2023 FIRST SEMESTER FINAL EXAMINATION

Faculty:	**Engineering and the Environment**
Department:	**Metallurgical Engineering**
Paper Code/Title:	**EMG 3106 FLUID MECHANICS**
Duration:	**3 Hours**
Examiner:	**Eng. S. Hobwana**

INSTRUCTIONS TO CANDIDATES

1. Answer **ANY 4** questions.
2. Start the answer to each question on a fresh page.
3. Show all your working.
4. Each question carries **25 marks**.
5. This question paper comprises 5 printed pages including cover page.

Question 1

(a) Starting with the Bernoulli and Continuity equations, show that the following expression gives the discharge measured by a venturimeter.

$$Q = C_d A_1 A_2 \sqrt{\frac{2g\left(\frac{p_1 - p_2}{\rho g} + z_1 - z_2\right)}{A_1^2 - A_2^2}}$$

[7 marks]

(b) A horizontal venturimeter is used to measure the flow of water in a 200mm diameter pipe. The throat diameter of the venturimeter is 80mm and the discharge coefficient is
0.85. If the pressure difference between the two measurement points is 10cm of mercury, calculate the average velocity in the pipe. Assume the relative density of mercury is 13.6. **[8 marks]**

(c) The velocity of the water flowing in the same pipe is also measured using a pitot-static tube located centrally in the flow. If the height measured on the attached manometer is 60mm and the relative density of the manometer fluid is 1.45, determine the velocity of the water. **[8 marks]**

(d) Explain why the velocity measured by the pitot-static tube is higher than that measured by the venturimeter. **[2 marks]**

Question 2

(a) Tabulate 4 different types of fluid flow and their corresponding examples. **[8 marks]**

(b) If we were to take a pipe of free flowing water and inject a dye into the middle of the stream, what would we expect to happen? Draw diagrams to express the 3 possible outcomes to this experiment. **[6 marks]**

(c) The phenomenon in **(b)** was first investigated in the 1880s by Osbourne Reynolds in an experiment which has become a classic in fluid mechanics.

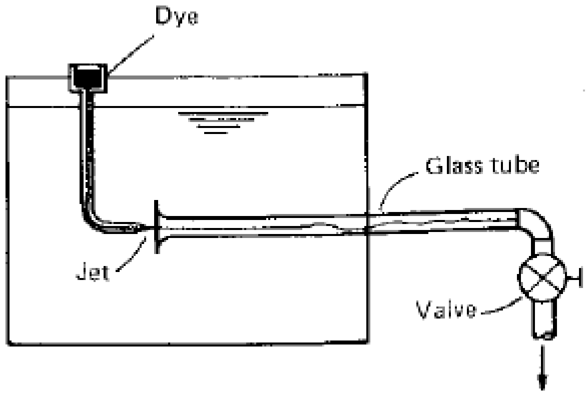

Figure 1

He used a tank arranged as above **Figure 1** with a pipe taking water from the centre into which he injected a dye through a needle. After many experiments he saw that this expression

$$Re = \frac{\rho u d}{\mu}$$

where ρ = density, u = mean velocity, d = diameter and μ = viscosity

would help predict the change in flow type.
i) Explain the significance of the Reynolds number? **[2 marks]**
ii) Give 3 points to each of the 3 outcomes questioned in **(b)** to summarize the types of flow giving the correct range of the Reynolds number, velocity and description of how it mixes with water. **[9 marks]**

Question 3

(a) An axial-flow ventilating fan driven by a motor that delivers 0.4 kW of power to the fan blades produces a 0.6-m- diameter axial stream of air having a speed of 12 m/s. The flow upstream of the fan involves negligible speed. See **Figure 2** below.

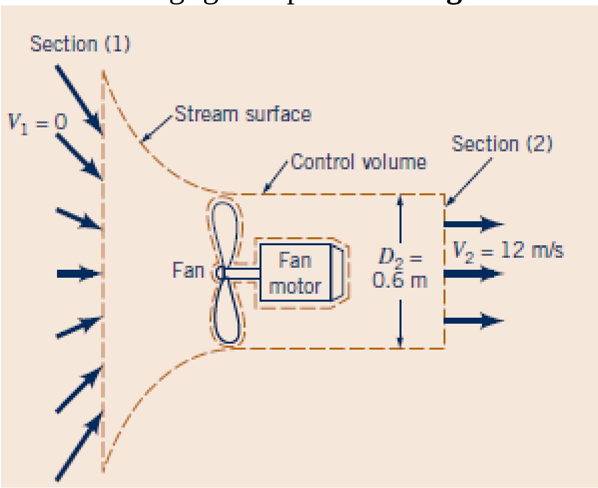

Figure 2

Determine how much of the work to the air actually produces useful effects, that is, fluid motion and a rise in available energy. Estimate the fluid mechanical efficiency of this fan. **[10 marks]**

(b) A viscous liquid $\rho = 1.18 \times 10^3$ kg/m^3; $\mu = 0.0045$ N.s/m^2 flows at a rate of 12 ml/s through a horizontal, 4-mm-diameter tube.

i) Determine the pressure drop along a l-m length of the tube which is far from the tube entrance so that the only component of velocity is parallel to the tube axis. **[8 marks]**
ii) If a 2-mm-diameter rod is placed in the 4-mm-diameter tube to form a symmetric annulus, what is the pressure drop along a l-m length if the flowrate remains the same as in part **i)**? **[7 marks]**

Question 4

(a) A pump P with a volume flow qv= 2.8 L/s brings water up between a basin B and a tank through a pipe with a diameter d=135 mm. See **Figure 3** below.

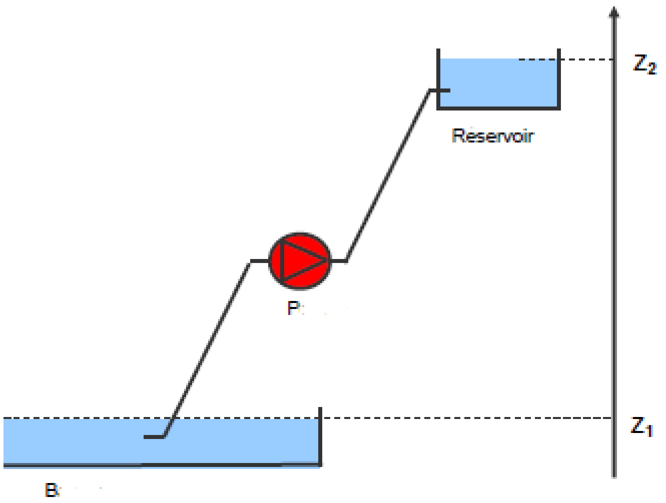

Figure 3

Given:
- $Z_1 = 0$; $Z_2 = 35$m
- $P_1 = P_2 = 1013$ mbar
- Dynamic viscosity of water: $\mu = 1.10^{-3}$ Pa·s.
- pipe length L=65 m

All singular head losses will be neglected.

i) Calculate the flow velocity V of the water in the pipe. **[2 marks]**

ii) Calculate the Reynolds number. Is the flow laminar or turbulent? **[2 marks]**

iii) Calculate the linear head loss coefficient. Deduce the losses of J_{12} charges throughout the flow. **[5 marks]**

iv) Apply Bernoulli's theorem to calculate the net power P_{net} of the pump. **[2 marks]**

v) The efficiency of the pump being 80%, calculate the power absorbed by the pump. **[2 marks]**

vi) What comment can you give on the calculated values above? **[2 marks]**

(b) The cylindrical tank with hemispherical ends shown in **Figure 4** contains a volatile liquid and its vapour. The liquid density is 800kg/m^3 and its vapour density is negligible. The pressure in the vapour is 120kPa (abs) and the atmospheric pressure is 101kPa (abs).

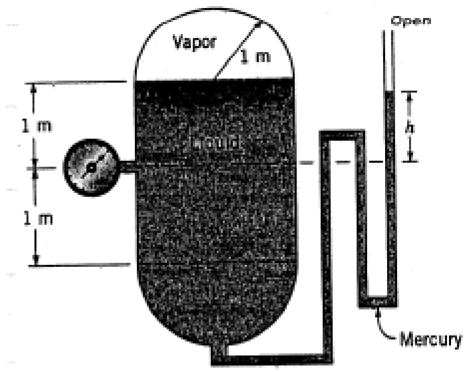

Figure 4

Determine:

i) The gage pressure reading on the pressure gage. **[5 marks]**

ii) The height h of the mercury manometer. **[5 marks]**

Question 5

(a) A tank contains compressed air at a pressure Pi = 4 bars, assumed stop pressure in the initial state. Opening a valve in this tank causes the expansion of the air towards the outside in the form of a jet having a diameter d = 5 mm.
The external parameters of the air jet in the final state are:
- Pressure P= 1 bar,
- Temperature T=25°C,
Given: γ = 1.4 and r =287 J/Kg.°K.
i) Calculate the speed of sound C outside the tank in (m/s). **[2 marks]**
ii) Determine the density ρ of the air outside the tank in (kg/m3). (Air is assumed to be an ideal gas.) **[2 marks]**
iii) Write the Saint-Venant equation, in terms of the pressure ratio, between a stopping point and a point on the air jet. **[3 marks]**
iv) Deduce the number of Mach M at the level of the air jet. **[2 marks]**
v) What is the nature of the flow? **[2 marks]**
vi) Calculate the flow velocity V of the air jet in (m/s). **[2 marks]**
vii) Deduce the mass flow q_m (kg/s). **[2 marks]**

(b) A waste-heat boiler forms an essential part for the treatment of high temperature flue-gases in most metallurgical processes. The **Figure 5** below represents a boiler C which produces steam at a mass flow q_m =13.4 kg/s.

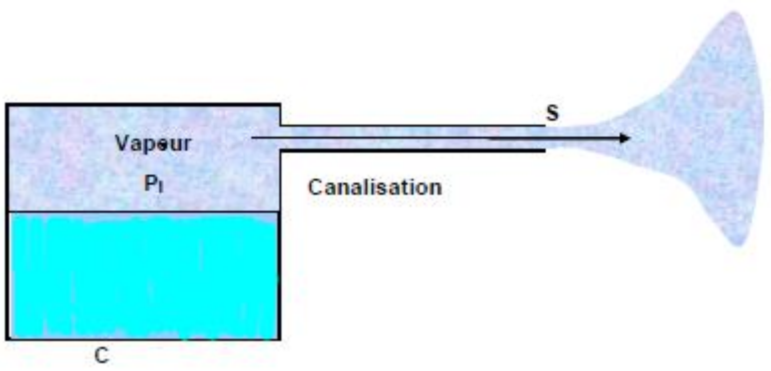

Figure 5

Through a cylindrical pipe, the steam arrives in a section S of diameter d=10 cm at a pressure P=15 bar and a temperature T=541 °K.
The characteristics of water vapor are given:
- γ =1.3.
- r = 462 J/kg°K.
i) Assuming that the vapor is an ideal gas, calculate the density ρ of steam leaving the boiler. **[2 marks]**
ii) Determine the flow velocity V. **[2 marks]**
iii) Calculate the speed of sound C. **[2 marks]**
iv) Deduce the Mach number M. Specify the nature of the flow. **[2 marks]**
v) Write the Saint-Venant equation in terms of the pressure ratio, and calculate the stop pressure Pi inside the boiler. **[2 marks]**

*************************END OF QUESTION PAPER***************************