00053

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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX5206 Applied Fluid Dynamics II**
Academic Year	: 2021/22
Date	: 4th Saturday, March 2023
Time	: 1330-1630hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. Answer **five (05)** Questions only. All questions carry equal marks.
3. Relevant charts/ codes are provided.
4. This is a Closed Book Test (CBT).
5. Answers should be in clear handwriting.
6. Do not use Red colour pen.
7. Take the specific gas constant (R) for air as $0.287 kJ/ kgK$.
8. Density of Water is $1000 kg/m^3$
9. For air $C_v = 0.718\ kJ/kg.K$ and $C_p = 1.005\ kJ/kgK$

Q1 (a) Streamlines in a steady, two-dimensional, incompressible flow field are shown in Figure Q1. The flow in the region can be approximated as irrotational. Sketch a few equipotential curves (curves of constant potential function) in this flow field. Explain how you arrive at the curves you sketch. (5 marks)

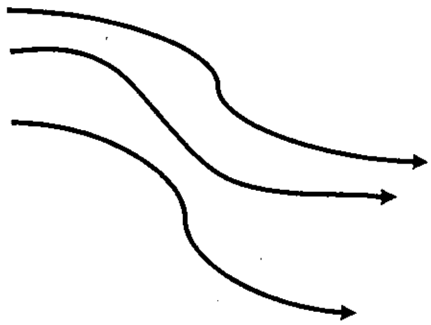

Figure Q1

(b) A steady, two-dimensional, incompressible, irrotational flow field is specified by its velocity potential function, $\emptyset = 5(x^2 - y^2) + 2x + 4y$. (15 marks)

(a) Calculate velocity components u and v.

(b) Verify that the velocity field is irrotational in the region

(c) Generate an expression for the stream function in this region.

Q2 (a) Compare flow separation for laminar and turbulent boundary layers. Specifically, indicate which case is more resistant to flow separation? (5 marks)

(b) The streamwise velocity component of a steady, incompressible, laminar, flat plate boundary layer of thickness, δ is approximated by the simple linear expression, $u = \frac{Uy}{\delta}$ for $y < \delta$, and $u = U$ for $y > \delta$. (15 marks)

(a) Generate expressions for displacement thickness (δ^*) and momentum thickness (θ) as functions of δ, based on this linear approximation.

(b) Compare the approximate values of δ^*/δ and θ/δ to the values of δ^*/δ and θ/δ obtained from the Blasius solution. You may use the equations given in Table 1 if necessary.

Q3 (a) Compare the speed of sound in air at two different pressures, but at the same temperature. (5 marks)

(b) A subsonic airplane is flying at a 3000 m altitude where the atmospheric conditions are 70.109 kPa and 268.65 K. A Pitot static probe measures the difference between the static and stagnation pressures to be 22 kPa. Calculate the speed of the airplane and the flight Mach number. (15 marks)

Q4 (a) Derive an expression for the ratio of the stagnation pressure after a shock wave to the static pressure before the shock wave in terms of ratio of specific heat capacities (k) and the upstream Mach number of the shock wave (Ma1). (6 marks)

(b) Nitrogen enters a converging–diverging nozzle at 700 kPa and 300 K with a negligible velocity, and it experiences a normal shock at a location where the Mach number Ma = 3.0. The properties of nitrogen with usual notation are R= 0.297 kJ/kg.K and k = 1.4). (7 marks)

(a) Calculate pressure, temperature, velocity Mach number, and stagnation pressure for the downstream of the shock. (7 marks)

(b) Compare these results with those of air undergoing a normal shock at the same conditions

Q5 (a) Explain the term "doublet" in the context of flow patterns. (5 marks)

(b) A source of strength 10 $m^2 s^{-1}$ at (1, 0) and a sink of the same strength at (−1, 0) are combined with a uniform flow of 25 $m\ s^{-1}$ in the $-x$ direction. Determine the size of Rankine body formed by the flow and the difference in pressure between a point far upstream in the uniform flow and the point (1, 1). (15 marks)

Q6 Complex potential of flow over a circular cylinder is the sum of the complex potential of a uniform flow and the same of a doublet. Show that the stream function (φ) and potential function ($\emptyset$) of flow over a circular cylinder is given by, (20 marks)

$$\emptyset = U_\infty x\left(1+\frac{a^2}{x^2+y^2}\right)$$

$$\varphi = U_\infty y\left(1-\frac{a^2}{x^2+y^2}\right)$$

You may use following relationships if necessary.
Complex potential of uniform flow = $U_\infty z$
Complex potential of a doublet of strength $\mu = \frac{\mu}{z}$

Q7 (a) Write the Navier stokes equations and explain the significance of each term. (5 marks)

(b) Consider the flow of a viscous Newtonian fluid between two solid boundaries at y = ±h driven by a constant pressure gradient $\nabla p = [-P, 0, 0]$. Show that, (15 marks)

$$u = \frac{P}{2\mu}(h^2 - y^2), v = w = 0$$

u, v, w are the velocity components of the flow in x, y and z directions respectively.

Table 01 : Blasius solution for boundary layer parameters

Property	Laminar	(a) Turbulent[(†)]
Boundary layer thickness	$\frac{\delta}{x} = \frac{4.91}{\sqrt{Re_x}}$	$\frac{\delta}{x} \cong \frac{0.16}{(Re_x)^{1/7}}$
Displacement thickness	$\frac{\delta^*}{x} = \frac{1.72}{\sqrt{Re_x}}$	$\frac{\delta^*}{x} \cong \frac{0.020}{(Re_x)^{1/7}}$
Momentum thickness	$\frac{\theta}{x} = \frac{0.664}{\sqrt{Re_x}}$	$\frac{\theta}{x} \cong \frac{0.016}{(Re_x)^{1/7}}$
Local skin friction coefficient	$C_{f,x} = \frac{0.664}{\sqrt{Re_x}}$	$C_{f,x} \cong \frac{0.027}{(Re_x)^{1/7}}$

END