

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering



Study Programme : Bachelor of Science Honours in Engineering
Name of the Examination : Final Examination
Course Code and Title : DMX5206 Applied Fluid Dynamics II
Academic Year : 2024/25
Date : 20th February 2026
Time : 14.00hrs -17.00 hrs
Duration : 3 hours

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General instructions

1. Read all instructions carefully before answering the questions.
- 2.
3. This question paper consists of **Five (5)** questions in **Four (4)** pages.
4. Answer **all** questions.
5. All questions carry equal marks.
6. Answer for each question should commence from a new page.
7. This is a Closed Book Test (CBT).
8. **Attach Page Number 5 to the answer book**
9. **All equations are represented by standard notation.**

Question – 01-

- a) Consider a fluid flowing through a small cubical control volume of dimensions dx , dy and dz . Using the principle of conservation of mass, show that the differential form of the continuity equation for a fluid of density ρ is given by,

8 Marks

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{V}) = 0$$

Where,

$$\nabla = \frac{\partial}{\partial x} \hat{i} + \frac{\partial}{\partial y} \hat{j} + \frac{\partial}{\partial z} \hat{k} \quad \text{and} \quad \vec{V} = u\hat{i} + v\hat{j} + w\hat{k}$$

7 Marks

- b) An incompressible three-dimensional flow field is defined by the velocity components:

5 Marks

$$u = x^2y + yz^2, \quad v = y^2z + zx^2, \quad w = f(x, y, z)$$

Determine the velocity component $w(x, y, z)$, given that $w(x, y, z) = 0$ at $z = 0$.

- c) Determine the resultant velocity and the acceleration of the fluid at point $P(1, 2, 0)$.

Question 2

- a) Briefly explain the engineering applications of rotational flow (vorticity).

3 Marks

- b) The rotational vector of a fluid particle in three-dimensional flow is defined as:

$$\omega = \nabla \times \vec{V}$$

3 Marks

Show that, for a two-dimensional flow in the x-y plane the rotation vector ω is given by,

$$\omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

- c) In an industrial mixing tank, the velocity field of a liquid in the horizontal plane is measured as:

4 Marks

$$u(x, y) = -y + xy \quad \text{and} \quad v(x, y) = x - xy$$

- I. Derive an expression for the rotation about the z-axis ($\omega_z(x, y)$)
- II. Show that the rotation at the origin in the counterclockwise direction is $\omega_z(0, 0) = 2$.

- d) A two-dimensional, incompressible irrotational flow is formed by combining a uniform flow with velocity $\mathbf{U} = 10 \text{ ms}^{-1}$ in the positive x-direction and a source of strength $m = 20\pi \text{ m}^2\text{s}^{-1}$ located at the origin.

5 Marks

- I. Derive the stream function and the velocity potential for the combined flow.
- II. Find the location of the stagnation point $\mathbf{P}(r, \theta)$.

5 Marks

Question 03

- a) What is the physical interpretation of momentum thickness?

2 Marks

Show that the momentum thickness (θ) for a boundary layer for a flow on top of a flat plate with velocity profile $u(y)$ is given by:

$$\theta = \int_0^{\delta} \frac{u}{U_{\infty}} \left(1 - \frac{u}{U_{\infty}}\right) dy$$

6 Marks

Where:

ρ : density of the fluid, U_{∞} : freestream velocity and δ : boundary layer thickness

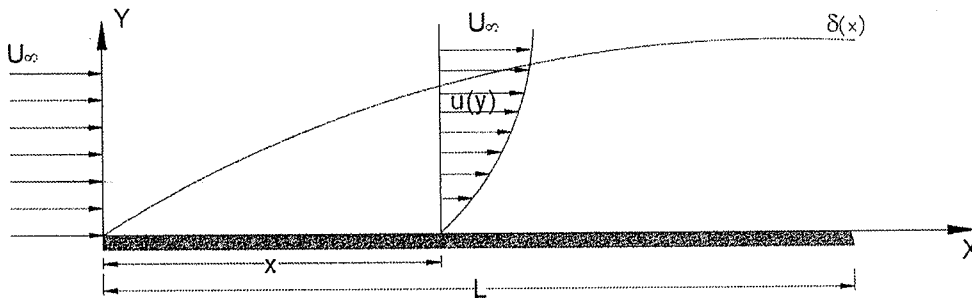


Figure Q3

- b) Air flows with a free stream velocity of $U_{\infty} = 50 \text{ ms}^{-1}$ and density $\rho = 1.225 \text{ kg.m}^{-3}$ over a flat plate as shown in Figure Q3. The length of the plate is $L = 2\text{m}$ and its width $b = 1\text{m}$. At the trailing edge of the plate (at $x=L$), the velocity profile $u(y)$ within the boundary layer is approximated by the following parabolic equation:

$$\frac{u(y)}{U_{\infty}} = 2 \left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

Show that momentum thickness $(\theta) = \frac{2}{15} \delta$

7 Marks

- c) By assuming flow over one side and the boundary layer thickness is at trailing edge $\delta_L = 12\text{mm}$, Determine the total drag force on the plate.

5 Marks

Question 4

- a) What is the significance of Mach number in the context of compressible flow?

6 Marks

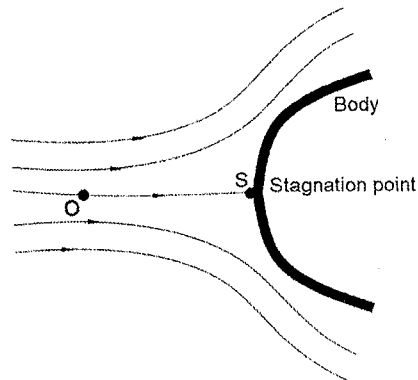


Figure Q4.

For an adiabatic flow of compressible fluid past an immersed body as shown in Figure Q4, the stagnation pressure is given by:

$$P_s = P_0 \left[1 + \left(\frac{\gamma - 1}{2} \right) M_0^2 \right]^{\frac{\gamma}{\gamma - 1}}$$

Where:

P_s : Stagnation pressure,

P_0 : Pressure of compressible fluid at point O

M_0 : Mach number of the flow

γ : Specific heat ratio

8 Marks

- b) Derive an expression for stagnation temperature (T_s)

6 Marks

- c) An aircraft flies at an altitude where the ambient (static) temperature is **223 K** and the flight Mach number is **$M = 2.0$** . Assuming the air behaves as an ideal gas with a ratio of specific heats **$\gamma = 1.4$** , determine the **stagnation temperature (T_s)** at the leading edge of the wing.

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Question 5 - (Attach this page to the answer book.)

- a) Explain the main functions of a CFD code in transforming a physical fluid problem into a numerical solution.

3 Marks

- b) Figure Q5, shows a 1D grid of cells with fixed boundary temperature values.

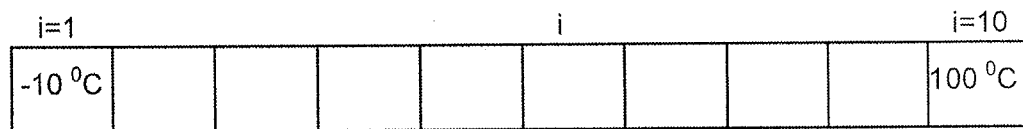


Figure Q5

3 Marks

- What is the general equation for calculating cell temperature using the simplified finite difference (cell averaging) method?
- Write an algorithm to find the steady-state temperature of the 1D system shown in Figure Q5 using the simplified finite difference method (cell averaging method).
- Complete the table below by calculating the cell temperatures for 5 iterations (*The initial temperature of the internal cells can be assumed to be 0 °C*).

4 Marks

10 Marks

NB: You may fill the table and attached to the answer script).

	Cell Number									
Iteration	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										

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