NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2017-2018

MA3006 – FLUID MECHANICS

November/December 2017 Time Allowed: $2^1/_2$ hours

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **SIX (6)** pages.
2. Answer **ALL FOUR (4)** Questions.
3. All questions carry equal marks.
4. This is a **CLOSED BOOK** examination.

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1 (a) A water jet from a nozzle strikes a semi-hemispherical vane of a cart which is mounted on wheels as shown in Figure 1. The water leaves the 4 cm diameter nozzle exit at a velocity of 12 m/s. The water is diverted through 180^0 upon leaving the vane. The mass of the cart and the vane is 200kg.

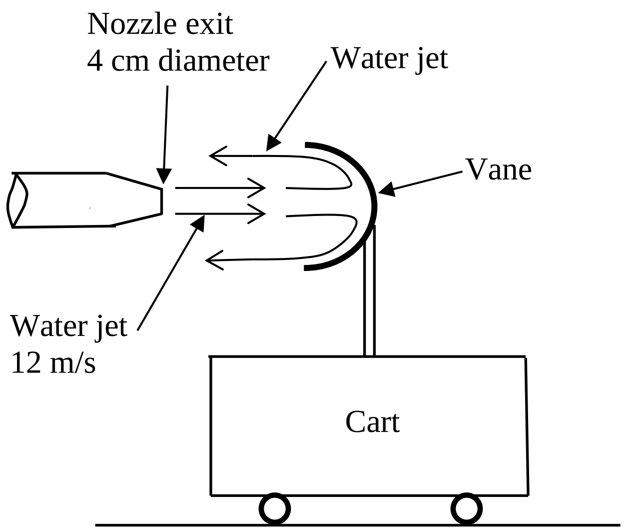

Figure 1

(i) Determine the applied force to prevent the cart from moving.

(ii) If the restraining force is removed, determine the time taken for the cart to move from rest to a velocity of 3 m/s.

The density of water is 1000 kg/m^3. Assume the flow is frictionless throughout and the weight of water in the vane to be negligible. Neglect any frictional forces between the wheels and the ground. Changes in height in the flow can also be neglected.

(13 marks)

Note: Question 1 continues on page 2.

(b) Water from two dams flows into a turbine through two pipes which are then merged into a common pipe, just before entering the turbine as shown in Figure 2. The water leaving the turbine flows through a pipe which has an orifice plate installed at the pipe exit. At the 0.5 m diameter orifice exit, the water is discharged into the atmosphere. The discharge coefficient of the orifice is 0.62. At section 1, the water flows at 8 m/s through a 0.4 m diameter pipe at 300 kPa (absolute pressure) while at section 2, the water pressure in the 0.3 m diameter pipe is 400 kPa (absolute pressure). At section 3 which is just upstream of the orifice plate, the water pressure in the 0.8 m diameter pipe is 200 kPa (absolute pressure). The total power loss for flows between sections 1 and 2 to section 3 is 50 kW. Sections 1, 2 and 3 are at the same height. The atmospheric pressure is 100 kPa (absolute pressure) and the density of water is 1000 kg/m^3. Determine the turbine power output if the turbine efficiency is 80%.

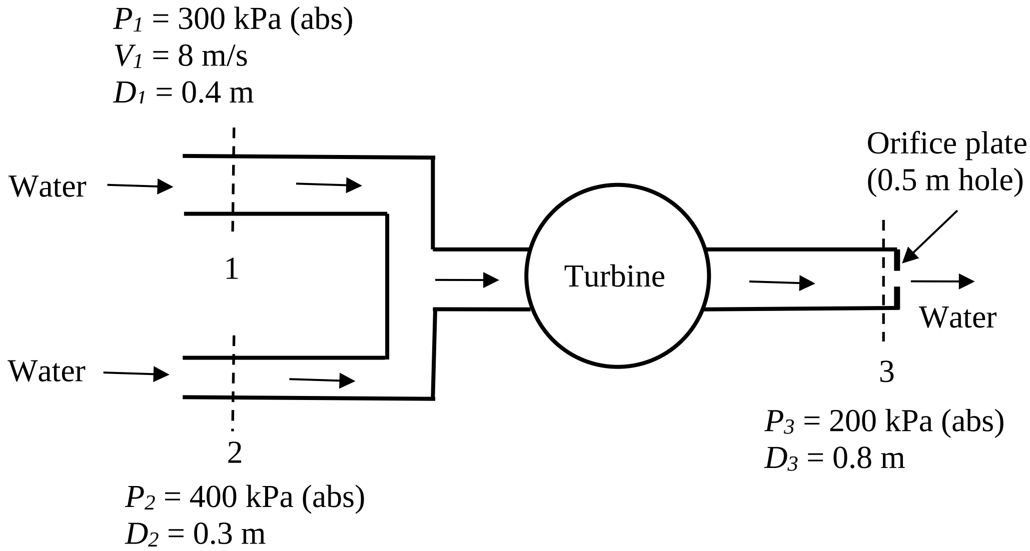

Figure 2

(12 marks)

2 (a) The lift force F_L of an aircraft depends on the aircraft speed V, the chord length of the wing l, the wing span S, the angle of attack α, the speed of sound c, the fluid density ρ and the dynamic viscosity μ of the fluid. Using dimensional analysis, derive the dimensionless groups and hence show their functional relationship.

(9 marks)

(b) A 1:20 scale model of an aircraft is tested in a wind tunnel where the temperature, density and dynamic viscosity of air are 20^0 C, 1.204 kg/m^3 and 1.82 $\times 10^{-5}$ N·s/m^2, respectively. The lift force of the model aircraft in the wind tunnel is found to be 1.25 kN. The prototype aircraft is flying at an altitude of 8,500 m above sea-level where the temperature, density and dynamic viscosity of air are -40^0 C, 1.514 kg/m^3 and 1.57 $\times 10^{-5}$ N·s/m^2, respectively. Using suitable dimensionless groups derived in part 2(a) above for dynamic similarity between the model and prototype aircrafts, determine the lift force of the prototype aircraft.

(6 marks)

(c) For steady laminar pipe flow, the local velocity in the pipe is given as:

$$u_r = V_c\left[1-\left(\frac{2r}{D}\right)^2\right]$$

where V_c is the centre-line velocity.

$$V_c = \left(\frac{\Delta p D^2}{16\mu l}\right)$$

Show that the volume flow rate is : $Q = \left(\dfrac{\pi D^4 \Delta p}{128\mu l}\right)$

The pipe diameter is 1 cm and the Reynolds number is 800, determine the centre-line velocity and the pressure gradient required for the flow

Density of fluid = 1050 kg/m^3 and dynamic viscosity is 0.00025 N.s/m^2.

(10 marks)

3 (a) Show that the velocity in a pipe can be expressed as:

$$V = \sqrt{\frac{2\Delta p}{f}\frac{d}{l}\frac{1}{\rho}}$$

where

Δp = pressure drop in the pipe
f = frictional factor of pipe
d = diameter of pipe
l = length between 2 points where pressure drop is measured
ρ = density of fluid

Water flows in a smooth pipe of diameter d = 0.01m. The pressure drop over a length of 10 m is 500 Pa. If the flow is laminar, determine the flow rate in the pipe.
(Water: ρ = 1000 kg/m^3, and μ = 0.001 Ns/m^2)

(10 marks)

(b) Water from a pressurized tank is discharged to the atmosphere through a 100 mm diameter pipe and nozzle as shown in Figure 3. The total loss in the piping system, (including nozzle and other minor losses) is $H_L = 2.5V_1^2/2g$.

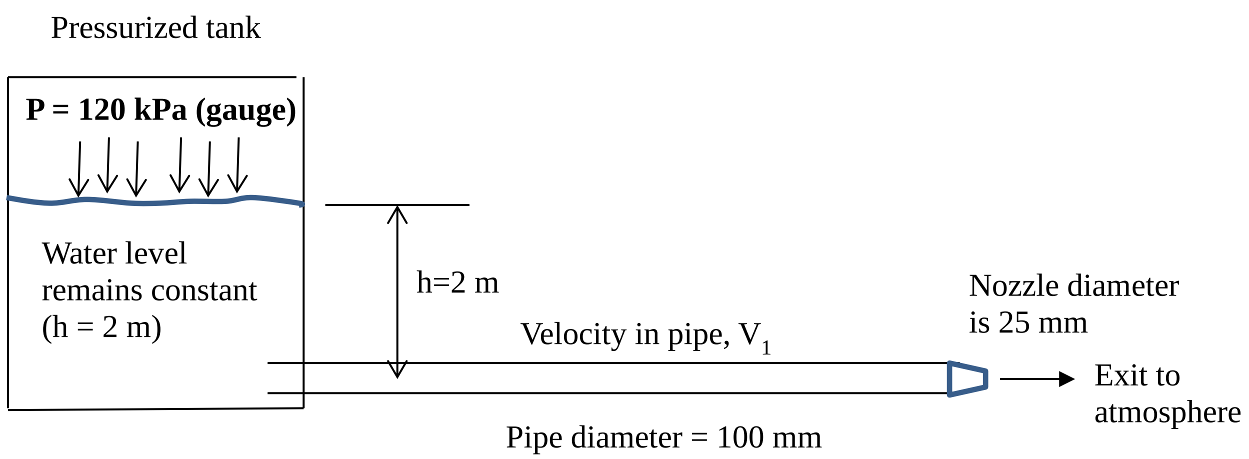

Figure 3

(i) Determine the volume flow rate in the system and velocity head at the nozzle outlet.

(ii) If the pressurized tank is to be replaced by a pump, determine the power input required by pump to produce the same volume flow rate. Total loss coefficient and h = 2 m remains unchanged. Pump efficiency is 70%.

(iii) Sketch the EGL and HGL for above (i) and (ii) and indicate clearly the pressure head at pipe inlet, velocity head at nozzle exit and pump head.

(15 marks)

4 (a) In a desalination plant, a mix-flow pump draws seawater from the coast to a storage tank as shown in Figure 4. The piping system comprises of the following:

Suction
Carbon steel 12” pipe, internal diameter = 305 mm
Overall length, inclusive of equivalent length for minor losses = 125 m
Frictional factor = 0.016

Discharge
Carbon steel 10” pipe, internal diameter = 250 mm
Overall length, inclusive of equivalent length for minor losses = 65 m
Frictional factor = 0.016

Show that the system characteristic can be expressed as:

$$E = (Z_2 - Z_1) + 0.08262\left(\frac{f_1 l_1}{d_1^{\,5}} + \frac{f_2 l_2}{d_2^{\,5}}\right)Q^2$$

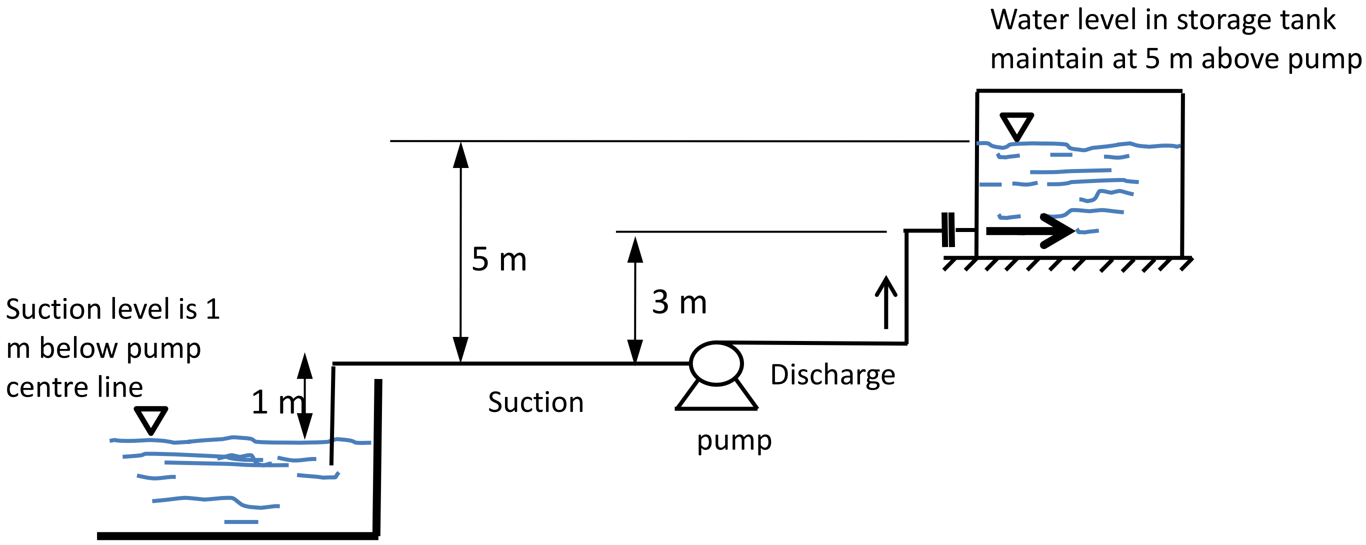

Figure 4

(4 marks)

Note: Question 4 continues on page 6.

where Z_2-Z_1 is the difference in elevation between suction and discharge surface (m)
f is the frictional factor of the pipe
l is length (m)
d is the internal diameter of pipe (m)
Q is the flow rate in m^3/s

(b) The pump characteristic, $NPSH_R$ and efficiency is given in the graph.

(i) Determine the operating flow rate and the power required by the pump.
(8 marks)

(ii) Where in the piping system is cavitation most likely to occur? Explain.
(2 marks)

(iii) Will cavitation occurs in the piping? (5 marks)

(iv) During low tide, the suction level is expected to drop. What is the limiting suction level for cavitation free operation? Is this pump suitable for this operation?
(6 marks)

Given

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

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

Seawater
Density = 1020 kg/m^3
Dynamic viscosity = 0.00086 Ns/m^2
Vapour pressure of seawater = 2750 Pa
Atmospheric pressure is 100 kPa

END OF PAPER