Ex/CE/PC/B/ME/T/212/2023

B. E. CIVIL ENGG. 2ND YR 1ST SEMESTER EXAMINATION 2023

FLUID MECHANICS

Time: Three Hours **Full Marks: 100**

Assume any relevant data** if necessary **with suitable justifications.
***SYMBOLS** should be **properly described** along with the **necessary SKETCHES** whenever applicable.*
Symbols used in this question paper carry their usual meanings.

Answer any FIVE Questions.
All the parts of a question** must be **answered together.

1. (i) Define the following terms along with proper units and types of quantities (scalar or vector) whenever applicable: fluid, kinematic viscosity, pressure head, manometer, convective acceleration, and Reynolds number.

   (ii) With a neat diagram, explain different kinds of real and ideal fluids. In this context, explain Newtonian and non-Newtonian fluids with some examples.

   (iii) A shaft (of 80 mm diameter) rotates at 1800 rpm in a bearing sleeve (of 80.2 mm diameter and 0.3 m long). The clearance space between the shaft and bearing is flooded with lubricating oil of viscosity 0.1 kg/ms and specific gravity 0.9. With proper assumptions, estimate the resisting torque exerted by the oil and the power required to rotate the shaft. Can the power requirement be reduced using a dilatant lubricant? **[6+(5+2)+(6+1)]**

2. (i) State Pascal's law of hydrostatic pressure and derive the expression of the hydrostatic pressure equation in the Cartesian coordinate system.

   (ii) Using the area moment of Inertia and a simple plane, derive an expression for the depth of the Centre of Pressure of a submerged flat surface. From it, establish that the centre of pressure is always located below the centre of gravity of the plane.

   (iii) A circular plate 2.5 m in diameter is immersed in water its greatest and least depth below the free surface being 3 m and 1 m respectively. Find the total pressure on side of the plate and the position of the centre of pressure.
   [(2+5)+(6+1)+6]

3. (i) Define streamlines, stream function, steady flow, and laminar flow.

   (ii) If $u = 2x^2 + 3y$, $v = -2xy + 3y^2 + 3zy$, and $w = -(3/2)z^2 + 2xz - 9y^2z$ are the components of flow velocity, find the magnitudes and directions of (i) translational velocity, (ii) rotational velocity, (iii) acceleration, and (iv) the vorticity of a fluid element at (1, 1, 1). Is it irrotational flow? **[8+(3×4)]**

4. (i) With a neat sketch and usual symbols, derive the general form of the Continuity equation. How you can use it for one-dimensional unsteady compressible flow and two-dimensional steady incompressible flow?

   (ii) A venturi meter has its axis vertical, the inlet and throat diameters being 150 mm and 75 mm respectively. The throat is 225 mm above the inlet and Cd = 0.96. Petrol of specific gravity 0.78 flows up through the meter at a rate of 0.029 metre cube per second. Find the pressure difference between the inlet and the throat, and the reading recorded by a mercury U-tube manometer. Do you know on which principle this device works? **[(7+3)+(5+4+1)]**

[Turn over

5. (i) Write down the Hagen-Poiseuille's velocity profile for pipe flow. Using it, derive the expression of Hagen-Poiseuille's pressure drop. Mention all the assumptions and flow geometry/situations for the applicability of Hagen-Poiseuille equations.

   (ii) An oil (specific gravity 0.83 and viscosity 0.08 kg/ms) passes through a pipe of 12 mm diameter with a maximum velocity of 4.6 m/s. Determine (a) Reynolds number, (b) mass flow rate in kg/s, (c) friction coefficient f, and (d) pressure gradient along the pipe. **[(1+5+4)+10]**

6. (i) Flow of air at 49°C is measured by a pitot-static tube. If the velocity of air is 18.29 m/s and the coefficient of the tube is 0.95, what differential reading will be shown in a water manometer? Assume the density of air to be constant at 1.2 kg/m^3.

   (ii) A bend in a pipeline conveying water gradually reduces from 0.6 m to 0.3 m in diameter and deflects the flow through an angle of 60°. At the larger end, the gauge pressure is 171.675 kN/m^2. If the frictional head in this bend is 0.5 m, determine the magnitude and direction of the force exerted on the bend when the flow is 876 litres/second. What principles are used to solve this problem? Is it a laminar flow problem? **[6+(10+2+2)]**

7. (i) Stating the appropriate flow conditions/assumptions, derive Chezy's equation for open channel flow (along with a neat sketch indicating all the forces).

   (ii) A channel of the trapezoidal section, having side slopes 3 horizontal to 2 vertical, is to carry a flow of 10m^3/s on a longitudinal slope of 1 in 5000. The channel is to be lined for which the value of friction coefficient in Manning's formula is n = 0.012. Find the dimensions of the economic channel section and identify the state of flow (whether rapid or tranquil). **[(2+6)+(9+3)]**

8. Answer **ANY FOUR** **[5×4 = 20]**

   Write short notes on the following.

   i) Continuum Hypothesis and Knudsen number
   ii) Stability of floating body
   iii) Eulerian and Lagrangian descriptions of fluid flow
   iv) Minor losses in flow through pipes.
   v) Pipes in parallel.
   vi) Hydraulic Jump