

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : $1 \times 10 = 10$
 - (i) Define specific heat of a body.
 - (ii) Define surface of equal pressure.
 - (iii) For an irrotational flow $\text{curl } \vec{q} \neq 0$.
(State True or False)
 - (iv) State Charle's law.
 - (v) Name the instrument used to measure atmospheric pressure.
 - (vi) What is tube of flow ?

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- (vii) What is the physical meaning of $\text{curl } \vec{q}$?
- (viii) Define absolute zero of temperature.
- (ix) Name the two methods of treating the general problem of Hydrodynamics.
- (x) What is meant by rotational flow ?

2. Answer the following questions : $2 \times 5 = 10$

- (a) Show that the surface of equal pressure is intersected orthogonally by the lines of force.
- (b) If ρ_0 and ρ be the densities of a gas at 0° and t° centigrade respectively, then establish the relation $\rho_0 = \rho(1 + \alpha t)$

where $\alpha = \frac{1}{273}$.

- (c) Establish the relation between local and individual time rate of change.
- (d) What is meant by velocity potential ? Does velocity potential exist for a rotational flow ?
- (e) Define streamline and path line of a fluid particle.

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3. Answer **any four** of the following questions :
 $5 \times 4 = 20$

- (a) A mass of fluid is at rest under the forces
 $X = (y+z)^2 - x^2$, $Y = (z+x)^2 - y^2$,
 $Z = (x+y)^2 - z^2$; find the density and the surfaces of equal pressure.
- (b) A fluid at rest is in equilibrium in the forces field $X = y^2 + z^2 - xy - zx$,
 $Y = z^2 + x^2 - yz - yx$,
 $Z = x^2 + y^2 - zx - zy$. Show that the curves of equal pressure and density are a set of circles.
- (c) If the absolute temperature T at a height z is a function of the pressures at two heights z_1 and z_2 then show that

$$\log \frac{p_2}{p_1} = -\frac{g}{R} \int_{z_1}^{z_2} \frac{dz}{f(z)}$$

R being the constant in the equation $p = R\rho T$.

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- (d) The velocity components of a flow in cylindrical polar coordinates are $(r^2 z \cos \theta, rz \sin \theta, z^2 t)$. Determine the components of the acceleration of a fluid particle.

- (e) Test whether the motion specified by

$$\vec{q} = \frac{k^2 (xi - yj)}{x^2 + y^2}, \quad k \text{ is constant, is a}$$

possible motion for an incompressible fluid. If so, determine the equations of streamlines.

- (f) The particles of a fluid motion move symmetrically in space with regard to a fixed centre; prove that the equation of

$$\text{continuity is } \frac{\partial \rho}{\partial t} + u \frac{\partial \rho}{\partial r} + \frac{\rho}{r^2} \frac{\partial}{\partial r} (ur^2) = 0,$$

where u is the velocity at a distance r .

4. Answer **any four** parts : $10 \times 4 = 40$

- (a) (i) Show that $x^2 \tan^2 t + \frac{y^2}{b^2} \cot^2 t = 1$ is a possible form of bounding surface of a liquid.

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- (ii) Two volumes V_1 and V_2 of different gases at pressures P_1 and P_2 and absolute temperatures T_1 and T_2 are mixed together, so that the volume of the mixture is V and absolute temperature is T . Prove that the pressure of the mixture is

$$\frac{T}{V} \left(\frac{P_1 V_1}{T_1} + \frac{P_2 V_2}{T_2} \right).$$

- (b) (i) A mass of homogeneous liquid, contained in a vessel, revolves uniformly about a vertical axis. Determine the pressure at any point and the surfaces of equal pressure.

- (iii) Show that the centre of pressure of a circular area immersed in the liquid whose centre is at a depth h below the surface, when the density of the liquid varies as the depth, is

$$\text{at a depth } \frac{2a^2 h}{a^2 + 4h^2} \text{ below the}$$

centre of the circle, where a is the radius of the circular area.

- (c) (i) A liquid of given volume V is at rest under the forces

$$X = \frac{\mu x}{a^2}, Y = -\frac{\mu y}{b^2}, Z = -\frac{\mu z}{c^2}. \quad \text{Find}$$

the pressure at any point of the liquid and the surfaces of equal pressure.

- (ii) For a perfect gas, establish the relation $C_p - C_v = R$, where the symbols have their usual meanings.

- (d) Obtain Euler's equation of motion for a non-viscous fluid in the form

$$\frac{D\vec{q}}{Dt} = \vec{F} - \frac{1}{\rho} \vec{\nabla} P.$$

- (e) Obtain the equation of continuity for a fluid in motion in the form

$$\frac{\partial p}{\partial t} + \text{div}(\vec{p}\vec{q}) = 0 \quad \text{where } p \text{ and } \vec{q} \text{ are}$$

respectively the density and the velocity of the fluid. Deduce the form of equation of continuity when the fluid is homogeneous and incompressible.

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- (f) Stream is rushing form a boiler through a conical pipe, the diameters of the ends of which are D and d ; if V and v be the corresponding velocities of the stream and if the motion be supposed to be that of divergence from the vertex of the cone,

$$\text{prove that } \frac{v}{V} = \frac{D^2}{d^2} e^{\frac{v^2 - V^2}{2k}} \quad \text{where } k \text{ is the pressure divided by the density and suppose constant.}$$

- (g) Prove that if the forces per unit of mass at (x, y, z) parallel to the axes are $y(a-z), x(a-z), xy$; the surface of equal pressure are hyperbolic paraboloid and the curves of equal pressure and density are rectangular hyperbolas.

- (h) A hemispherical bowl is filled with water and two vertical planes are drawn through its central radius, cutting off a semilune of the surface, if 2α be the angle between the planes, prove that the angle which the resultant pressure on the surface makes with the vertical is

$$\tan^{-1} \left(\frac{\sin \alpha}{\alpha} \right)$$

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