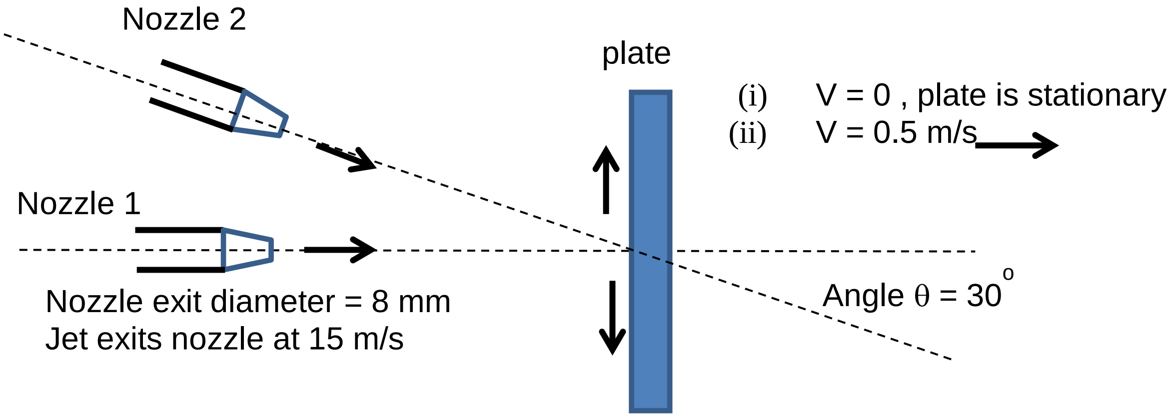

Figure 1

Note: Question 1 continues on page 2.

(b) Figure 2 shows water flows in a tapered pipe. The pressure difference between section 1 and section 2 is indicated in terms of pressure head, h mm. If the volume flow rate is 0.0048 m^3/s, determine:

(i) the height, h for frictionless flow

(ii) the power loss between section 1 and 2 if the actual height measured is: h = 0.175 m.

(10 marks)

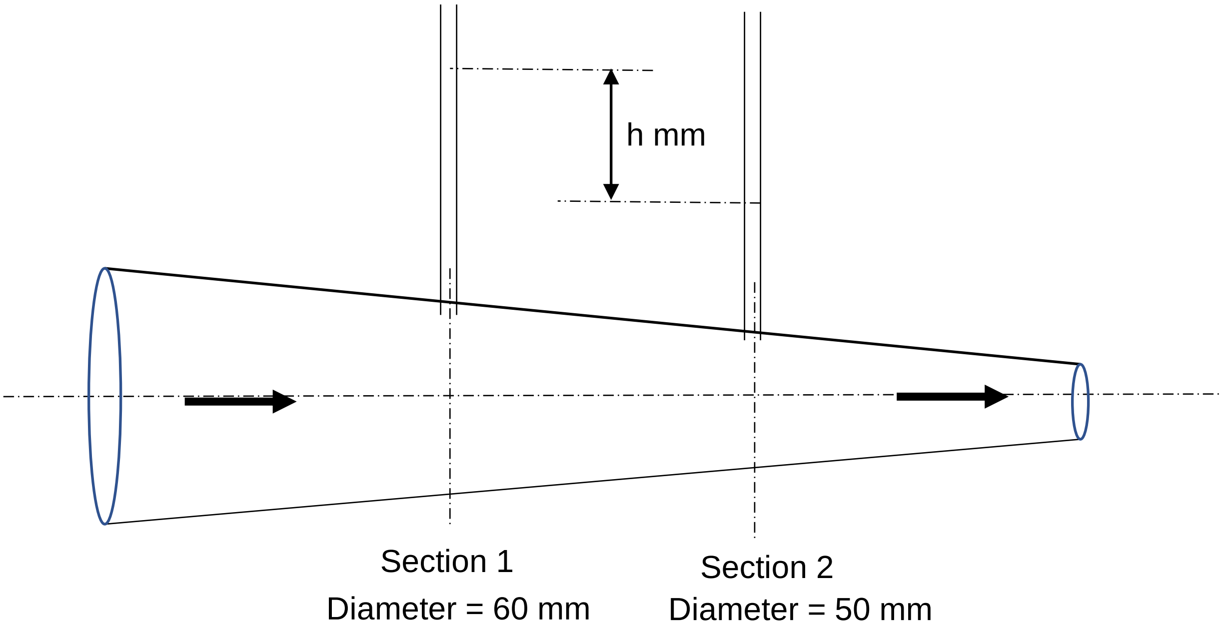

Figure 2

2 (a) A nozzle of diameter d is installed in a pipe of diameter D to monitor volume flow rate. Show that the pressure drop across the nozzle can be expressed as:

$$(p_1 - p_2) = \frac{(Q_{ideal})^2}{(A_2)^2} \frac{\rho\left(1-\beta^4\right)}{2}$$

where
p_1 = upstream pressure
p_2 = pressure at nozzle
Q_{ideal} = ideal volume flow rate
A_2 = area at nozzle
ρ = density of fluid
$\beta = \dfrac{d}{D}$

A nozzle is installed in a piping system to monitor the water flow rate. The diameter of the pipe is 60 mm and the nozzle diameter is 42 mm. During operation, the maximum mass flow rate is 12 kg/s. Find the range of pressure difference required for this monitoring device.

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 a nozzle plate.

(12 marks)

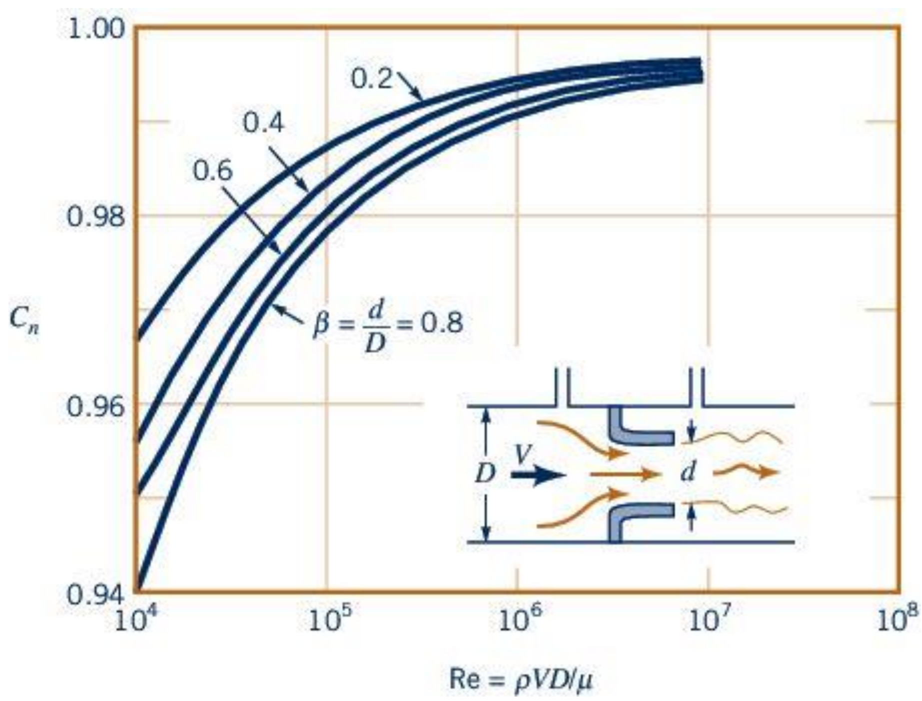

Figure 3

Note: Question 2 continues on page 4.

(b) The drag force F_d acting on a sonar scanner for deep sea application depends on the speed V, diameter of scanner D, surface roughness of the scanner e, density ρ and dynamic viscosity μ of the fluid.

Using ρ, V and D as repeating variables, determine suitable dimensionless groups.

(6 marks)

(c) A deep sea sonar scanner is designed to travel at a constant speed of 1.5 m/s. A 1:5 scale down model is fabricated for evaluation in a wind tunnel.

(i) What should be the air speed in the tunnel for testing?

(ii) If the drag force measured on the model scanner is 68 N, what is the power required by the prototype scanner to overcome drag force.

Sea water : density = 1020 kg/m^3 and dynamic viscosity = 1.12 x 10^{-3} Ns/m^2

Air (wind tunnel) : density = 7.5 kg/m^3 and dynamic viscosity = 19.5 x 10^{-6} Ns/m^2

(7 marks)

3 (a) A Pitot tube is placed in a horizontal pipe of radius R to measure the flow velocity of a fluid of density ρ and dynamic viscosity μ. If the velocity profile of turbulent flow in a horizontal pipe of radius R is given as:

$$\frac{\bar{u}}{V_c} = \left(1 - \frac{r}{R}\right)^{1/n}$$

Where $\bar{u}$ is the velocity at radius r, V_c is the centerline velocity and n is a constant, determine the radial location of the Pitot tube where the velocity measured is the average flow velocity. The value of n is 7 and the volume flow rate, Q, can be expressed as:

$$Q = 2\pi R^2 V_c \frac{n^2}{(n+1)(2n+1)}$$

Determine the shear stress at the pipe centerline and at the pipe wall. Comment on the results obtained.

(10 marks)

(b) Water flows from reservoir A into reservoir B as shown in Figure 4 via pipes 1 and 2. The difference in elevations of the free surface of reservoirs A and B is H m. To increase the volume flow rate from A to B, a pipe is connected from D to F as shown. Determine the percentage increase in flow rate. You may make use of the following information:

Description	Diameter (m)	Length (m)	Friction factor	ΣK_L
Pipe 1	d	L	f	0
Pipe 2	d	L	f	0
Pipe 3	d	L	f	0

Sketch and compare the energy grade line (EGL) from reservoir A to reservoir B for both cases, taking into account the effects of frictional loss, entry loss and exit loss. You may ignore the minor loss at the junction D.

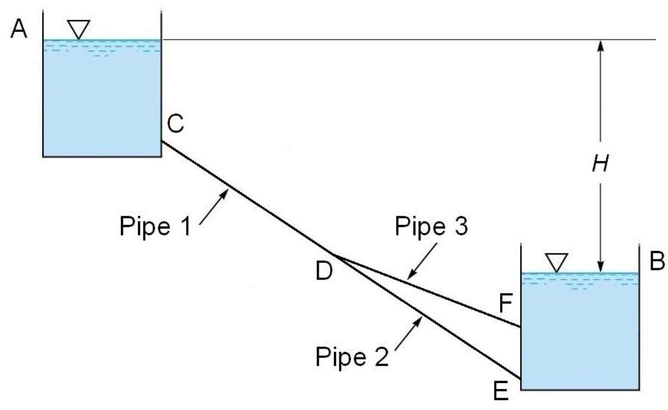

Figure 4

(15 marks)

4 (a) The efficiency of a pump is given as:

$$\eta = AQ - BQ^3$$

Where A and B are constants. If the pump maximum efficiency is 80 percent when the flow rate is 0.08 m^3/s, determine the values of A and B.

The sales engineer recommends this pump to 2 installations having the following system characteristics:

$E_1 = 20 + 2700Q^2$ and $E_2 = 20 + 10000Q^2$

He claims that the pump will be operating at an efficiency that is higher than 70 percent for both installations. Given that the pump characteristics is:
$Hp = 50 - 2000Q^2$, determine if the engineer's claim is true.

(10 marks)

(b) The pump in part (a) is used to draw water from a pond to irrigate a farm through 100 identical sprinklers connected in parallel, as shown in Figure 5. If the flow velocity in each sprinkler is 2.5 m/s, using the pump characteristics and efficiency given in part (a), determine the length of each sprinkler L and the pump input power.

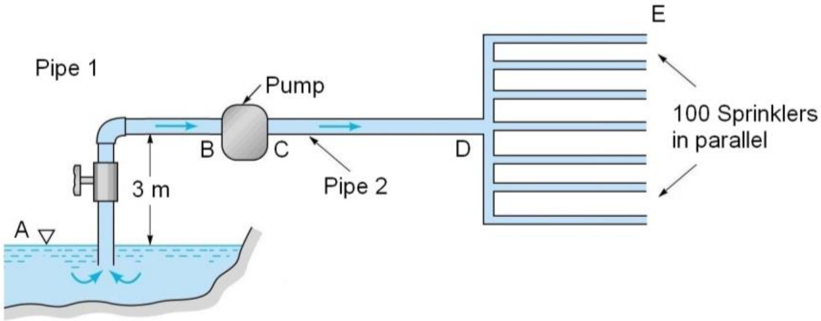

Figure 5

You may make use of the following information.

Description	Diameter (m)	Length (m)	Friction factor	ΣK_L
Pipe 1	0.25	20	0.02	5
Pipe 2	0.25	20	0.02	2
Sprinkler	0.02	L	0.025	2

The $NPSH$ required is given by: $NPSH_R = 2 + KQ^2$

Where K is a constant. If the pump is to avoid cavitation, what is the maximum value of K? To increase the velocity in the sprinkler, the operating speed of the pump is increased, do you think that cavitation will occur? Explain your answer.

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

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

(15 marks)

END OF PAPER