UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2026

Module Number: ME3303 **Module Name: Fluid Mechanics (C-23)**

Part A: One Hour

Answer **all questions**, The total mark allocation for Part A is 20 marks as 1 mark per question

Indicate your answer by placing 'X' in the appropriate box according to the guidelines in each section.

Follow the guidelines given in Table 1 to answer the questions from Q1 to Q11

Table 1. Answer guidelines for the questions from Q1 to Q11.

1	2	3	4	5
(a) and (b) are correct	(b) and (c) are correct	(c) and (d) are correct	(d) and (a) are correct	Only one choice is correct or another combination is correct

1. A Fluid travels freely along the x axis with a velocity ***U*** at steady state. In this flow
    a. Space derivatives of velocity components are zero
    b. Time derivatives of velocity components are zero
    c. Chain rule of differentiation is helpful to determine the acceleration
    d. The resultant acceleration is zero

2. If the above fluid(1), enters into a circular pipe and the flow is assumed to be Laminar,
    a. At the entrance, fluid has ***U*** velocity near the pipe boundary
    b. Magnitude of the velocity at the pipe boundary approaches zero in a short time
    c. When the fluid leaves the pipe, the maximum velocity can be observed at the pipe wall
    d. Streamlines are irregular

3. Subsequently, the above fluid leaves the pipe and follows a random 2D flow, the new velocity can be represented as a potential function of $\Phi = 4x^2y - 5xy^2 + 2t$
    a. The velocity component ***u*** has a magnitude of 8 units
    b. The velocity component ***v*** is directed upwards
    c. The magnitude of the velocity at the point (2,1,3) is **11.7** units
    d. The flow direction is downward to the right side

4. Consider a super imposed flow of source and sink pair
    a. Potential lines of the pure sink flow are directed radially inward
    b. Streamlines of the pure source flow are circular paths tangential to the flow
    c. Source strength has the units of dynamic viscosity
    d. The resultant flow can be derived with the aid of Cartesian- or polar-coordinate-based partial differential equations

5. Reynolds number (Re) is a popular term in Fluid Mechanics.
    a. Higher the Reynolds number, higher the turbulence
    b. Re is the ratio between the inertial forces and the intrinsic internal forces of a Fluid
    c. Higher the Reynolds number, lower the intersection of streamlines
    d. High Reynolds numbers are preferred for good mixing

6. What are the correct statements about classification of centrifugal pumps?
    a. Pumps can be classified based on casing type such as volute and diffuser pumps.
    b. Pumps can be classified according to working head as low, medium, and high head pumps.
    c. Pumps can be classified according to direction of flow through the impeller.
    d. Pumps can only be classified according to impeller diameter.

7. What are the correct statements about Static Head and Manometric Head
    a. Static head is the sum of suction head and delivery head.
    b. Manometric head is the actual head developed by the pump.
    c. Static head includes friction losses.
    d. Manometric head may include losses in the impeller and casing.

8. What is/are the correct statement/s about Net Positive Suction Head (NPSH)
    a. It represents the pressure head available at the suction side.
    b. It prevents cavitation if sufficient value is maintained.
    c. It is related to vapor pressure of the liquid.
    d. It depends only on the pump speed.

9. What are the correct statements about model testing of centrifugal pumps?
    a. It is performed using a geometrically similar smaller pump.
    b. Similarity laws are used to predict prototype performance.
    c. Model testing increases development cost.
    d. It helps to estimate head, discharge, and power of the prototype pump.

10. Consider the velocity relationships and performance of an impulse turbine
    a. Maximum hydraulic efficiency occurs when the ratio of bucket speed to jet speed is approximately 0.5
    b. The outlet absolute velocity is zero when the turbine operates at maximum efficiency.
    c. The jet deflection angle in a Pelton bucket is ideally 180°.
    d. Relative velocity of water remains constant over the bucket surface if friction is neglected.

11. What are the correct statements about jet formation
    a. Nozzle converts pressure energy into kinetic energy
    b. Jet velocity depends on the available head.
    c. Jet diameter affects discharge.
    d. Jet velocity is independent of nozzle design.

There are two statements given for each question from Q12 to Q16. Follow the guidelines given in Table 2 to answer the questions from Q12 to Q16

Table 2. Select the most appropriate choice according to the given guidelines

Choice	**Statement 1**	**Statement 2**
1	True	True and it explains the statement 1
2	True	True but it doesn't explain the statement 1
3	True	False
4	False	True
5	False	False

	Statement 1	**Statement 2**
12	A Newtonian fluid displays a straight line in its Shear stress vs Shear rate plot	This Fluid has a constant viscosity regardless of the shear rate
13	Continuity equation indicates the conservation of volumetric flow rate	Bernoulli's equation indicates the conservation of energy
14	Dynamic Pressure has the dimensions of Kinetic Energy	Hydrostatic Pressure has the dimensions of Potential Energy
15	Momentum Thickness is introduced to compensate for the loss of momentum due to the formation of boundary layer	Displacement Thickness is introduced to compensate for the loss of mass flow rate
16	Velocity Gradient is equivalent to Shear Strain	When we consider the Momentum transfer flux, driving force for the momentum transfer is Velocity Gradient

For the questions 17-20, select the most appropriate answer from the given 5 choices

17. In hydraulic model testing of a spillway, a 1:25 scale model is constructed. The flow is dominated by gravity forces. What is the correct statement
    1) Reynolds similarity must always be satisfied for accurate free-surface flow modeling.
    2) The Froude number must be the same for both the model and prototype.
    3) Velocity scale is equal to the length scale.
    4) Time scale is equal to the square of the length scale.
    5) Pressure scale is independent of geometric scale.

18. The drag force acting on a sphere moving through a viscous fluid depends on the fluid density ρ, viscosity μ, velocity V, and sphere diameter D. Select the correct statement
    1) The dimensional formula of dynamic viscosity μ is $M^0L^{-1}T^{-1}$
    2) The Reynolds number can be expressed as $\frac{\rho VD}{\mu}$
    3) The drag force must always vary linearly with velocity according to dimensional analysis.
    4) Dimensional analysis can determine the exact numerical constant in the drag equation.
    5) The number of independent dimensionless groups equals the number of repeating

19. A hydraulic model is used to simulate prototype flow involving gravity, viscous forces, and surface tension simultaneously. Select the correct statement
    1) Exact similarity can always be achieved by matching Reynolds, Froude, and Weber numbers simultaneously.
    2) Exact dynamic similarity is impossible if the same working fluid is used in both model and prototype.
    3) Surface tension effects vanish automatically when Reynolds similarity is satisfied.
    4) Matching the Froude number guarantees similarity of pressure distribution.
    5) Distorted models eliminate all scale effects.

20. Consider the fundamental characteristics of reaction turbines operating under varying load conditions.
    1) Reaction turbines operate efficiently even when the runner is partially filled with water.
    2) The guide vanes only control the direction of water flow and do not affect discharge.
    3) The pressure at the runner inlet must always be equal to atmospheric pressure.
    4) Cavitation is independent of the pressure distribution inside the turbine.
    5) The pressure at the runner outlet can fall below atmospheric pressure, which necessitates the use of a draft tube.

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Module Number: ME3303 **Module Name: Fluid Mechanics (C-23)**

Part A + Part B: Three Hours

[Answer **all questions**, each question carries **10 marks**]

Q1 a) Prove that the summation of space derivatives are zero for two dimensional fluid flow through a cuboidal channel

[4 Marks]

b) In a municipal water distribution network, a central storage tank is utilized to keep ground water and subsequently to distribute water into two different channels towards a school and a hospital. This arrangement can be depicted as shown in Figure Q1 in Page 2. The pipe diameter and flow velocity values of each pipe channel are given in Table Q1 in Page 2 . Answer the following questions by considering the storage tank as a control volume.

a) Calculate the **flow velocity** u_c and the **mass flux** in channel C

[2 Marks]

b) Calculate the **Dynamic pressure** and the **momentum transfer rate** through channel B

[2 Marks]

c) Determine the minimum **kinematic viscosity** of incoming ground water into the storage tank in channel A to maintain a **Laminar flow** always.

[2 Marks]

Table Q1

Channel	Pipe Diameter (cm)	Flow Velocity (m/min)
Channel A	30	150
Channel B	20	120
Channel C	15	u_c

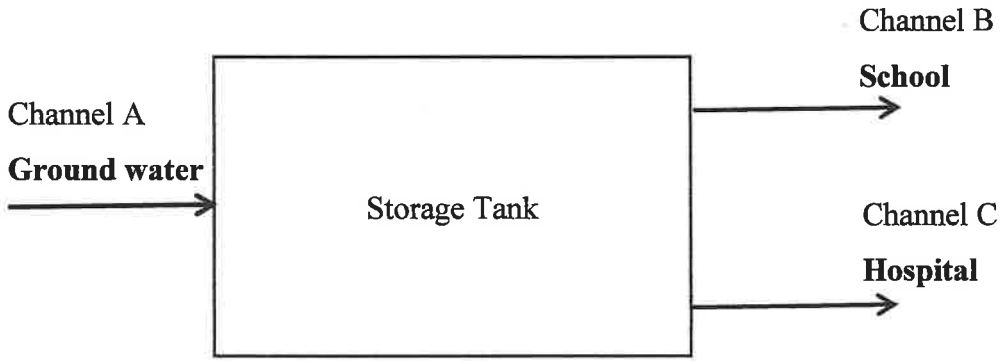


Figure Q1

Q2 a) List out the characteristics of fully developed fluid flow inside a cylindrical pipe

[2 Marks]

b) Starting from the **Poiseuille equation** for the fluid flow through a capillary tube, prove that the **head loss due to fiction (h_f)** for a fluid flow inside a cylindrical pipe is given by $\frac{32\,\mu\,u_{avg}L}{\rho g D^2}$, where each notation has its standard meaning as mentioned in the information sheet in page 6.

[3 Marks]

c) A galvanized iron pipe of 200 mm diameter and 200 m length transports water from a reservoir at a temperature of 20°C. The kinematic viscosity and the volumetric flow rate of water are 0.01 stokes and 0.09 m^3/s respectively. Calculate the **pressure gradient** throughout this flow.

[5 Marks]

Q3 a) State the advantages of centrifugal pumps over reciprocating pumps.

[1.5 Marks]

b) Define cavitation in centrifugal pumps and explain its harmful effects.

[1.5 Marks]

c) A three stage centrifugal pump has impellers 400 mm in diameter and 20 mm wide at outlet. The vanes are curved back at the outlet at 45° and reduce the circumferential area by 10%. The manometric efficiency is 90 % and the overall efficiency is 80 %. The pump is running at 1000 r.p.m. and delivering 0.05 m3/s. Determine the following.

(i) Head generated by the pump.

(ii) Shaft power required to run the pump.

[4 Marks]

d) A torpedo shaped object, 900 mm diameter is to move in air at 60 ms-1 and its drag is to be estimated from tests in water on a half scale model. Determine the necessary speed of the model and the drag of the full scale object if that of the model is 1140 N. (Viscosity of air= 1.86×10^{-5} Nsm^{-2}, Viscosity of water = 1.01×10^{-3} Nsm^{-2}, Density of air = 1.2 kgm^{-3}, water density= 1000 kgm^{-3})

[3 Marks]

Q4 a) State the advantages of reaction turbines over impulse turbines.

[1.5 Marks]

b) State the conditions required for geometric similarity, kinematic similarity, and dynamic similarity between a model and prototype.

[1.5 Marks]

c) The water available for a Pelton wheel is 4 m3s-1 and the total head from the reservoir to the nozzle is 250 m. The turbine has two runners with two jets per runner. All the four jets have the same diameters. The pipe is 3 km long. The efficiency of transmission through the pipeline and the nozzle is 91 % and efficiency of each runner is 90 %. The velocity co-efficient of each nozzle is 0.975 and friction factor 'f' for the pipe is 0.0045. Determine the following.

(i) The power developed by the turbine,

(ii) The diameter of the jet, and

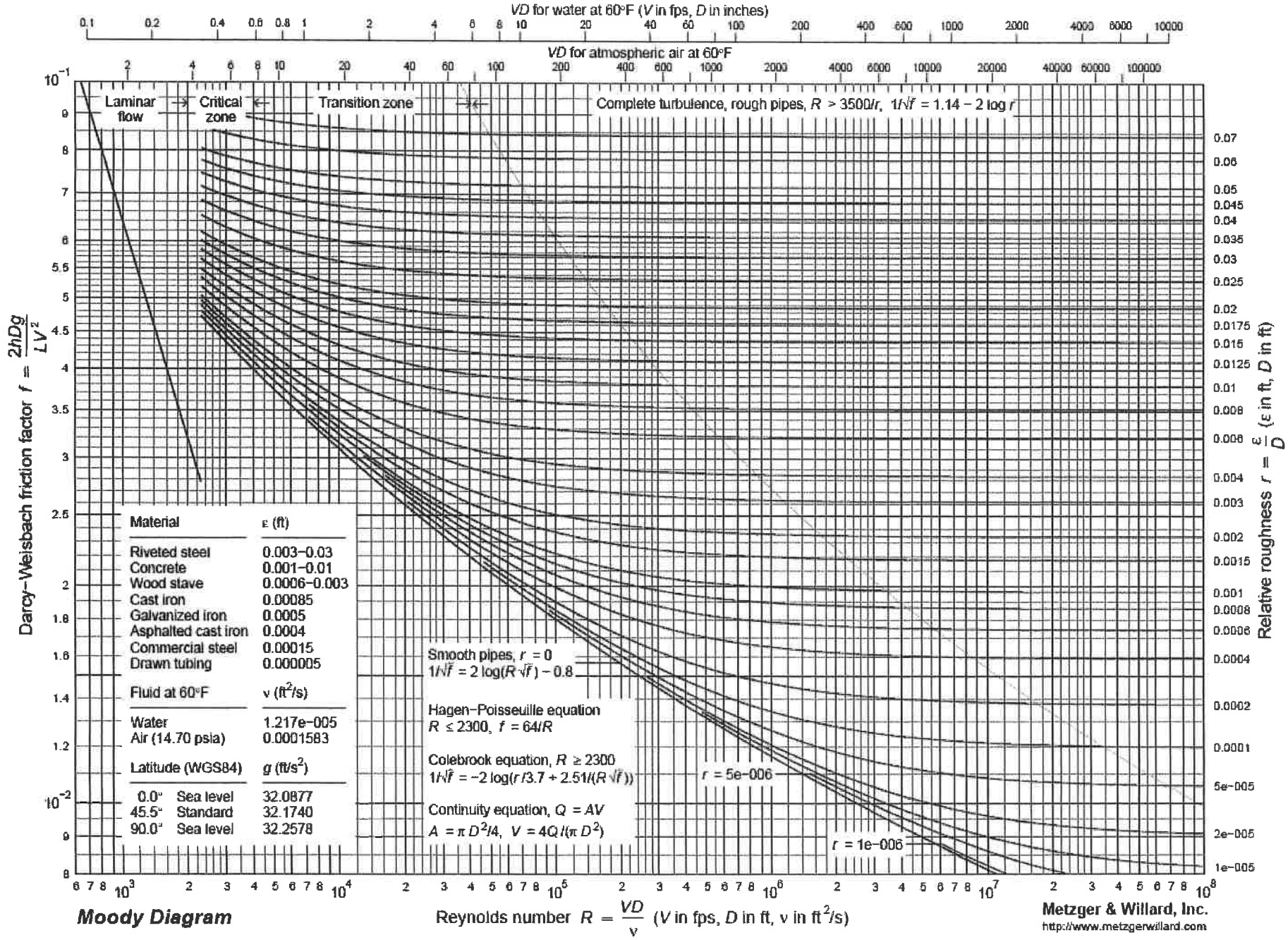
(iii) The diameter of the pipeline.

[4 Marks]

d) A partially submerged body is towed in water. The resistance R to its motion depends on the density ρ, the viscosity μ of water, length L of the body, velocity V of the body and acceleration due to gravity. Use the Buckingham's π-theorem to show that the resistance to motion R is given by the following equation

$$R = \rho L^2 v^2 \phi \left[\frac{\mu}{\rho L v}, \frac{Lg}{v^2}\right]$$

[3 Marks]


VD for water at 60°F (V in fps, D in inches)
VD for atmospheric air at 60°F
Laminar flow
Critical zone
Transition zone
Complete turbulence, rough pipes, R > 3500/r, 1/√f = 1.14 − 2 log r
Darcy–Weisbach friction factor f = 2hDg/LV²
Relative roughness r = ε/D (ε in ft, D in ft)
Material | ε (ft)
Riveted steel 0.003–0.03
Concrete 0.001–0.01
Wood stave 0.0006–0.003
Cast iron 0.00085
Galvanized iron 0.0005
Asphalted cast iron 0.0004
Commercial steel 0.00015
Drawn tubing 0.000005
Fluid at 60°F | ν (ft²/s)
Water 1.217e−005
Air (14.70 psia) 0.0001583
Latitude (WGS84) | g (ft/s²)
0.0° Sea level 32.0877
45.5° Standard 32.1740
90.0° Sea level 32.2578
Smooth pipes, r = 0
1/√f = 2 log(R √f) − 0.8
Hagen–Poisseuille equation
R ≤ 2300, f = 64/R
Colebrook equation, R ≥ 2300
1/√f = −2 log(r/3.7 + 2.51/(R √f))
Continuity equation, Q = AV
A = π D²/4, V = 4Q/(π D²)
r = 5e−006
r = 1e−006
Moody Diagram
Reynolds number R = VD/ν (V in fps, D in ft, ν in ft²/s)
Metzger & Willard, Inc.
http://www.metzgerwillard.com

Information sheet

The relevant equations and the meaning of the notations of the given equations are listed below. If any notation is not mentioned specifically, consider those by their standard meaning.

Equations

- Darcy-Weisbach equation $h_f = \frac{fLV^2}{2Dg}$

Notations

1) ρ = Fluid density
2) μ = Dynamic Viscosity
3) U = Free stream velocity of Fluid
4) h_f = Head loss due to friction
5) f = Darcy-Weisbach friction factor
6) L = Pipe length
7) V = Fluid flow velocity at a particular measurement
8) U_{avg} = Average velocity
9) D= pipe diameter/characteristic length for a circular pipe flow
10) g = acceleration due to gravity