(vi) Reynolds number is defined as the
(a) ratio of inertia force to gravity force
(b) ratio of viscous force to gravity force
(c) ratio of viscous force to elastic force
(d) ratio of inertia force to viscous force.

(vii) $\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0$ this equation is known as
(a) Newton's Equation (b) Laplace Equation
(c) Thomas's Equation (d) Darcy Equation.

(viii) At the point of separation of boundary layer
(a) velocity is negative (b) shear stress is zero
(c) shear stress is maximum (d) pressure gradient is zero.

(ix) The drag force on a body is the
(a) net frictional force on the body
(b) net pressure force on the body in the direction of the relative velocity
(c) component of the resultant force in the direction of the relative velocity
(d) component of the resultant force in a direction perpendicular to the direction of gravity.

(x) The repeating variables in dimensional analysis should
(a) be equal in number to that of the fundamental dimensions involved in the problem variables
(b) include the dependent variable
(c) have at least one variable containing all the fundamental dimensions
(d) collectively contain all the fundamental dimensions.

Group - B

2. (a) A circular plate 3 m diameter is immersed in water in such a way that the plane of the plate makes an angle of 60° with the free surface of water. Determine the total pressure and position of centre of pressure when the upper edge of the plate is 2m below the free surface.

(b) A rectangular block of width 'b' and submerged depth 'H' floating in water with its axis vertical, has its centre of gravity at the waterline. Find the metacentric height in terms of (b/H) and hence show that for stable equilibrium of the block $\frac{b}{H} > \sqrt{6}$.

6 + 6 = 12

(b) With neat sketch, explain effect of pressure gradient on boundary layer separation over a curved surface

(3 + 3 + 3) + 3 = 12

9. (a) Calculate the diameter of a hemispherical parachute to be used for dropping an object of mass 100 kg, so that the maximum terminal velocity of dropping is 5m/s. For the parachute the drag coefficient is 1.3. The density of air is 1.216 kg/m^3. Neglect weight of the parachute.

(b) The resisting force of a supersonic plane during flight can be considered as dependent upon the length of aircraft L, velocity V, air viscosity μ, air density ρ and bulk modulus of air K. Express the functional relationship between these variables and resisting force.

4 + 8 = 12

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FLUID MECHANICS
(MECH 2103)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The piezometric head of a flow is
(a) the sum of the velocity head and datum head
(b) the sum of the pressure head and datum head
(c) the sum of the velocity head and pressure head
(d) the sum of the velocity head, datum head and pressure head.

(ii) The coefficient of lift and drag are independent of the size of the body but depends on the shape and __________ of the flow.
(a) Euler number (b) Reynolds number
(c) Weber number (d) Mach Number.

(iii) If the meta centric height is negative then the floating body is in under
(a) stable equilibrium (b) un-stable equilibrium
(c) neutral equilibrium (d) both (a) & (b).

(iv) The flow of a liquid at constant rate in a conically tapered pipe is classified as
(a) steady, uniform flow (b) steady, non-uniform flow
(c) unsteady, uniform flow (d) unsteady, non uniform flow.

(v) A flow is said to be rotational when
(a) the streamlines are curved
(b) a velocity gradient in the normal direction to flow exists
(c) every fluid element has finite angular velocity about its mass centre
(d) every fluid element has an angular velocity about a common axis.

3. (a) The velocity vector in a two-dimensional flow field is given by $\mathbf{V} = 2x^3\mathbf{i} - 6x^2y\mathbf{j}$.
   (i) Verify whether flow is possible.
   (ii) Check whether the flow is rotational or irrotational. If rotational, determine the angular velocity, shear strain rate and linear strain rates.

   (b) The velocity for a steady, incompressible fluid flow in the ***x-y*** plane is given by $\mathbf{V} = \left(\frac{2}{x}\right)\mathbf{i} + \left(\frac{2y}{x^2}\right)\mathbf{j}$ where velocity is in m/s and the coordinates are measured in m. Obtain an equation for the streamline that passes through the point (x, y) = (1, 3).

   (c) Define: stream function.

(2 + 4) + 4 + 2 = 12

Group - C

4. (a) State Euler's equation of motion along a streamline.

   (b) A vertical venturi meter carries water and has inlet and throat diameters of 150 mm and 75 mm respectively. The pressure connection at the throat is 150 mm above that at the inlet. If the actual rate of flow is 40 litre/s and the coefficient of discharge is 0.96, calculate
   (i) the pressure difference between inlet and throat, and
   (ii) the difference of the levels in a vertical U-tube mercury manometer connected between these points, the tubes above the mercury being full of water.

   (c) A pitot static tube is used to measure the velocity of water in a pipe. The stagnation pressure head is 6 m and static pressure head is 5 m. Calculate the velocity of flow assuming the coefficient of velocity for the tube equal to 0.98.

2 + (3 + 3) + 4 = 12

5. (a) Considering 2-D flow, derive the expression of force exerted by a flowing fluid on a pipe bend (inclination θ with horizontal).

   (b) Water flows over a rectangular weir of 1m wide at a depth of 150 mm and afterwards passes through a right-angled triangular weir. Taking the discharge coefficients of the triangular and rectangular

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weirs as 0.59 and 0.62 respectively, find the depth over the triangular weir.

6 + 6 = 12

Group - D

6. (a) Glycerin (relative density 1.26, viscosity 0.9 N.s/m^2) is pumped at 20 litre/s through a straight, 100mm diameter pipe, 45m long, inclined upwards at 15° to the horizontal. The piezometric pressure (gauge) at the lower inlet end of the pipe is 590 kN/m^2. Verify that the flow is laminar and, neglecting 'end effects', calculate the pressure at the outlet end of the pipe and the shear stress at the wall. Assume lower inlet end of pipe as datum reference level.

(b) For laminar viscous flow in a circular pipe of radius '***R***', at what radius '*r*' from the axis of pipe, does the local velocity equal the average velocity of flow?

(c) State Hagen-Poiseuille equation along with its assumptions.

5 + 5 + 2 = 12

7. (a) What is meant by minor losses in pipes?

(b) Show that, the losses in the pipe due to sudden enlargement from cross-section area A_1 to A_2 is given by

$h_{\exp} = \left[1 - \left(\frac{A_1}{A_2}\right)\right]^2 \frac{V_1^2}{2g} = k_{\exp}\frac{V_1^2}{2g}$ where $k_{\exp}$ = expansion loss coefficient, V_1 is the average velocity at cross-section area A_1.

(c) A smooth wrought iron pipe 200 mm in diameter conveys crude oil at a velocity of 3 m/s. Find the loss of head per 100 m length of pipe. Take kinematic viscosity of crude oil as 0.5 stoke.

2 + 5 +5 = 12

Group - E

8. (a) Find the displacement thickness $\left(\delta^*\right)$, the momentum thickness $\left(\theta\right)$ and shear stress at wall (τ_ω) for the velocity distribution in the boundary layer given by $u/U = 2(y/\delta) - (y/\delta)^2$, where u is the velocity (parallel to the plate) at a distance y (measured vertically upward) from the plate and $u = U$ at $y = \delta$, where δ is the boundary layer thickness.

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