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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX 5242 Mechanics of Fluids**
Academic Year	: 2021/22
Date	: 11th February 2023
Time	: 13:30-16:30hrs
Duration	**: 03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **FIVE (05)** questions on **FOUR (04)** pages.
3. Answer **ALL FIVE (05)** questions. All questions carry equal marks.
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 hand writing.
8. Do not use Red colour pen.
9. Take,

   Density of water = 1000 kgm^{-3} Acceleration due to gravity = 9.81 ms^{-2}

   Kinematic viscosity of water = 8.36×10^{-05} m^2/s at 28 °C

Question 01

(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 $t = 3$.

(06 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 $\varphi = (x^2 - y^2) + 3xy$. Compute the flow rate between the streamlines passing through points (1,1) and (2,3).

(06 marks)

Question 02

(a) The following velocity profile is approximated for the boundary layer in a flow over a flat plate,

$$\frac{u}{U_S} = 2\left(\frac{y}{\delta}\right) - 2\left(\frac{y}{\delta}\right)^3 + \left(\frac{y}{\delta}\right)^4$$

where, U_S is the free stream velocity. δ is the boundary layer thickness and y is the distance to a point in the boundary from the flat plate in the normal direction to the flow. The shear stress on the plate is given by,

$$\tau_0 = \frac{37}{315}\rho U_S^2 \frac{\partial \delta}{\partial x}.$$

Show that the friction drag, F_D on one side of the plate is given by,

$$F_D = 0.6855 b\mu U_S\sqrt{\rho U_S L/\mu}$$

where, ρ and μ are the density and the dynamic viscosity of the flowing fluid, respectively. b and L are the width and the length of the flat plate, respectively.

(10 marks)

(b) A kite is in the form of a rectangular airfoil with a chord length of 75 cm and a width of 50 cm. It is maintained at an angle of 12^0 to the horizontal and the string makes an angle 45^0 to the vertical. The weight of the kite is 0.1 kg. If the wind speed is 12 km/hr and the drag coefficient, C_D is 0.23, estimate,

(i) The tension in the string

(ii) The lift coefficient, C_L, if the density of air is 1.2 kg/m^3.

(10 marks)

Question 03

(a) Show that the velocity components, u_r and u_θ corresponding to the flow around a circular cylinder of radius a with a circulation, Γ are given by,

$$u_r = U\left(1 - \frac{a^2}{r^2}\right)\cos\theta$$

$$u_\theta = -\left[U\left(1 + \frac{a^2}{r^2}\right)\sin\theta + \frac{\Gamma}{2\pi r}\right]$$

where, U is the free stream velocity.

When the complex potential for a 2D potential flow having no rigid boundaries in the z-plane is given by, $f(z)$, the complex potential for a flow around a circular cylinder whose radius, $r = a$ is given by,

$$F(z) = f(z) + \overline{f\left(\frac{a^2}{\bar{z}}\right)}$$

(13 marks)

(b) If the stream function associated with a *doublet* in polar coordinates is given by,

$$\psi = -K\frac{\sin\theta}{r}$$

where K is the strength of the *doublet*. Determine,

(i) The velocity and

(ii) The value of the stream function

for a point P (0.6,1.2) is situated in the flow field of a *doublet* of strength 6 m^3/s.

(07 marks)

Question 04

A reservoir supplies water at a steady mean velocity, v to the turbine of a power plant through a long pipe in which the friction loss may be assumed to be proportional to v^2. The system is protected against high-pressure transients by means of a surge tank.

(a) If the flow to the turbine is stopped instantaneously, show that at any time the level in the surge tank, z is related to by an equation of the form,

$$2C_1C_2\left[v\frac{d^2v}{dz^2} + \left(\frac{dv}{dz}\right)^2\right] - 2C_1v\frac{dv}{dz} + 1 = 0$$

The above differential equation has the following solution

$$v^2 = \frac{1}{C_1}(z + C_2) + C_3e^{\frac{z}{C_2}}$$

where, C_1, C_2 and C_3 are constants. (12 marks)

(b) Water from a reservoir is supplied to a power plant through a pipe of diameter 0.75 m and length 1500 m at a steady flow rate of 1.2 m^3/s. A surge tank of diameter 3 m is connected 100 m upstream of the turbine. If the base of the surge tank is 20 m below the free surface of the reservoir, estimate the height of tank required to accommodate instantaneous complete shut-down of the system without overflowing. The friction factor may be assumed constant and equal to 0.006. (08 marks)

Friction head loss along a pipe, $h_f = 4f\frac{l}{d}\frac{v^2}{2g}$

Question 05

(a) Consider a compressible fluid flowing past an immersed body under frictionless adiabatic conditions as shown in Figure Q5. Show that the stagnation pressure, p_2 is given by,

$$p_2 = p_1\left[1+\frac{1}{2}(\gamma-1)Ma_1^2\right]^{\gamma/(\gamma-1)}$$

where, p_1 and Ma_1 are the pressure and the Mach number at a point 1, respectively. γ is the ratio of the specific heat at constant pressure to the specific heat at constant volume.

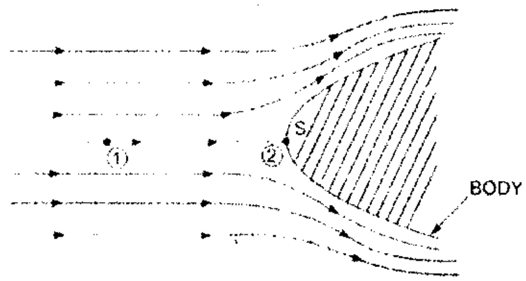

Figure Q5

(13 marks)

(b) An aircraft flying at an altitude where the pressure was 37.5 kPa and the temperature was -30 ^{0}C, stagnation pressure measured was 75 kPa. Assuming γ = 1.4 and R = 287 J/kg.K, calculate the speed of the aircraft. (07 marks)

The Bernoulli's equation for compressible flow undergoing adiabatic process is given by,

$$\left(\frac{\gamma}{\gamma-1}\right)\frac{p}{\rho g}+\frac{v^2}{2g}+z = \text{constant}; \text{ For adiabatic processes, } \frac{p}{\rho^\gamma} = \text{constant}, \quad C = \sqrt{\gamma\frac{p}{\rho}}$$