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

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX5242 Mechanics of Fluids**
Academic Year	: 2024/2025
Date	: 27th January 2026
Time	: 1330-1630 hrs
Duration	: **03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **SIX (05)** questions on **Five (04)** pages.
3. Answer **All** questions.
4. Answer for each question should commence from a new page.
5. Necessary additional information is provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear handwriting.
8. Do not use a Red colour pen.
9. Students are expected to know the standard denominations used for equations

Q1)

a) An unsteady incompressible flow field is given by, $u = t^2 + 3y$ *and* $v = 4t + 5x$. Determine the acceleration at the point (4,3) at time $t = 3$. (6 marks)

b) Confirm that the following flow exists and obtain the associated stream function.

$$u = -cx/y$$
$$v = c \ln xy$$

(08 marks)

c) A velocity potential for a 2-Dimensional flow is given by $\phi = (x^2 - y^2) + 3xy$. Compute the flow rate between the streamlines passing through points (1,1) and (2,3).

(06 marks)

Q2)

a) Two incompressible viscous fluids flow on top of the other down an inclined plate at an angle α. They both have the same density ρ, but different viscosities μ_1 and μ_2. The lower fluid has depth of h and the depth of upper flow is $2h$. Assuming that viscous forces from the surrounding air is negligible and the pressure on the free surface is constant, Show that:

(10 marks)

$$u_1(y) = \left[(h_1 + h_2)y - \frac{1}{2}y^2\right]\frac{g \sin \alpha}{v_1}$$

b) Find the convective acceleration at the middle of a pipe which converges uniformly from 0.4m diameter to 0.2m diameter over a 2m length. The rate of flow is $0.02 m^3 s^{-1}$. If the rate of flow changes uniformly from $0.02 m^3 s^{-1}$ to $0.04 m^3 s^{-1}$ in 30 seconds, find the total acceleration at the middle of the pipe at 15th second.

(10 marks)

Q3)

Assuming that the gradient of the velocity profiles with respect to x can be neglected as compared with respect to y, the asymptotic velocity profile for a laminar boundary layer on a porous flat plate (with zero pressure gradient) with suction could be obtained.

(a) Show that the Prandtl's boundary layer equation reduces to,

$$v\frac{du}{dx} = \nu\frac{d^2u}{dy^2}$$

and

$$\frac{dv}{dy} = 0$$

With boundary conditions,

y=0; u=0

y=δ; u=U (8 Marks)

(b) Introducing suction, $v = -Vw$, show that the solution for Prandtl's equation is given by,

(12 Marks)

$$\frac{u}{U} = 1 - e^{\frac{V_w}{v}y}$$

Q4)

a) Using the diagrams of flow profiles (Figure 4.1) and the partial derivative $(\frac{\partial u}{\partial y})$, explain the occurrence of boundary layer separation for a steady, two-dimensional incompressible laminar flow. (8 Marks)

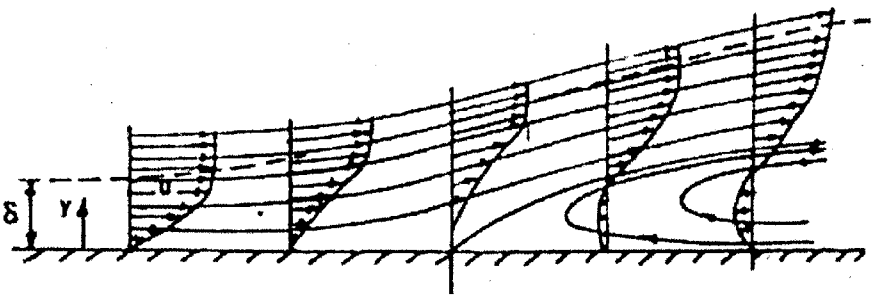

Figure 4.1

b) Derive the following equation from the Prandtl's boundary layer equation at the surface where $u = 0$. Using this equation, explain how the curvature of the velocity profile can be utilized to explain the occurrence of boundary layer separation. You may use the velocity profile diagrams for your explanations. (12 Marks)

$$\frac{dp}{dx} = \mu\left(\frac{\partial^2 u}{\partial y^2}\right)_0$$

Q5)

Figure 5.1 shows a semi-finite plate positioned within a parallel flow. The flow is not subjected to any pressure gradient.

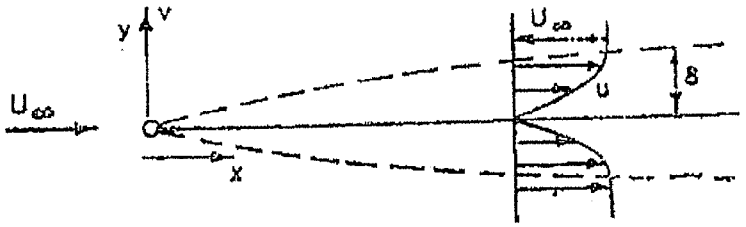

Figure 5.1

a) Using boundary layer equation derive the following expression

(5 Marks)

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2}$$

b) The simplified boundary layer equation obtained in the above question 5 (a) can be solved to obtain simplified equation of motion for boundary layer by employing subjected approximations. Using appropriate approximations, drive the following non-linear third-order differential equation. (7 Marks)

$$f(\eta)\ f''(\eta) + 2f'''(\eta) = 0$$

You may use

$$\delta \propto \sqrt{\nu x/U_\infty}$$

$$\eta = y\sqrt{\frac{U_\infty}{\nu x}} = \frac{y}{\delta}$$

$$\psi = \sqrt{\nu x U_\infty}\, f(\eta)$$

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

c) Use the numerical results of Howarth given in Table 5.1, evaluate the boundary layer thickness δ, Displacement thickness δ^*, and momentum thickness θ for laminar boundary layer on a flat plate. (8 Marks)

Table 5.1: The function η for the laminar boundary layer along a flat plate at zero incidence (After L. Howarth)

$\eta = y\sqrt{\frac{U_\infty}{\nu x}}$	f	$f' = \frac{u}{U_\infty}$	f''
0	0	0	0.33206
0.4	0.02656	0.13277	0.33147
1.0	0.16557	0.32979	0.32301
1.4	0.32298	0.45627	0.30787
2.0	0.65003	0.62977	0.26675
2.4	0.92230	0.72899	0.22809
3.0	1.39682	0.84605	0.16136
3.4	1.74696	0.90177	0.11788
4.0	2.30576	0.95552	0.06424
4.4	2.69238	0.97587	0.03897
5.0	3.28329	0.99155	0.01591
5.4	3.68094	0.99616	0.00793
6.0	4.27964	0.99898	0.00240
6.4	4.67938	0.99961	0.00098
7.0	5.27926	0.99992	0.00022
7.4	5.67924	0.99998	0.00007
8.0	6.27923	1.00000	0.00001
8.4	6.67923	1.00000	0.00000