00054

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	: 2020/2021
Date	: 30th January 2022
Time	: 14.00-17.00hrs
Duration	: **3 hours**

General Instructions

1. Read all the instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer **any 5** questions only.
4. Take acceleration due to gravity as **9.81 N/kg** and the density of water as **1000 kg/m^3** respectively where necessary.

Q1).

a) By considering the rotation of a fluid element, derive an expression for the rotation vector (ω). 5 marks

b) The velocity distribution for a three dimensional flow is given by,

$$V = (a + by - cz)i + (d - bx - ez)j + (f + cx - ey)k$$

Where, *a, b, c, d, e* and *f* are arbitrary constants. 15 marks

I. Show that the flow satisfies the continuity equation.

II. Does the velocity vector (V) represent irrotational flow? if not, determine the vorticity and rotation.

Q2).

a) What is the importance of potential flow theory? 3 marks

b) In the context of potential flow theory, what is the importance of Laplace equation? 5 marks

c) A source and sink of strength 4 m^{2}s^{-1} and 8 m^{2}s^{-1} are located at (-1,0) and (1,0) respectively. Determine the velocity and stream function at a point P(1,1) which is on the flownet of the resultant stream line. 12 marks

Q3).

a) What do you understand by boundary layer thickness? **3 marks**

b) A velocity profile of a boundary layer on a flat plate is given by,

$$\frac{u}{U_0} = \left(\frac{y}{\delta}\right)^{\frac{1}{m}}$$

I. Derive the expressions for the displacement thickness (δ^*) and the momentum thickness (θ). **5 marks**

II. Show that the frictional drag (F_d) force per unit area due to the boundary layer is given by. **12 marks**

$$F_d = \frac{\rho U_0^2 m \delta}{(m+1)(m+2)}$$

Where, ρ=density of the fluid, U_0=free-stream velocity and δ=boundary layer thickness

Q4).

a) By considering the velocity field $V(x,y,z,t)$, write down the expressions for,

I. Material derivative

II. Local acceleration

III. Convective acceleration

6 marks

b) A two dimensional velocity field is given by,

$$V = (0.5 + 0.8x)i + (1.5 - 0.8y)j$$

14 marks

I. Show that the given flow is steady and incompressible.

II. Determine if there are any stagnation points in this flow field.

III. Calculate the velocity and the acceleration at the point x=2m and y=3m

Q5).

a) By considering a differential fluid element in a flow field, write down the expressions for the surface forces and the body forces.

5 marks

b) A steady laminar flow of a viscous incompressible fluid between two long parallel plates with spacing ***b*** is driven by the motion of the lower plate moving at a constant velocity ***U*** as shown in the Figure Q5. By applying suitable boundary conditions and assumptions, show that the velocity profile (**u(y)**) is given in the form,

10 marks

$$u(y) = K_1\left(y^2 - by\right) + U\left(1 - \frac{y}{b}\right)$$

Where K_1 is a constants.

5 marks

c) Find the values of the u(y) for y =0.2cm and y=0.4cm.

[*Take Viscosity =0. 19 Pa s, U=0.6 m* s^{-1}, *b=0.5cm and dp/dx=-0.2 Nm*$^{-3}$]

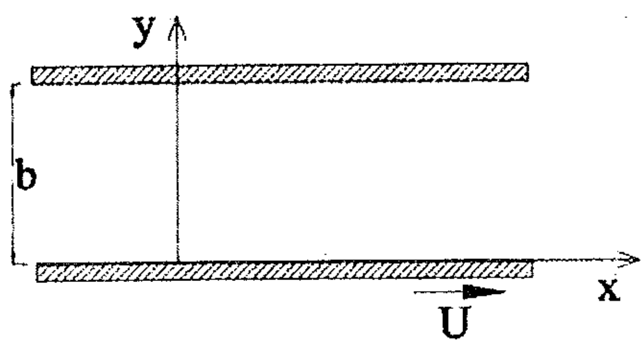

Figure Q5

Q6).

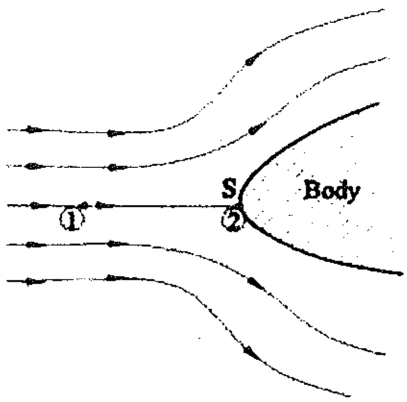

Figure Q6

a) By considering a compressible fluid flowing past an immersed body under frictionless adiabatic conditions as shown in Figure Q6. Show that the stagnation pressure is,

8 marks

$$P_s = P_1\left(1 + \frac{(\gamma - 1)}{2} M_1^{\,2}\right)^{\left(\frac{\gamma}{\gamma - 1}\right)}$$

b) Calculate the pressure, temperature and density at the stagnation point on the nose of a plane which is flying at 800km/hr through still air having a pressure 8.0 Ncm^{-2} (abs.) and temperature -10 ^0C. Take R=287 $Jkg^{-1}K^{-1}$ and γ=1.4.

12 marks

Q7).

a) Discuss the advantages and limitations of CFD with respect to experimental methods.

5 marks

b) Write the steps that should be followed to construct a CFD Flow simulation of a fluid flow through the pipe system given in Figure Q7

15 marks

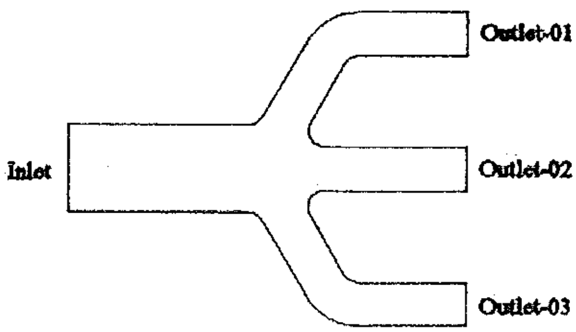

Figure Q7

Q8).

A supersonic jet is travelling at its maximum speed of **V** ms^{-1}, given that the speed of sound is **C** ms^{-1}, show that the Mach angle α can be given by,

5 marks

$$\alpha = \sin^{-1}\left(\frac{C}{V}\right)$$

A supersonic fighter plane of Mach number =2 is flying at an altitude of 6600m. The jet passes above point A at t=0 s as shown in Figure Q8.

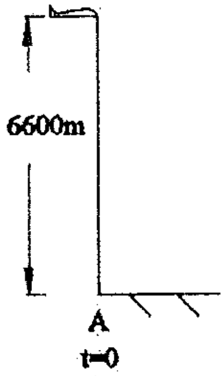

Figure Q8

Taking speed of sound in air as 330 ms^{-1},

5 marks

b) Calculate the time taken for the shock wave to reach point A on the ground.
c) Find the distance the jet has travelled when the shock wave is heard at point A. 10 marks

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Navier-Stokes equations for incompressible flow:-

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=\rho g_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=\rho g_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=\rho g_z-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)$$

Gradient operator in cylindrical coordinates $\nabla = \left(\frac{\partial}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial}{\partial \theta}\hat{\theta} + \frac{\partial}{\partial z}\hat{z}\right)$

End of Paper