NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2021-2022

MA3006 – FLUID MECHANICS

April/May 2022 Time Allowed: $2^1/_2$ hours

INSTRUCTIONS

1. This paper contains **SECTION A & SECTION B** and comprises **EIGHT (8)** pages including **ONE (1)** page of Appendix.

2. **COMPULSORY** to answer **ALL** questions in both sections.

3. All questions carry equal marks.

4. This is a **CLOSED-BOOK** examination.

SECTION A

1. Heavy fuel oil is stored in the large storage tank located at the bottom of a ship. When in need, it is pumped to the day tank 8 m above at a steady volume flow rate of 30 L/s using a 10 kW pump, as shown in Figure 1. The pipes connected to the pump at the inlet and outlet have a constant cross section area of 100 cm^2. Both tanks are open to the atmosphere. Disregarding any frictional losses in the pipes,

(a) Determine the overall efficiency of the pump. (8 marks)

(b) Determine the pressure difference between the inlet and the exit of the pump. (7 marks)

(c) The mass of the horizontal pipe section when filled with oil is 20 kg/m. The pipe is anchored at the outlet flange of the pump at point A using bolts and nuts. Determine the required length of the horizontal section, *l*, that make the bending moment acting on the flange at point A zero. (10 marks)

The density of the heavy fuel oil is assumed to be 1000 kg/m^3.

Figure 1 appears on page 2.

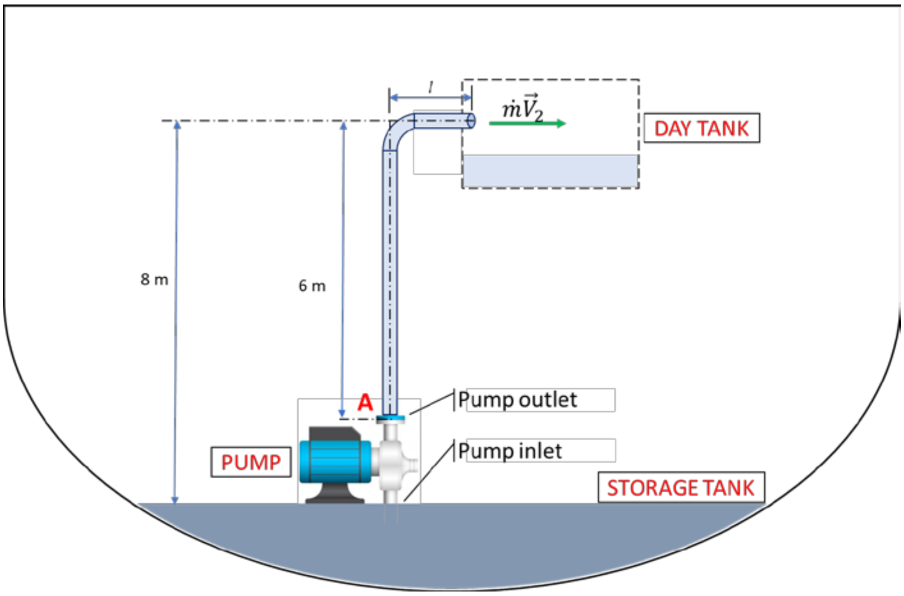


Figure 1

2. Autonomous Underwater Vehicles (AUVs) are very useful in underwater survey missions such as detecting and mapping submerged wrecks, rocks, and obstructions that can be a hazard to navigation for commercial and recreational vessels, as shown in Figure 2.
The drag force acting on the AUVs navigating well below the free surface is a function of fluid density ρ, dynamic viscosity of the fluid μ, navigation speed V, as well as the characteristic length of the vehicle L.

(a) Using dimensional analysis with ρ, μ, L as repeating variables, establish a non-dimensional relationship between the drag force and other variables.

(11 marks)

In the design process of an AUV, a model test is planned to be conducted in the wind tunnel to predict the drag force. The model AUV is 2.0 m long, corresponding to a full-scale prototype length of 5.0 m. The design speed of the AUV is 6 km/h in seawater at T=15°C. The air in the wind tunnel is at 24°C and at one standard atmosphere pressure. For seawater at T = 15°C and atmospheric pressure, ρ_{sw} = 1025 kg/m^3 and μ_{sw} = 1.138 × 10^{-3} kg/m·s. For air at T = 24°C and atmospheric pressure, ρ_a = 1.184 kg/m^3 and μ_a = 1.849 × 10^{-5} kg/m·s.

(b) At what air speed should be the tested conducted to achieve similarity?

(7 marks)

(c) If the measured aerodynamic drag force in wind tunnel is 12 N, estimate the hydrodynamic drag force acting on the prototype AUV advancing at design speed.

(7 marks)

State the assumptions you apply and discuss the limitations of the solution.

Note: Figure 2 appears on page 3.

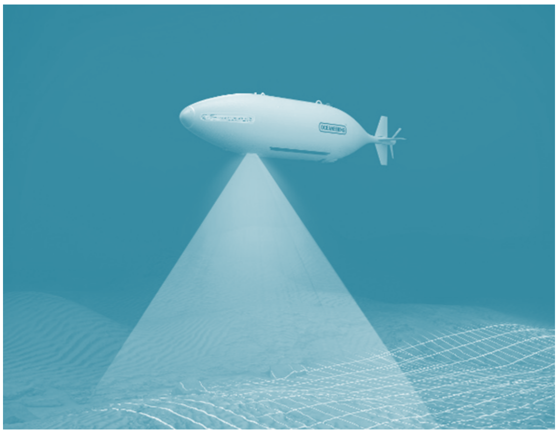


Figure 2

SECTION B

3 (a) Water flows through a pipe as shown in Figure 3. A static probe and pitot probe are installed at a distance 400 mm apart and the diameter of the pipe is 20 mm. If the Reynolds number (R_e) is 1280

(i) Derive an expression for H , in terms of f, l, d and $\frac{V^2}{2g}$.

(ii) Determine the height H, if the Reynolds number is 2000.

Density of water is 1000 kg/m^3
Dynamic viscosity of water is 1.00 x 10^{-3} N.s/m^2
Laminar flow: $f = \frac{64}{Re}$

(10 marks)

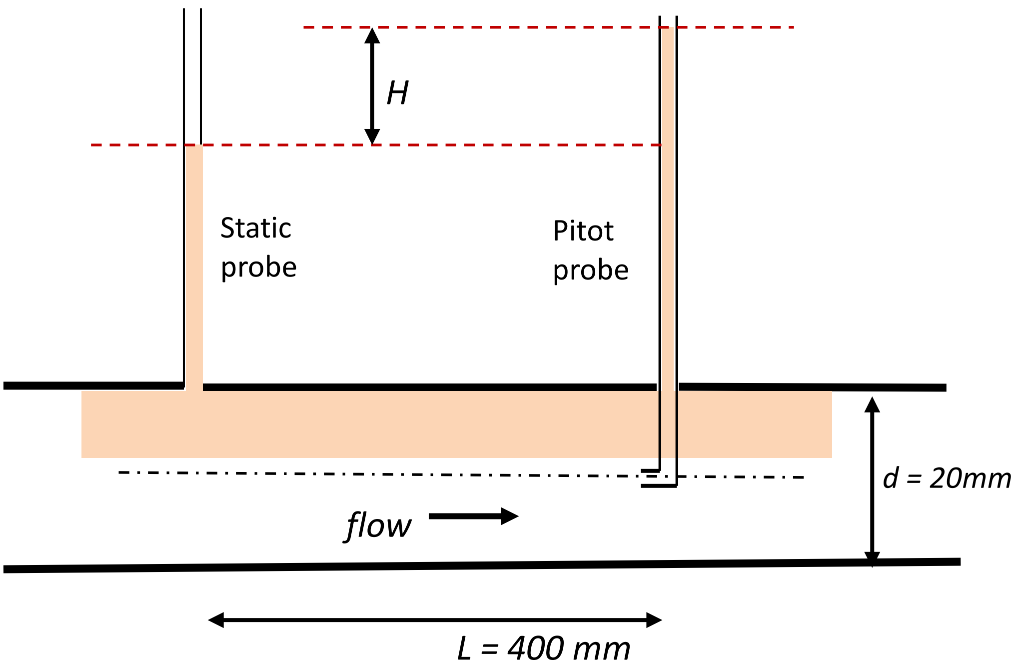


Figure 3

Note: Question 3 continues on page 5.

(b) A pump in the settling tank as shown in Figure 4 provides 800 Watts of fluid power to maintain continuous circulating flow to the aquarium. The overall length of the pipe from the pump to the exit is 3.5 m and its diameter is 30 mm. And the distance from the pump to the narrowest point of that nozzle-diffuser section is 3.2 m, and its diameter is 3.5mm.

The roughness of the pipe is 0.005 mm.
Head loss in the nozzle-diffuser can be assumed to be the same as head loss in the pipe and all other minor losses can be neglected

(i) Find the volume flow rate assuming that flow is wholly turbulent

(ii) Is flow the wholly turbulent? What should be the frictional factor? (You do not need to recompute flow rate)

(iii) What is the pressure at the narrowest section of the nozzle-diffuser? (use the new frictional factor)

(iv) Sketch the energy grade line and hydraulic line and clearly indicate regions of positive and negative pressure head.

Moody Chart is provided
Density of water = 1000 kg/m^3
Dynamic viscosity of water = 1.002 x 10^{-3} N.s/m^2

(15 marks)

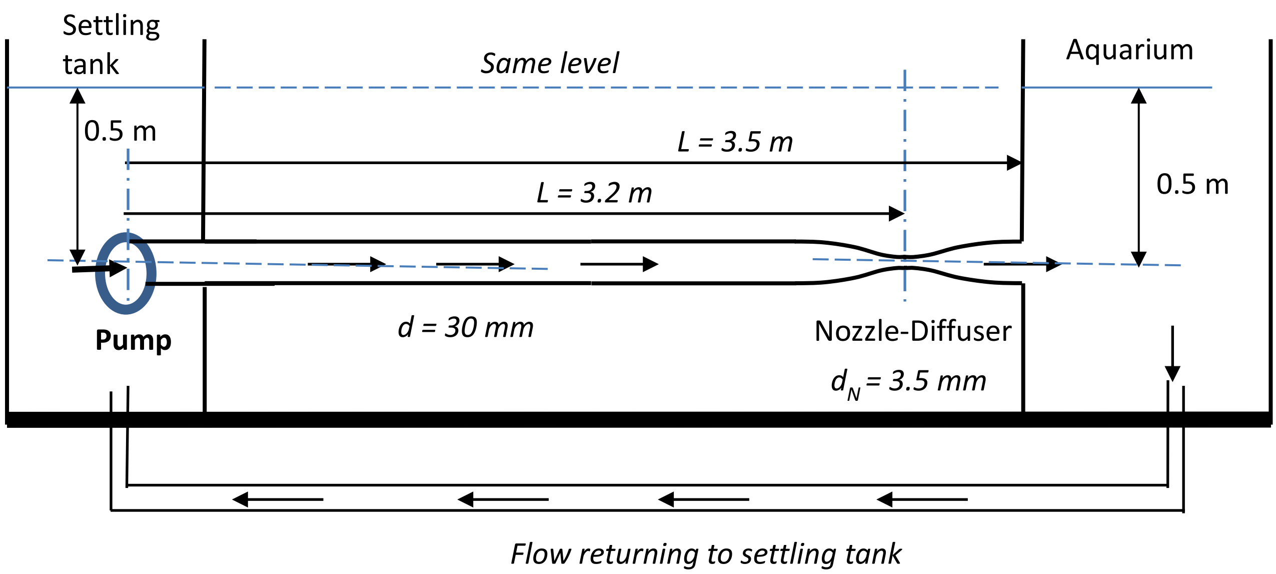


Figure 4

4 (a) Water is pumped from atmospheric Tank A to Tank B as shown in Figure 5. The system characteristic is computed to be $E = 53 + 1200Q^2$, where Q is the volume flow rate in m^3/s and E is the system head in metre.
The pump characteristic is given as $Hp = 85 - 750Q^2$ and its corresponding efficiency is :
$\eta = 605Q - 4000Q^3$.

(i) Determine the elevation of Tank A and the pump shut-off head

(ii) Determine the input power required to run the pump

(iii) The diameter of the pump is 0.5 m and the input speed available is 2000 rpm. Recommend an appropriate type of pump for the operation.

Pump specific speed is given as : $N_s = \dfrac{\omega\sqrt{Q}}{(gh_p)^{3/4}}$

(iv) Another identical pump is added to the system, arranged in parallel. Determine the input power required by one pump.

(15 marks)

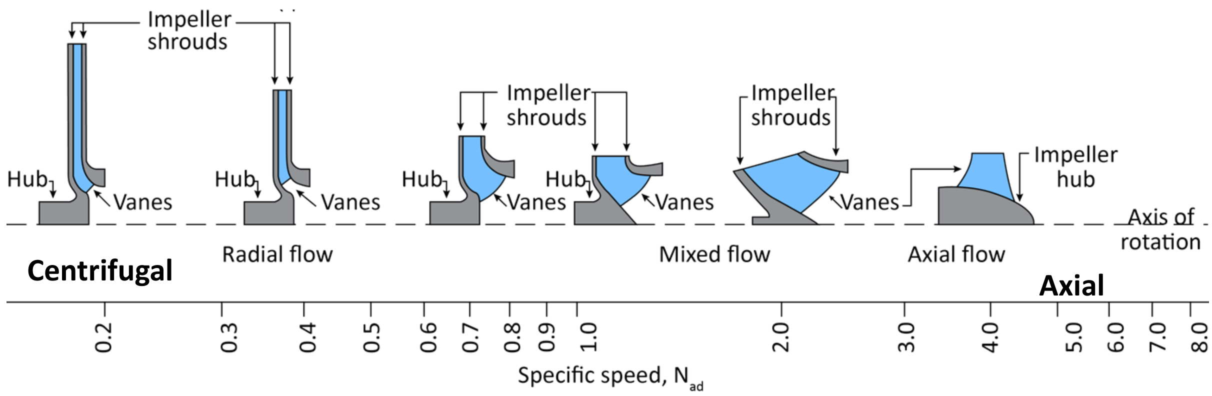


Figure 5: Specific Speed. N_s

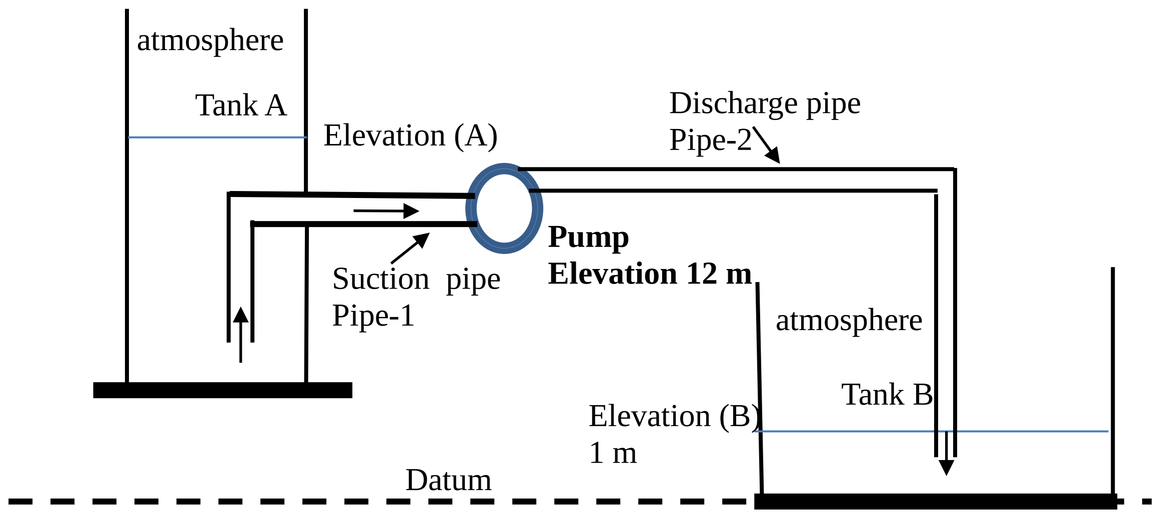


Figure 5

Note: Question 4 continues on page 7.

(b) After running the pump for sometimes, the elevation of Tank A drops to 2 m below the pump while the elevation of Tank B increases to 10 m. At this operating condition of the pump, the NPSH required is 3.6 m.

The following information is for the suction side of piping system.

Description	Diameter (m)	Total Length (m)	Frictional factor	$\sum K_L$
Suction pipe	0.25	12	0.025	4

The atmospheric pressure is 1 bar and the vapour pressure of water is 3000 Pa and NPSH available is given as:

$$NPSH_A = \frac{P_S - P_v}{\rho g} + \frac{V^2}{2g}$$

(i) What is the new system characteristics?

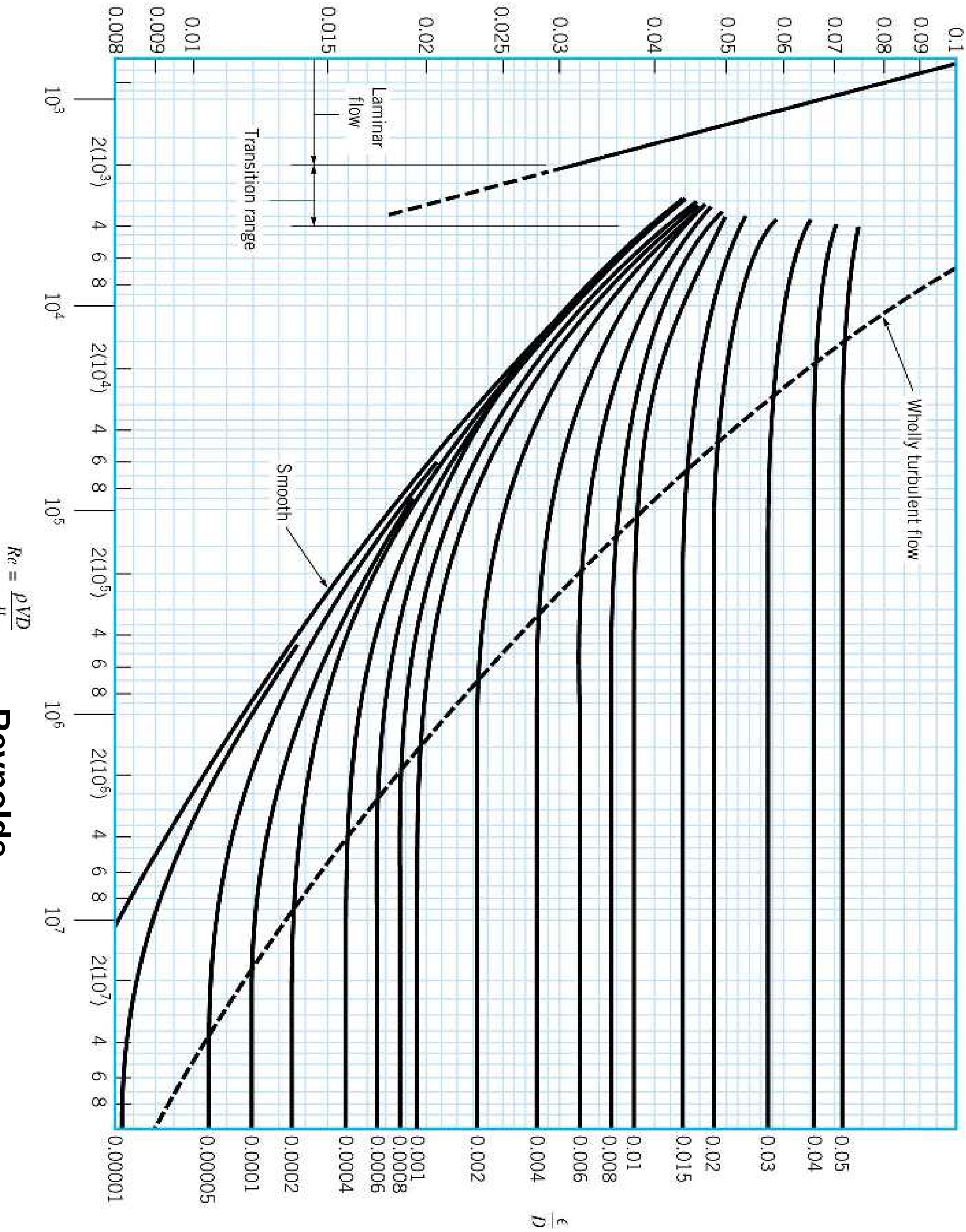
(ii) Will the pump cavitate?

(iii) Assuming the same operating flow rate, what is the limiting elevation of Tank A for onset of cavitation of pump?

(10 marks)

Appendix

frictional factor f



Reynolds

Relative roughness

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