University of Ruhuna- Faculty of Technology

Bachelor of Engineering Technology Honours
Level 4 (Semester II) Examination, November/December 2025
Academic year 2023/2024

Course Unit: ENT4232 Fluid Dynamics and Machinery (Written) **Duration: 02 hours**

Instructions to candidates:

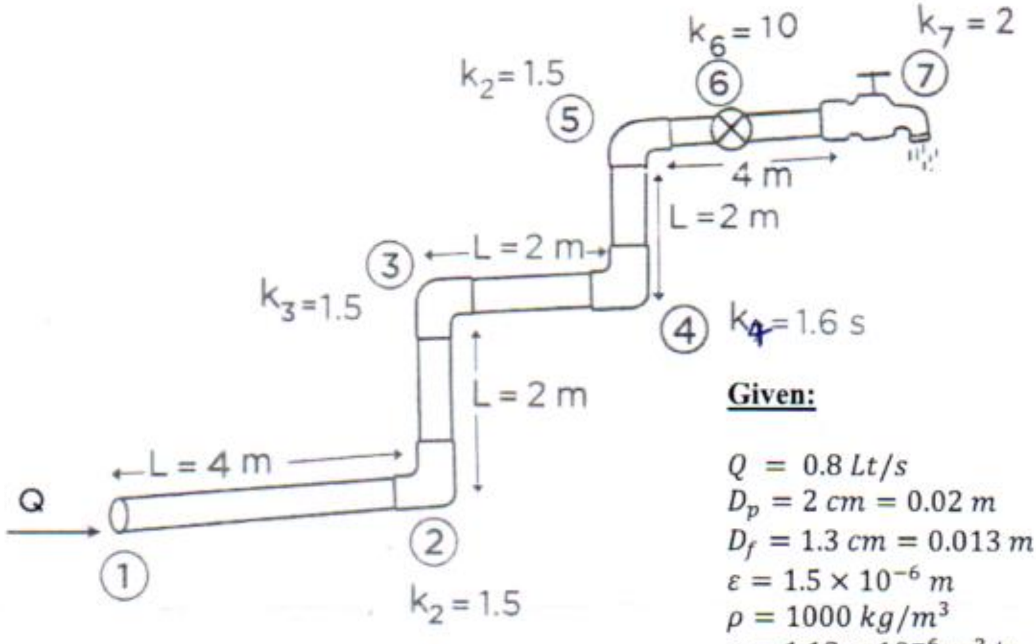
- This question paper contains **Four (04)** questions in four (04) pages.
- Use a separate book for answering the questions and each question should start with a new page.
- This examination accounts for 60% of the module assessment. Total mark given is 60.
- This is a close book examination.
- Answer all the questions.
- Each question carries 15 marks. The maximum mark attainable for the sub parts of each question is indicated in the bracket.
- Electronic communication devices are strictly prohibited. Only calculators approved by the Faculty of Technology, University of Ruhuna, are permitted.
- g = gravitational acceleration 9.81 m/s^2
- Density of water 1000 kgm^{-3}
- All symbols have their usual meaning.

1. Water flows from the basement to the second floor through a 2 cm diameter copper pipe line at a flow rate of $Q = 0.8$ Lt/s, and discharges through a tap with an exit diameter of 1.3 cm, as shown in Figure 01. Determine the pressure at point 1 under the following conditions:

   a) Neglecting all viscous effects, (06 marks)

   b) Considering only major losses, (05 marks)

   c) Considering all losses (both major and minor losses). (04 marks)



Given:

$Q = 0.8\ Lt/s$
$D_p = 2\ cm = 0.02\ m$
$D_f = 1.3\ cm = 0.013\ m$
$\varepsilon = 1.5 \times 10^{-6}\ m$
$\rho = 1000\ kg/m^3$
$\nu = 1.13 \times 10^{-6}\ m^2/s$

Figure 01

2. The pressure difference (Δp) across a partially blocked artery (stenosis) can be estimated using the equation,

$$\Delta p = K_v \left(\frac{\mu V}{D}\right) + K_u \left(\frac{A_0}{A_1} - 1\right)^2 \rho V^2$$

Where V is the blood velocity, μ is the blood viscosity ($ML^{-1}T^{-1}$), ρ is the blood density, D is the artery diameter, A_0 is the cross-sectional area of the unobstructed artery, and A_1 is the area at the stenosis.

   i) Write down the dimensions of parameters in the above equation, Δp, V, ρ, D, A_0, and A_1. (03 marks)

   ii) Determine the dimensions of $\boldsymbol{K_v}$ and $\boldsymbol{K_u}$. (06 marks)

   iii) Rewrite the equation in non-dimensional form using the dynamic pressure ρV^2 to normalize Δp, and identify the relevant dimensionless group (e.g. Reynolds number). (04 marks)

   iv) Comment on whether the given equation is valid in any system of units. (02 marks)

3. Answer all the short questions (a) to (g).

a) What are the **four** basic types of flow patterns used to visualize flow fields? (02 marks)

b) What are the **two** approaches used in fluid dynamics to study fluid motion? (02 marks)

c) The particle motion in a fluid flow can be decomposed into **four** fundamental components. What are those four fundamental components? (02 marks)

d) Name ideal fluid flow patterns which are categorized according to streamline and velocity geometry of fluid flow. (02 marks)

e) Define the vorticity (ζ) of fluid and write down the relationships between vorticity and rotation vector (ω) and relationships between vorticity and the velocity vector (V). (02 marks)

f) The rotation of the fluid element about the x, y and z axes are denoted as ω_x, ω_y, and ω_z respectively. Where u, v and w are velocity vector components in x, y and z directions respectively.

$$\omega_x = \frac{1}{2}\left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right);\ \omega_y = \frac{1}{2}\left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right);\ \omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right); \qquad \overrightarrow{\omega} = \omega_x\,\hat{\imath} + \omega_y\,\hat{\jmath} + \omega_z\,\hat{k}$$

These three components can be combined to define the rotation vector (ω) in terms of the velocity vector (V), Write down the relationship between the rotation vector (ω) and the velocity vector (V). (02 marks)

g) Draw the flow pattern of a point source located at the origin. On your diagram, clearly label and indicate the following: Direction of flow, Streamlines and Velocity potential lines. (03 marks)

4. The general continuity equation can be written by expanding the vector equation as below,

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

The stream function $\{\psi(x,y)\}$ and velocity potential function $\{\phi\ (x,y)\}$ relate to the velocity components in such a way that continuity equation is satisfied.

$$u = \frac{\partial \psi}{\partial y} = \frac{\partial \phi}{\partial x} \quad and \quad v = -\frac{\partial \psi}{\partial x} = \frac{\partial \phi}{\partial y}$$

i) Derive reduced form of the continuity equation for a steady, incompressible, plane, two-dimensional flow. (02 marks)

ii) Determine the velocity potential function and (ϕ) and stream function (ψ) for uniform flow with velocity components $u = 5$ ms^{-2} and $v = 0$. Draw the velocity potential line and streamline diagrams. (03 marks)

iii) If the streamline represented by stream function, $\psi = x^2 + y^2$.

a) Determine the velocity components u and v in two-dimensional steady flow. Hence find the resultant magnitude of velocity (V) and velocity vector ($\bar{V}$) of flow. (04 marks)

b) Sketch the streamline represented by stream function showing the direction of flow. (03 marks)

c) Find the velocity (V) and its direction at (-1,2). (03 marks)

*** **End of the Examination Paper*****

Annex

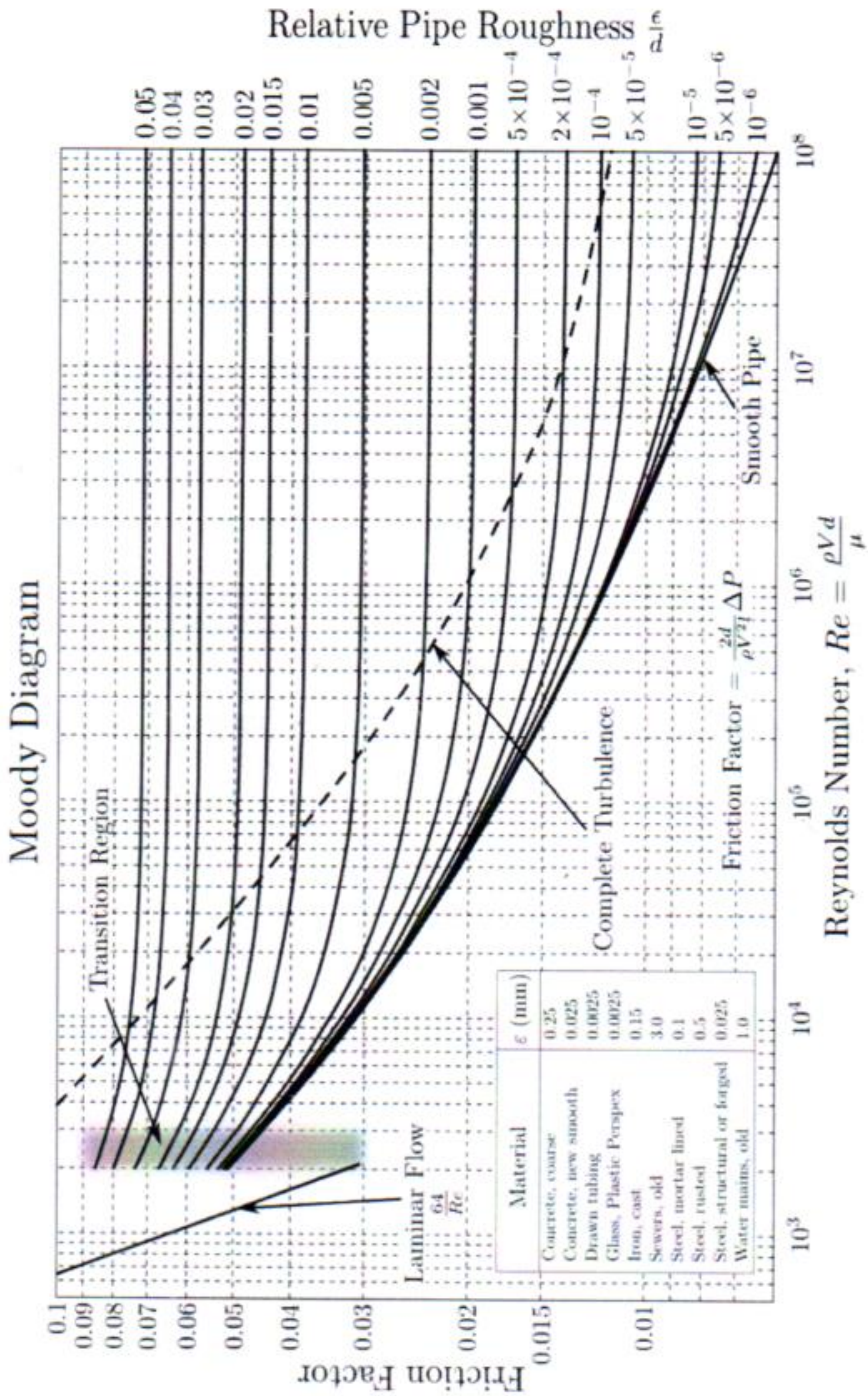


Figure 02: Moody diagram (Annex 01)