Ref. No. Ex/PG/PE/T/112A/2024

M. POWER ENGINEERING FIRST SEMESTER EXAMINATION 2024

SUBJECT: ***APPLIED FLUID MECHANICS***

Time: Three Hours **Full Marks 100**

GRAPH PAPER WILL BE PROVIDED

CO 1: (Answer any one: 30 marks)

1.

(a) A two-dimensional velocity field is given by $u = -Ky/(x^2+y^2)$ and $v = -Kx/(x^2+y^2)$. Comment on the flowing features of the flow field:
(i) Is the flow steady or unsteady?
(ii) Is the flow compressible or incompressible?
(iii) Is the flow rotational or irrotational?
(iv) What is the shear strain rate in the flow at a location (1,1)? **10**

(b) A gas flows along the x axis with a speed of V = 5x m/s and pressure of $p = 10x^2$ N/m^2, where x is in meters. Determine (a) the time rate of change of pressure at the fixed location x = 1 m, (b) the time rate of change of pressure for a fluid element flowing past the point x = 1. **5**

(c) An accident at a nuclear power plant has caused leakage of radioactive steam from time t=0 to t= 5 hr. The power plant is located at x= –20 km, y = 30 km. The following wind velocity conditions are expected: $\vec{V} = (10\hat{i} - 5\hat{j})$ km/h for 0<t< 3 hr, $\vec{V} = (15\hat{i} + 8\hat{j})$ km/h for 3<t< 4 hr and $\vec{V} = 5\hat{i}$ km/h for t>10 hr. Draw in a graph paper, the expected streakline of the radioactive steam for t = 3, 5, and 6 hr. **15**

2.

(a) A layer of oil of thickness h flows down a vertical plate as shown in Fig 2(a) with a velocity of $\boldsymbol{V} = (V_0/h^2)(2hx-x^2)\hat{\boldsymbol{j}}$, where V_0 and h are constants. Calculate (a) the fluid velocity and shear stresses on the wall and the free surface. (c) Determine the flowrate across surface AB. Assume the width of the plate is b and the viscosity of the fluid is μ. **8**

(b) The fluid velocity along the x axis shown in Figure 2(b) changes from 6 m/s at point A to 18 m/s at point B. It is also known that the velocity is a linear function of distance along the streamline. Determine the acceleration at points C. Assume steady flow. **10**

(c) An incompressible, inviscid fluid flows steadily past a sphere of radius a as shown in Fig. P1c. If the fluid velocity along the streamline A—B is given by $\vec{V} = u(x)\hat{\imath} = V_0\left(1 + \frac{a^3}{x^3}\right)\hat{\imath}$, where V_0 is the upstream velocity far ahead of the sphere. Deduce the expression of acceleration experienced by the fluid as it flows along this streamline. **12**

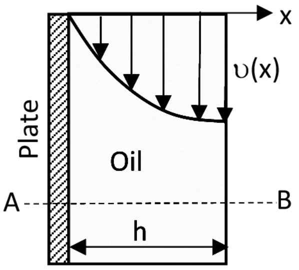

Fig. 2(a)

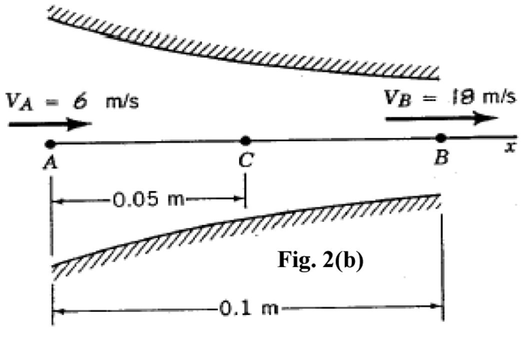

Fig. 2(b)

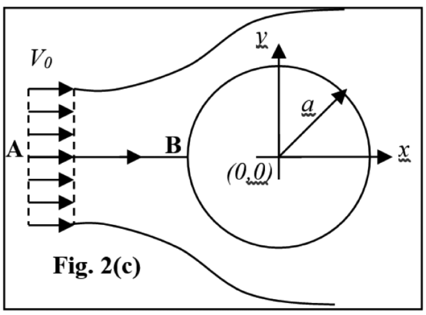

Fig. 2(c)

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CO 2: (Answer any <u>two:30 marks)</u>

3.

(a) (i) Define stream function and state its unit. (ii) What kind of flow may be described by stream function? (iii) In a flow described by stream function, two adjacent stream functions have values of 10 and 20 (appropriate units). Deduce to show what information you get about the flow. (iv) Does the scalar function $\psi(x, y) = 2x^2y - \frac{2}{3}y^3$ represent a realistic flow? **4+3+3+5= 15**

(b) State Reynolds Transport Theorem and describe its purpose. State how the conservation of mass and momentum equations in the differential forms can be deduced using RTT. **3+5+7=15**

(c) Starting from the continuity and momentum equations for a steady, incompressible laminar fully developed flow between a pair of fixed, parallel pates, separated by a distance H, deduce the velocity profile. Consider that the flow is subjected to an axial pressure gradient $G = dp/dx$. Show that the average velocity is $2/3^{rd}$ the maximum velocity. **15**

(d) A continuous belt passing upward through a chemical bath at a velocity U_0 picks up a liquid film of thickness δ, density ρ, viscosity μ. Gravity tends to drain the fluid down, but the movement of the belt keeps the fluid from draining off completely. Assume that the flow is fully developed and the free surface (in contact with air) produces no shear. Starting from the continuity and momentum equations, obtain an expression for the velocity profile. **15**

CO 3: (Answer any <u>one: 40 marks)</u>

4.

(a) Describe the Stokes' First problem. State the governing differential equation and the underlying assumptions and impose the appropriate boundary condition. **15**

(b) Suggest an appropriate similarity variable and convert the PDE describing the flow into and ODE. **15**

(c) Suggest how the final ODE may be solved with a qualitative graphical description of the variation of the similarity parameter. **10**

5.

(a) Starting from the continuity and momentum equations for a 2-D, steady flow in Cartesian coordinate system, deduce the governing equations for a boundary layer flow over a flat plate. **15**

(b) Using a similarity variable $\eta = \sqrt{\frac{U_\infty}{\nu}}\frac{y}{\sqrt{x}}$, with the symbols having their usual meaning, reduce the governing PDE into an ODE and apply the appropriate boundary condition to deduce the final form of the ODE as $2f''' + f \cdot f'' = 0$, where f has its standard meaning. **15**

(c) Show that the boundary layer thickness for such flow grows proportional to $\sqrt{x}$ where x denotes the distance from the leading edge of the plate. Express the wall shear stress as a function of the similarity variable. **10**