S'07 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc) should be answered at one place.

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Group A

1. (*a*) What is viscosity? Discuss its role in fluid flow and the factors on which shear stress rate depends in a flowing fluid. Give examples of different kinds of fluids from day-to-day life under different categories. 10

(*b*) A cylindrical gate of 4 m dia and 2 m long has water on its both sides as shown in Fig. 1. Determine the magnitude and direction of the resultant force exerted by the water on the gate. Also, find the least weight of the cylinder so that it may not be lifted away from the floor. 10

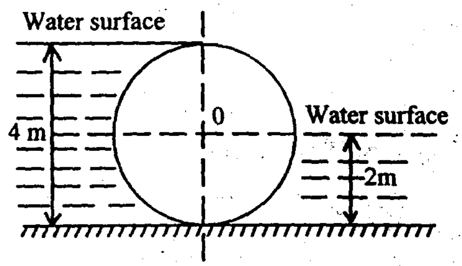

Fig. 1

2. (*a*) A liquid of specific gravity 1·52 is discharged from a tank through a siphon whose summit point is 1·2 m above the liquid level in the tank. The siphon has a uniform diameter of 10 cm and it discharges the liquid into atmosphere whose pressure is 101 kPa. If the vapour pressure of the liquid is 2δ kPa (abs), how far below the liquid level in the tank can the outlet be safely located? What is the maximum discharge? Neglect all losses of head. 10

(*b*) Determine the hydrodynamic force on a uniform 90° pipe elbow of 15 cm diameter through which water flows at a constant velocity of 8·4 m/s and constant pressure of 116 kPa (gauge). Assume the elbow to be in horizontal plane. 10

3. (*a*) Starting from continuity and momentum equations, derive the governing equation for Couette flow. Determine velocity profile when lower plate is stationary and upper plate moves with velocity U for different pressure gradient situation. 12

(*b*) What do you understand by constitutive relations for a fluid? Discuss their importance. 8

4. (*a*) Using order of term approach, obtain boundary layer equations. Discuss nature of these equations. 8

(*b*) Two reservoirs, whose water level elevations differ by 12 m, are connected to the following horizontal compound pipes starting from the higher level reservoir: $L_1 = 200$ m, $D_1 = 0{\cdot}2$ m, $f_1 = 0{\cdot}008$ and $L_2 = 500$ m, $D_2 = 0{\cdot}3$ m, $f_2 = 0{\cdot}006$. Considering all head losses and assuming that all changes of section are abrupt, compute the discharge through the system. Determine the equivalent length of a 0·25 m diameter pipe, if minor losses are neglected and friction factors are assumed to be same. 12

Group B

5. (*a*) Water flows into atmosphere through a vertical bend nozzle assembly, as shown in *Fig. 2*. The pipe diameter is 10 cm and the nozzle exit diameter 5 cm. The flow rate of water is 2400 lpm. The interior volume of the assembly is 18·2 litre. The head loss in bend is $0{\cdot}5\ V^2/2g$ and in the nozzle it is $2\ V^2/2g$, where V is the flow velocity in the pipe. Compute the hydrodynamic force on the system. 12

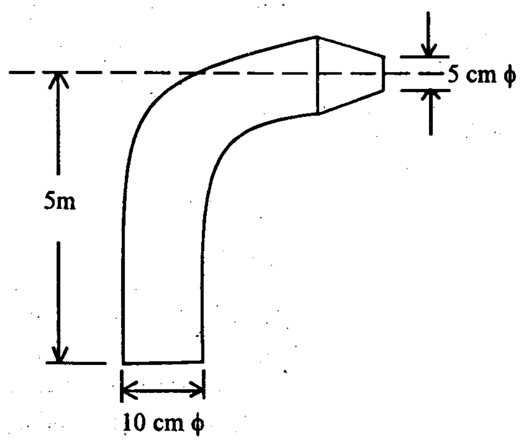

Fig. 2

(*b*) Define mixing length and explain its importance in the analysis of flow through pipes. 8

6. (*a*) In a gas flow through a convergent nozzle, the gas at exit is always cooler than the gas at entrance. Explain the phenomenon. 7

(*b*) Define Rayleigh and Fanno lines. 7

(*c*) A shell is fired from a field gun with a velocity of 400 m/s in air. What is the maximum rise in its skin temperature? 6

7. (*a*) Determine the velocity field in a flow developed by placing a source in uniform flow. 10

(*b*) Name the flow measuring methods used for flow measurement in open channels. Under what conditions would you suggest to use (*i*) V notch, (*ii*) Rectangular notch, or (*iii*) weir and why? 10

8. Write short notes on the following: 6 + 8 + 6

(*a*) Boundary layer and its control

(*b*) Venturimeter

(*c*) Turbulent boundary layer.

Group C

9. Choose the *correct* answer for the following: 1 × 20

(*i*) One SI unit of viscosity is equal to

(*a*) 10 poise

(*b*) 981 poise

(*c*) 0·1 poise

(*d*) None of these

(*ii*) Pressure head of a fluid is the ratio of pressure to

(*a*) fluid height

(*b*) specific weight

(*c*) density

(*d*) specific gravity

(*iii*) In a differential manometer, the flowing fluid is water and the gauge fluid is mercury. If the manometer reading is 10 cm, the differential head in *m* of water is

(*a*) 13·6

(*b*) 1·36

(*c*) 1·47

(*d*) 1·26

(*iv*) Along a stream line,

(*a*) velocity is constant

(*b*) ϕ is zero

(*c*) ψ is zero

(*d*) ψ is constant

(*v*) Doublet is a combination of

(*a*) source and vortex

(*b*) source and sink

(*c*) source and uniform flow

(*d*) None of these

(*vi*) Flow in a whirlpool in a river is an example of

(*a*) free vortex

(*b*) spiral vortex

(*c*) forced vortex

(*d*) radial vortex

(*vii*) The coefficient of contraction of a sharp-edged small orifice under normal conditions is

(*a*) 0·985

(*b*) 0·82

(*c*) 0·707

(*d*) 0·62

(*viii*) An error of 1·5 mm is committed in the measurement of head over a triangular notch. The head over the notch is 0·5 m. The percent error in computing discharge is

(*a*) 0·5

(*b*) 0·75

(*c*) 1·5

(*d*) 3·0

(*ix*) In series pipes, the parameter which is same in each pipe is

(*a*) h_f

(*b*) Q

(*c*) f

(*d*) None of these

(*x*) The following is not a minor loss :

(*a*) friction loss

(*b*) bend loss

(*c*) enlargement loss

(*d*) contraction loss

(*xi*) In laminar flow between two fixed parallel plates, the ratio of average to maximum velocities is

(*a*) 1/3

(*b*) 1/2

(*c*) 2/1

(*d*) 2/3

(*xii*) In which of the following types of flows, the shear stress is uniform across the cross-section:

(*a*) Simple Couette flow

(*b*) Generalised Couette flow

(*c*) Poiseuille flow

(*d*) None of these

(*xiii*) The thickness of a laminar boundary layer on a flat plate varies as

(*a*) x

(*b*) $x^{1/2}$

(*c*) $x^{-1/2}$

(*d*) $x^{1/7}$

(*xiv*) The average drag coefficient of a laminar layer is

(*a*) $\frac{1 \cdot 328}{\sqrt{R_e}}$

(*b*) $\frac{0 \cdot 664}{\sqrt{R_e}}$

(*c*) $\frac{0 \cdot 0587}{R_e^{1/5}}$

(*d*) $\frac{0 \cdot 0735}{R_e^{1/5}}$

(*xv*) Reynolds turbulent shear stress is given by

(*a*) $\varrho l \bar{u}$

(*b*) $\varrho \bar{u}' \bar{v}'$

(*c*) $\varrho \frac{du}{dy}$

(*d*) $\nu \frac{du}{dy}$

(*xvi*) In a given rough pipe, the losses depend on

(*a*) Q

(*b*) R_e

(*c*) μ, ϱ

(*d*) f, D, V

(*xvii*) Kinematic eddy viscosity has units

(*a*) poise

(*b*) pascal

(*c*) N/s

(*d*) m^2/s

(*xviii*) Effect of compressibility of fluid can be neglected if Mach number is

(*a*) 0·3 to 1·0

(*b*) < 0·3

(*c*) > 0·1

(*d*) None of these

(*xix*) In a diverging passage, the velocity of supersonic flow

(*a*) decreases linearly

(*b*) decreases exponentially

(*c*) increases

(*d*) remains constant

(*xx*) Across a normal shock in compressible fluid, there is

(*a*) increase in p and decrease in M

(*b*) increase in p and s and decrease in M

(*c*) increase in p, M and no change in s

(*d*) increase in p, M and T

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Group A

1. (*a*) Define (*i*) specific gravity, (*ii*) vapour pressure, (*iii*) viscosity, (*iv*) compressibility, and (*v*) surface fension. 2×5

(*b*) Explain the terms (*i*) total pressure, and (*ii*) centre of pressure. 4

(*c*) A circular plate, 2·50 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 (*i*) total pressure on one face of the plate, and (*ii*) position of centre of pressure. 6

2. (*a*) Explain the terms (*i*) metacentre, and (*ii*) metacentric height. 4

(*b*) A wooden cylinder of circular section, uniform density, and specific gravity 0·6, is required to float in oil of specific gravity 0·8. If the diameter of the cylinder is d and its length is l, show that l cannot exceed 0·817 d for cylinder to float with its longitudinal axis vertical. 6

(*c*) Distinguish between streamline, path line, and streak line. 3

(*d*) Define (*i*) rotational and irrotational flow, and (*ii*) uniform and non-uniform flow. 3

(*e*) A stream function is given by $\psi = 3x^2 - y^3$. Determine the magnitude of velocity components at point (2, 1). 4

3. (*a*) Derive Bernoulli's equation from Euler's equation of motion. 6

(*b*) A venturi meter, having a diameter of 75 mm at the throat and 150 mm diameter at the enlarged end, is installed in a horizontal pipeline 150 mm in diameter carrying an oil of specific gravity 0·9. The difference in pressure head between the enlarged end and the throat recorded by on U-tube is 175 mm of mercury. Determine the discharge through the pipe. Assume the coefficient of discharge of the meter as 0·97. 6

(*c*) Derive an expression for mean velocity for laminar flow between parallel plates. 8

4. (*a*) Explain the characteristics of laminar and turbulent layer. 6

(*b*) Show that, for laminar flow in circular pipes, the friction factor is inversely proportional to the Reynolds number. 6

(*c*) A smooth brass pipeline, 75 mm in diameter and 900 m long, carries water at the rate of 7 litres/sec. If the kinematic viscosity of the water is 0·0195 stokes, calculate the loss of head, wall shearing stress, centre line velocity and thickness of the laminar sublayer. Take $\varrho = 1000$ kg/m^3. 8

Group B

5. (*a*) Discuss the phenomenon of separation in a diverging flow. 8

(*b*) If a laminar boundary layer at zero pressure, gradient over a flat plate is described by the velocity profile

$$V / V_0 = 3/2\ \eta - \eta^3/2$$

in which $\eta = (y/\delta)$. Show that the boundary layer thicknes, δ, wall shear strees J_0 and coefficient of drag C_D are given by

$$\delta = \frac{4{\cdot}65\,x}{\sqrt{Re_x}}; \quad \tau_0 = \frac{0{\cdot}322\,\varrho\,V_0^2}{\sqrt{Re_x}}$$

$$C_D = 1{\cdot}328/\sqrt{Re_L}.$$ 12

6. (*a*) Obtain an expression for the sound wave in a compressible fluid in terms of change of pressure and change of density. 8

(*b*) Define Mach number and explain its significance in compressible fluid flow. 4

(*c*) Find the velocity of air flowing at the outlet of a nozzle, fitted to a large vessel which contains air at a pressure of 29·43 bar (abs) and at a temperature of 20°C. The pressure at the outlet of the nozzle is 20·6 bar (abs). Take $K = 1{\cdot}4$ and $R = 287$ J/kgK. 8

7. (*a*) Define the terms (*i*) Vortex flow, (*ii*) Forced vortex flow, and (*iii*) Free vortex flow. 6

(*b*) Derive, from first principles, the condition for irrotational flow. Prove that, for potential flow, both the stream function and velocity function satisfy the Laplace equation. 10

(*c*) Describe the use and limitations of the flow nets. 4

8. Write short notes on the following: 5×4

(*i*) Orifice meter

(*ii*) Pitot tube

(*iii*) Source and sink pair

(*iv*) Doublet.

Group C

9. Choose the *correct* answer for the following: 2×10

(*i*) Poise is the unit of

(*a*) mass density

(*b*) kinematic viscosity

(*c*) viscosity

(*d*) velocity potential

(*ii*) The point of action of hydrostatic force is known as

(*a*) centre of gravity

(*b*) centre of buoyancy

(*c*) centre of pressure

(*d*) meta centre

(*iii*) Bernoulli's theorem deals with law of conservation of

(*a*) mass

(*b*) momentum

(*c*) energy

(*d*) None of the above

(*iv*) The coefficient of friction for laminar flow through a circular pipe is given by

(*a*) $f = 0{\cdot}791/Re^{1/4}$

(*b*) $f = 16/Re$

(*c*) $f = 64/Re$

(*d*) $f = 32/Re$

(*v*) The boundary layer separation takes place if

(*a*) pressure gradient is zero

(*b*) pressure gradient is positive

(*c*) pressure gradient is negative

(*d*) pressure gradient is constant

(*vi*) Compressibility is equal to

(*a*) $(dV / v) / dP$

(*b*) $dP / -(dV / v)$

(*c*) $dP / d\varrho$

(*d*) $\sqrt{dP / d\varrho}$

(*vii*) When the fluid is at rest the shear stress is

(*a*) maximum

(*b*) zero

(*c*) minimum

(*d*) None of the above

(*viii*) For a floating body, if the metacentre coincides with the centre of gravity, the equilibrium is called

(*a*) stable

(*b*) unstable

(*c*) neutral

(*d*) None of the above

(*ix*) An oil of specific gravity 0·7 and pressure 0·14 kgf/cm ^{2} will have the height of oil as

(*a*) 70 cm of oil

(*b*) 2 m of oil

(*c*) 20 cm of oil

(*d*) 14 cm of oil

(*x*) The velocity distribution across a section of a circular pipe having viscous flow is given by

(*a*) $u = u_{max} [1 - (r)_R)^2]$

(*b*) $u = u_{max} [R^2 - r^2]$

(*c*) $u = u_{max} [1 - r / R]^2$

(*d*) None of the above.

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Group A

1. (*a*) Define (*i*) weight density, (*ii*) specific volume, (*iii*) capillarity, and (*iv*) Newton's law of viscosity. 4×2

(*b*) Derive an expression for the force exerted on a submerged vertical plane surface by the static liquid and locate the position of centre of pressure. 7

(*c*) An oil of viscosity 5 poise is used for lubrication between a shaft and sleeve. The diameter of the shaft is 0·5 m and it rotates at 200 rpm. Calculate the power lost in oil for a sleeve length of 100 mm. The thickness of oil film is 1·0 mm. 5

2. (*a*) With neat sketches, explain the condition of equilibrium of submerged bodies. 7

(*b*) Define (*i*) steady and unsteady flow, (*ii*) one, two and three-dimensional flow, and (*iii*) laminar and turbulent flow. 3 × 2

(*c*) Show that a cylindrical buoy of 1 m diameter and 2 m height weighing 7·848 kN will not float vertically in sea water of density 1030 kg/m^3. 7

3. (*a*) Derive an expression for continuity equation for a three-dimensional flow. 10

(*b*) A venturimeter of 30 cm inlet diameter and 15 cm throat diameter is provided in a vertical pipeline carrying oil of specific gravity 0·9, the flow being upward. The difference in elevation of the throat section and entrance section of the venturimeter is 30 cm. The differential U-tube mercury manometer shows a gauge deflection of 25 cm. Calculate the (*i*) discharge of oil, (*ii*) pressure difference between the entrance section and the throat section. Take coefficient of meter as 0·98 and specific gravity of mercury as 13·6. 10

4. (*a*) Derive an expression for the velocity distribution for viscous flow through a circular pipe. Also, sketch the velocity distribution and shear stress distribution across the section of pipe. 8

(*b*) Explain, with necessary sketch, the following: 5

(*i*) Laminar boundary layer

(*ii*) Turbulent boundary layer

(*iii*) Laminar sub-layer

(*iv*) Boundary layer thickness.

(*c*) A laminar flow is taking place in a pipe of diameter 200 mm. The maximum velocity is 1·5 m/s. Find the mean velocity and the radius at which this occurs. Also, calculate the velocity at 4 cm from the wall of the pipe. 7

Group B

5. (*a*) Derive the expression for the loss of head due to friction in pipe

$$h_f = 4fLV^2/2g \times d$$

where h_f is the loss of head due to friction; L, the length of the pipe; f, the coefficient of friction; v, the velocity; and d, the diameter of pipe. 10

(*b*) A smooth pipe of diameter 400 mm and length 800 m carries water at the rate of 0·04 m^3/s. Determine the head lost due to friction, wall shear stress, centre-line velocity and thickness of laminar sub-layer. Take the kinematic viscosity of water as 0·018 stokes. 10

6. (*a*) For a compressible fluid flowing through the nozzle, the area velocity relationship is given by the equation

$$(dA/A) = (dV/V)\,[M^2 - 1]$$

where A is the area of the nozzle; V, the velocity of the fluid; and M, the Mach number. Prove the above equation. Using this equation, sketch the shape of the nozzle and diffuser. 12

(*b*) Determine the exit velocity and mass flow rate for isentropic flow of air through a nozzle from inlet stagnation conditions of 7 bar and 320 °C to an exit pressure of 1·05 bar and the exit area of the nozzle is 6·25 cm^2. Also, determine the throat area of the nozzle. Assume $\chi = 1·4$. 8

7. (*a*) Define (*i*) stream lines, (*ii*) path lines, and (*iii*) streak lines. 3 × 1

(*b*) A fluid flow field is given by

$$V = x^2 yi + y^2 zj - (2xyz + yz^2)\,k$$

Prove that it is a case of possible steady incompressible fluid flow. Calculate the velocity at the point (2, 1, 3). 6

(*c*) Define (*i*) vortex flow, (*ii*) forced vortex flow, and (*iii*) free vortex flow. 3 × 1

(*d*) Prove that, in case of forced vortex, the rise of liquid level at the ends is equal to the fall of liquid level at the axis of rotation. 8

8. (*a*) Define an orifice meter. Prove that the discharge through an orifice meter is given by

$$Q = C_d\, a_0 a_1 \sqrt{2gh}/\sqrt{a_1^2 - a_0^2}$$

where a_1 is the area of pipe; a_0, the area of orifice; c_d, the coefficient of discharge. 10

(*b*) An orifice meter with diameter 15 cm is inserted in a pipe of 30 cm diameter. The pressure difference measured by a mercury oil differential manometer on two sides of the orifice meter gives a reading of 50 cm of mercury. Find the rate of flow of oil of specific gravity 0·9 when the coefficient of discharge of the meter is 0·64. 6

(*c*) What is the difference between pitot tube and pitot static tube? 4

Group C

9. Choose the *correct* answer for the following: 1 × 20

(*i*) The buoyant force for the floating body passes through the

(*a*) centre of gravity of the body.

(*b*) meta-centre of the body.

(*c*) centroid of the displaced volume.

(*ii*) The pressure difference between inside and outside of a droplet of water is given by

(*a*) $2\sigma/d$

(*b*) $4\sigma/d$

(*c*) $8\sigma/d$

(*d*) None of the above.

(*iii*) An ideal fluid is one which

(*a*) is frictionless and incompressible.

(*b*) is viscous.

(*c*) obey's Newton's law of viscosity.

(*d*) All of the above.

(*iv*) The position of centre of pressure of a plane surface immersed in a static fluid is

(*a*) at the centroid of the submerged surface.

(*b*) always above centroid.

(*c*) always below centroid.

(*d*) None of the above.

(v) Stream lines and path lines always coincide in

(a) steady flow

(b) uniform flow

(c) non-uniform flow

(d) laminar flow.

(vi) Navier-Stokes equations are useful in the analysis of

(a) turbulent flows.

(b) vortex flows.

(c) viscous flows.

(d) rotational flows.

(vii) The velocity distribution at any section of a pipe for steady laminar flow is

(a) linear

(b) exponential

(c) parabolic

(d) hyperbolic

(viii) The speed of pressure wave depends upon

(a) initial velocity of fluid.

(b) viscosity of flowing fluid.

(c) diameter of pipe.

(d) density of flowing fluid.

(ix) The velocity of sound is largest in

(a) air.

(b) kerosene.

(c) water.

(d) steel.

(x) The range of coefficient of discharge for a venturimeter is

(a) 0·6 - 0·7

(b) 0·7 - 0·85

(c) 0·85 - 0·92

(d) 0·92 - 0·98.

(xi) Correct unit of kinematic viscosity is

(a) m^2/s

(b) Ns/m^2

(c) m/kg-s

(d) kg/m^2-s

(xii) All liquid surfaces tend to stretch. This phenomenon is called

(a) cohesion.

(b) adhesion.

(c) surface tension.

(d) cavitation.

(xiii) A metallic piece weighs 78·5 N in air and 58·8 N in water. The relative density of the metal would be

(a) 8

(b) 6

(c) 4

(d) 3

(*xiv*) In uniform flow, the velocities of fluid particles are

(*a*) equal at all sections.
(*b*) always dependent on time.
(*c*) mutually perpendicular to each other.
(*d*) the fluid particles move in well-defined paths.

(*xv*) Pressure loss for laminar flow through pipeline is dependent

(*a*) directly on square of flow velocity.
(*b*) directly on square of pipe radius.
(*c*) directly as length of pipe.
(*d*) inversely on viscosity of flowing medium.

(*xvi*) The velocity potential function in a two-dimensional flow field is given by $\phi = x^2 - y^2$. The magnitude of velocity at point $P(1, 1)$ is

(*a*) zero
(*b*) 2
(*c*) $2\sqrt{2}$
(*d*) 8

(*xvii*) Identify the Bernoulli's equation, where each term represents energy per unit mass:

(*a*) $\frac{P}{w} + \frac{V^2}{2g} + y = \text{constant}$

(*b*) $\frac{P}{\varrho} + \frac{V^2}{2} + gy = \text{constant}$

(*c*) $P + \frac{\varrho V^2}{2} + wy = \text{constant}$

(*d*) None of the above.

 (Continued

(*xviii*) Discharge is measured by

(*a*) current meter.
(*b*) venturimeter.
(*c*) pitot tube.
(*d*) hot wire anemometer.

(*xix*) The relation $\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$ for an irrotational flow is referred to as

(*a*) Euler's equation.
(*b*) Laplace equation.
(*c*) Reynold's equation.
(*d*) Cauchy-Riemann's equation.

(*xx*) Poise is the unit of

(*a*) density
(*b*) velocity gradient
(*c*) kinematic viscosity
(*d*) dynamic viscosity

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Group A

1. (*a*) Define (*i*) Newtonian fluid, (*ii*) ideal plastic fluid, (*iii*) kinematic viscosity, (*iv*) specific weight, and (*v*) specific gravity. 5 × 2

(*b*) Explain the terms (*i*) buoyant force, and (*ii*) centre of buoyancy. 4

(*c*) A rectangular pontoon has a width of 6 m, a length of 12 m, and a draught of 1·5 m in fresh water (density 1000 kg m^{-3}). Calculate (*i*) the weight of the pontoon, (*ii*) its draught in sea water (density 1025 kg m^{-3}), and (*iii*) the load (in kilonewtons) that can be supported by the pontoon in fresh water if the maximum draughted permissible is 2 m. 6

2. (*a*) (*i*) What is the magnitude of buoyant force and where does the line of action of buoyant force pass? 2

(*ii*) What is the necessary condition for a body to float in stable equilibrium? 2

(*b*) A piece of wood (specific gravity = 0·6) of $10\,cm^2$ in cross-section and 2·5 m long floats in water. How much (specific gravity = 12) need to be fastened at the water end of the stick so that it floats upright with 0·5 m length out of water. 6

(*c*) What is the characteristics of laminar flow? 3

(*d*) Define (*i*) steady and unsteady flow, and (*ii*) compressible and incompressible flow. 3

(*e*) The velocity potential function is given by $\varphi = 5(x^2 - y^2)$. Calculate the velocity compensate at the point (4, 5). 4

3. (*a*) Derive the Euler's equation of motion. 6

(*b*) Water flows through a 100 mm pipe at the rate of $0{\cdot}027\,m^3/s$ and then through a nozzle attached to the end of the pipe. The nozzle tip is 50 mm in diameter, and the coefficients of velocity and contraction for the nozzle are 0·950 and 0·930, respectively. What pressure head must be maintained at the base of the nozzle if atmospheric pressure surrounds the jet? 6

(*c*) Derive an expression for velocity distribution in a circular pipe flow under fully developed condition. 8

4. (*a*) Describe the characteristics of boundary layer. 6

(*b*) Define momentum thickness and energy thickness of fluid flow over a flat plate. 6

(*c*) The velocity distribution in boundary layer is given by $u/v = y/\delta$, where u is the velocity at distance y from plate and $u = v$ at $y = \delta$, δ being boundary layer thickness. Find the (*i*) displacement thickness, (*ii*) momentum thickness, (*iii*) energy thickness, and (*iv*) value of δ^*/Q. 8

Group B

5. (*a*) Discuss the effect of pressure gradient on boundary layer separation. 8

(*b*) Water is flowing over a thin smooth plate of length 4 m and width 2 m at a velocity of 1·0 m/s. If the boundary layer flow changes from laminar to turbulent at a Reynold number 5×10^5, find the (*i*) distance from leading edge up to which boundary layer is laminar, (*ii*) thickness of the boundary layer at the transition point, and (*iii*) drag force on one side of the plate. Take velocity of water $\mu = 9{\cdot}8 \times 10^{-4}\,Ns/m^2$. 12

6. (*a*) Derive an expression for change of area and velocity for compressible fluid flow in a nozzle

$$dA/A = dV/V(\mu^3 - 1)$$ 8

(*b*) Define the terms (*i*) subsonic flow, and (*ii*) supersonic flow. 4

(*c*) Find the velocity of air flowing as the outlet of a nozzle fitted to a large vessel which contains air at a pressure of $294{\cdot}3\,N/cm^2$ and at a temperature of 20°C. The pressure at the outlet of the nozzle is $206\,N/cm^2$. Take $K = 1{\cdot}4$ and $R = 287\,J/kg\text{-}K$. 8

7. (*a*) Define the terms (*i*) viscosity, (*ii*) circulation, and (*iii*) flow net. 6

(*b*) What are the properties of stream function (ψ) and what do you mean by equipotential line and a line of constant stream function? 10

(*c*) Describe the relation between stream function and velocity potential. 4

8. Write short notes on the following: 4×5

(*a*) Venturimeter

(*b*) Bernoulli's equation

(*c*) Euler's equation

(*d*) Pitot tube.

Group C

9. Choose the *correct* answer for the following: 10×2

(*i*) Fluid is a substance which offers no resistance to change of

(*a*) pressure

(*b*) flow

(*c*) shape

(*d*) volume

(*e*) temperature

(*ii*) A fluid is said to be ideal, if it is

(*a*) incompressible

(*b*) inviscous

(*c*) viscous and incompressible

(*d*) viscous and compressible

(*e*) inviscous and incompressible

(*iii*) The unit of viscosity is

(*a*) m^2/s

(*b*) kg/(m-s)

(*c*) Ns/m^2

(*d*) Ns^2/m

(*e*) None of the above

(*iv*) A one-dimensional flow is one which

(*a*) is uniform flow.

(*b*) is steady uniform flow.

(*c*) takes place in straight lines.

(*d*) involves zero transverse component of flow.

(*e*) takes place in one dimension.

(*v*) The line of action of the buoyant force acts through the

(*a*) centroid of the volume of fluid vertically above the body.

(*b*) centre of the volume of floating body.

(*c*) centre of gravity of any submerged body.

(*d*) centroid of the displaced volume of fluid.

(*e*) None of the above.

(*vi*) Differential monometer is used to measure

(*a*) pressure in pipes, channels, etc.

(*b*) atmospheric pressure.

(*c*) very low pressure.

(*d*) difference of pressure between two points.

(*e*) velocity in pipes .

(*vii*) An ideal flow of any fluid must satisfy

(*a*) Pascal law

(*b*) Newton's law of viscosity

(*c*) boundary layer theory

(*d*) continuity equation

(*e*) Bernoulli's theorem

(*viii*) A stream line is defined as the line

(*a*) parallel to central axis flow.

(*b*) parallel to outer surface of pipe.

(*c*) a tangent to it cut the point gives the direction of velocity.

(*d*) along which the pressure drop is uniform.

(*e*) which occurs in all flows.

(*ix*) Separation of flow occurs when pressure gradient

(*a*) tends to approach zero.

(*b*) becomes negative.

(*c*) changes abruptly.

(*d*) reduces to value when vapour formation starts.

(*x*) For a laminar flow,

(*a*) flow occurs in zig-zag way.

(*b*) Reynolds number lies between 2000 and 3000 for pipes.

(*c*) Newton's law of viscosity is of importance.

(*d*) pipe losses are major considerations.

(*e*) velocity of flow is maximum.

S'09 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Define the following : (*i*) Surface tension, (*ii*) viscosity, (*iii*) specific gravity, and (*iv*) specific weight. 4×2

(*b*) What is centre of pressure? Obtain an expression for the depth of centre of pressure when the lamina is immersed in a liquid and is at angle with the horizontal. 7

(c) A steel pipeline, conveying gas, has an internal diameter of 1·20 m and an external diameter of 1·25 m. It is laid across a riverbed, completely submerged in water and is anchored at intervals of 3 m along its length. Calculate the buoyant force in *N* per metre run and the upward force on each anchorage.

Specific weight of steel and water are 75340 N/m^3 and 9810 N/m^3, respectively. 5

2. (a) Explain the following: 3 × 2

(i) Steady and unsteady flow

(ii) Uniform and non-uniform flow

(iii) Laminar and turbulent flow.

(b) State and prove Bernoulli's theorem. Mention its limitations. 8

(c) A horizontal water pipe of diameter 15 cm converges to 7·5 cm diameter. If the pressures at two sections are 400 kPa and 150 kPa, respectively, calculate the flow rate of water. 6

3. (a) Set up the Navier Stoke's equations and make suitable assumptions to prove that for a hydraulic mass of fluid, the pressure intensity at a depth *h* below the free surface is equal to the product of specific weight *W* and the depth *h*. 10

(b) A straight stretch of horizontal pipe of 5 cm diameter was used in the laboratory to measure the viscosity of a crude oil (specific weight 9000 N/m^3). During the test run, a pressure differential of 18000 N/m^2 was recorded from two pressure gauges located 6 m apart on the pipe. The oil was allowed to discharge into a weighing tank and 5000 N of oil was collected in 3 min duration. Work out dynamic viscosity of the oil. 10

4. (a) Assuming one of the standard velocity distributions for laminar boundary flow, obtain expression for the drag coefficient, boundary shear stress, and thickness of the boundary layer. 8

(b) A fluid of viscosity 0·7 Ns/m^2 and specific gravity 1·3 is flowing through a circular pipe of diameter 10 cm. The maximum shear stress at the pipe wall is given as 196·2 N/m^2. Find (i) the pressure gradient, (ii) average velocity, and (iii) Reynold number of the flow. 6

(c) Prove that for viscous flow through a circular the kinetic energy correction factor is equal to 2 while momentum correction factor = 4/3. 6

Group B

5. (a) Show that velocity distribution for turbulent flow through pipe is given by

$$u/u_{\star} = 5{\cdot}75 \log_{10}(y/k) + 8{\cdot}5$$

where $u_{\star}$ = shear velocity, y = distance from pipe wall, and k = roughness factor. 10

(*b*) Atmospheric air at 25°C flows parallel to a flat plate at a velocity of 3 m/s. Use the exact Blasius solution to estimate the boundary layer thickness and the local skin friction coefficient at $x = 1$ m from the leading edge of the plate. How these values would compare with the corresponding values obtained from the approximate von-Karman integral technique? Assume cubic velocity profile for air at 25°C, $\nu = 15{\cdot}53 \times 10^{-6} m^2/s$. 10

6. (*a*) Differentiate between the compressible and incompressible flow. Mention some of the flow situations where compressibility of fluid has to be considered. 5

(*b*) A source of disturbance travels in air alternatively at subsonic, sonic and supersonic velocities. Sketch and explain the propagation of disturbance in each of the above cases. 7

(*c*) A flat plate was positioned at zero incidence in a uniform flow streams of air. Assuming boundary layer to be turbulent over the entire plate, work out the ratio of skin-friction drag forces on the front and rear half part of the plate. 8

7. (*a*) Derive a stream function for (*i*) a flow from a line source of strength mm^2/s per metre, (*ii*) a flow to a line source of strength mm^2/s per metre, (*iii*) If the source and sink are placed $2a$ apart, obtain the stream function for a doublet. What is the strength of a doublet? 10

(*b*) For a doublet of strength 20 m^2/s, calculate the velocity at point $P(1, 2)$ and the value of stream function passing through it. 10

8. (*a*) Sketch a venturimeter and manometer arrangement, apply the steady flow energy equation, and derive an expression for the actual flow rate of an incompressible fluid. Define all symbols and state clearly all assumptions made. 10

(*b*) A submarine moves horizontally in sea with its axis much below the surface of water. A pitot-tube, properly placed just in front of the submarine and along its axis, is connected to two limbs of a U tube containing mercury. The difference of mercury level is found to be 17 cm. Find the speed of the submarine knowing that density of mercury is 13·6 and that of sea water is 1·026 with respect to fresh water. 10

Group C

9. Explain the following: 5×4

(*i*) Conditions of equilibrium of submerged bodies

(*ii*) Vortex flow, free vortex flow, forced vortex flow

(*iii*) Pitot tube and pitot-static tube

(*iv*) Couette flow and Poisseuille flow

(*v*) Real fluids, ideal fluids, Newtonian fluids and non-Newtonian fluids.

W'09 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Differentiate between the following: 3

(*i*) Newtonian and non-Newtonian fluids

(*ii*) Real fluids and ideal fluids

(*iii*) Surface tension and capillarity

(*b*) State Newton's law of viscosity. What is the effect of temperature on viscosity of water and that of air ?

(*c*) A rectangular plane surface, 2 m wide and 3 m deep, lies in water in such a way that its plane makes an angle of 30° with the free surface of water. Determine the total pressure and position of centre of pressure when the upper edge is 1.5 m below the free-water surface.

2. (*a*) With neat sketches, explain the condition of equilibrium of floating bodies. 7

(*b*) A wooden cylinder of specific gravity 0.6 and circular in cross-section is required to float in oil (specific gravity = 0.90). Find the L/D ratio for the cylinder to float with its longitudinal axis vertical on oil, where L is the height of cylinder and D its diameter. 7

(*c*) Define the following: 3 × 2

(*i*) Compressible and incompressible flow

(*ii*) One-, two- and three-dimensional flow

(*iii*) Steady and unsteady flow.

3. (*a*) Derive the Euler's equation of motion, stating clearly the assumptions made. 10

(*b*) Crude oil of specific gravity 0.85 flows upward at a volume rate of flow of 60 litre/sec through a vertical venturimeter with an inlet diameter of 200 mm and a throat diameter of 100 mm. The coefficient of discharge of the venturimeter is 0.98. The vertical distance between the pressure tappings is 300 mm.

(*i*) If two pressure gauges are connected at the tappings such that they are positioned at the levels of their corresponding tapping points, determine the difference of readings (in N/cm^2) of the two pressure gauges. 5

(*ii*) If a mercury differential manometer is connected, in place of pressure gauges, to the tappings such that the connecting tube up to mercury are filled with oil, determine the difference in the level of the mercury column. 5

4. (*a*) Derive an expression for the shear stress and velocity distribution for a flow of viscous fluid through a circular pipe. 8

(*b*) Briefly explain the characteristic of laminar and turbulent boundary layer. 6

(*c*) A crude oil of viscosity 0.97 poise and relative density 0.9 is flowing through a horizontal circular pipe of diameter 100 mm and of length 10 m. Calculate the difference of pressure at the two ends of the pipe, if 100 kg of oil is collected in a tank in 30 sec. 6

Group B

5. (*a*) Show that velocity distribution for turbulent flow in a smooth pipe is given by

$$\frac{u_{max} - u}{u_\star} = 5.75 \log_{10}\left(\frac{R}{y}\right)$$

where $u_\star$ = shear velocity, y = distance from pipe wall, and R = radius of pipe. 12

(*b*) A smooth pipe of diameter 80 mm and 800 m long carries water at the rate of 0.480 m^3/min. Calculate the loss of head, wall shearing stress, centre line velocity, velocity and shear stress at 30 mm from pipe wall. Also, calculate the thickness of laminar sub-layer. Take kinematic viscosity of water as 0.015 stokes. Take the value of co-efficient of friction f from the relation $f = 0.0791/Re^{1/4}$, where Re = Reynold number. 8

6. (*a*) Derive an expression for the sound wave in a compressible fluid in terms of change of pressure and change of density. 8

(*b*) Define (*i*) Mach number, (*ii*) subsonic flow, (*iii*) sonic flow, and (*iv*) supersonic flow. 4×1

(*c*) A nozzle is required to expand the air from 4.5 bar and 750 °C to 1.1 bar. Find the throat area, outlet area and outlet temperature for a mass flow rate of 0.5 kg/s. Take the nozzle efficiency as 85% and assume the following properties for air: 8

Ratio of specific heat , $\gamma = 1.4$
Gas constant, $R = 0.287$ kJ/kg°K
Constant pressure specific heat, $C_p = 1.005$ kJ/kg.K.

7. (*a*) Define (*i*) uniform flow, (*ii*) source flow, (*iii*) sink flow, (*iv*) free-vortex flow, and (*v*) superimposed flow. 5×1

(*b*) Define velocity potential function and stream function. 5

(*c*) A point P(0.5, 1) is situated in the flow field of a doublet of strength 5 m^2/s. Calculate the velocity at this point and also the value of the stream function. 10

8. (*a*) What is a venturimeter? Draw a neat sketch of the venturimeter showing the arrangement of the manometer. Derive an expression for the rate of flow of fluid through it. 10

(*b*) An orifice meter, with orifice diameter 10 cm, is inserted in a pipe of 20 cm diameter. The pressure gauges fitted upstream and downstream of the orifice meter given readings of 19.62 N/cm^2 and 9.81 N/cm^2, respectively. Coefficient of discharge for the meter is given as 0.6. Find the discharge of water through pipe. 5

(*c*) How will you determine the velocity of flow at any point with the help of pitot tube? 5

Group C

9. Choose the *correct* answer for the following: 10×2

(*i*) Stoke is the unit of

(*a*) surface tension.

(*b*) viscosity.

(*c*) kinematic viscosity.

(*d*) None of the above.

(*ii*) Surface tension has the unit of

(*a*) force per unit area

(*b*) force per unit length

(*c*) force per unit volume

(*d*) None of the above.

(*iii*) Continuity equation deals with the law of conservation of

(*a*) mass.

(*b*) momentum.

(*c*) energy.

(*d*) None of the above.

(*iv*) The rate of flow through a venturimeter varies as

(*a*) H

(*b*) $\sqrt{H}$

(*c*) $H^{3/2}$

(*d*) $H^{5/2}$

(*v*) Orifices are used to measure

(*a*) velocity

(*b*) pressure

(*c*) rate of flow

(*d*) None of the above.

(*vi*) For a floating body, if the metacentre is above the centre of gravity, the equilibrium is called

(*a*) stable.

(*b*) unstable.

(*c*) neutral.

(*d*) None of the above.

(*vii*) The coefficient of discharge (C_d) in terms of C_v and C_c is

(*a*) $C_d = C_v / C_c$

(*b*) $C_d = C_v \times C_v$

(*c*) $C_d = C_c / C_v$

(*d*) None of the above.

(*viii*) For viscous flow between two parallel plates, the pressure drop per unit length is equal to

(*a*) $12 \mu \bar{U} L / \rho g D^2$

(*b*) $12 \mu \bar{U} L / D^2$

(*c*) $32 \mu \bar{U} L / D^2$

(*d*) $12 \mu \bar{U} / D^2$

(*ix*) The velocity distribution in laminar flow through a circular pipe follows the

(*a*) parabolic law.

(*b*) linear law.

(*c*) logarithmic law.

(*d*) None of the above.

(*x*) For supersonic flow, if the area of flow increases, then

(*a*) velocity decreases.

(*b*) velocity increases.

(*c*) velocity remains constant.

(*d*) None of the above.

S'10 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

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Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Enunciate Newton's law of viscosity and distinguish between Newtonian and non-Newtonian fluids. 6

(*b*) What are the characteristic fluid properties of which the following phenomena are attributable: (*i*) Rise of sap in a tree, (*ii*) cavitation, and (*iii*) water hammer. 6

(*c*) The velocity profile in laminar flow through a round pipe is expressed as

$$v = 2u\,[1 - (r^2/r_0^2)]$$

where u is the average velocity; r, the radial distance from the centre line of the pipe; and r_0, the pipe radius. Draw the dimensionless shear stress profile τ/τ_0 against r/r_0, where τ_0 is the wall shear stress. Find the value of τ_0, when fuel oil, having an absolute viscosity $\mu = 4 \times 10^{-2}$ Ns/m^2, flows with an average velocity of 4 m/s in a pipe of diameter 150 mm. 8

2. (*a*) Derive the Bernoulli's equation with its assumption. 6

(*b*) As shown in Fig. 1, pipe *M* contains carbon tetrachloride of specific gravity 1.594 under a pressure of 1.05 kgf/cm^2 and pipe *N* contains air of specific gravity 0.8. If the pressure in the pipe *N* is 1.75 kgf/cm^2 and the manometric fluid is mercury, find the difference, *x*, between the levels of mercury. 8

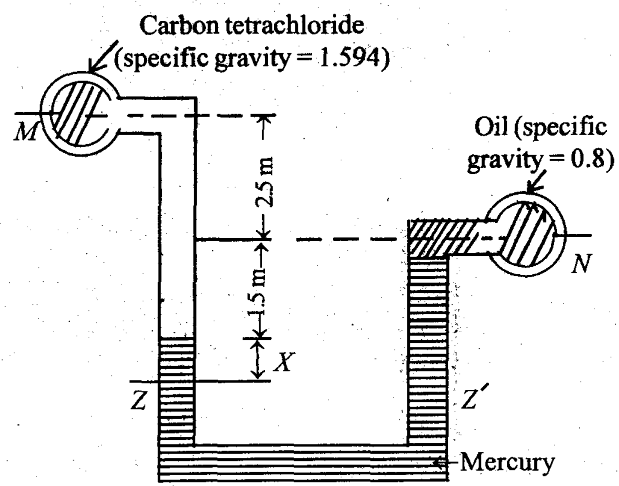

Fig. 1

(*c*) Discuss the shape of floating body and its stability. 6

3. (*a*) Derive the expression for Hegen-Poiseullie flow. 6

(*b*) Air ($\varrho = 1.2$ kg/m^3, $\mu = 1.81 \times 10^{-5}$ Ns/m^2) is forced at 25 m/sec through $a = 0.3$ m^2 steel duct, 148 m long. Calculate the headloss and power $f = 0.015$. 6

(*c*) A circular disc of diameter *d* is slowly rotated in a liquid of large viscosity μ at a small distance *h* from a fixed surface (Fig. 2). Derive an expression for torque *T* necessary to maintain an angular velocity ω. 8

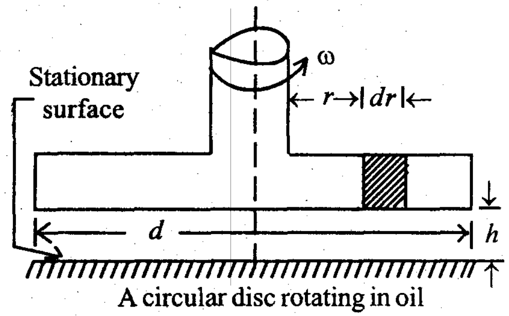

Fig. 2

4. (*a*) If the velocity distribution in the boundary layer is given by $u/v = y/8$, find δ^*/δ and θ/δ, where δ = boundary layer thickness, δ^* = displacement thickness, and θ = momentum thickness. 8

(*b*) Water at 15°C flows over a flat plate at a speed of 1.2 m/sec, the plate is 0.3 m long and 2 m wide. The boundary layer on each surface of the plane is laminar. Assume the velocity profile is approximated by a linear expression for which $\delta/x = 3.46/\sqrt{R_{ey}}$. Determine the drag force on the plate. For $v = 1.1 \times 10^{-6}$ m^2/s, $\varrho = 1000$ kg/m^3. 6

(c) Discuss the following terms: (i) No slip boundary condition, (ii) fully developed flow, and (iii) boundary layer thickness. 3 × 2

Group B

5. (a) Explain the phenomena of boundary layer growth over a flat plate. Explain phenomenon of boundary layer separation with a neat sketch. 8

(b) Air (ϱ = 1.23 kg/m^3 and r = 1.5 × 10^{-5} m^2/s) is flowing over a flat plate. The free stream speed is 15 m/s. At a distance of 1 m from the scaling edge, calculate δ and τ_w for (i) completely laminar flow, and (ii) completely turbulent flow for a one-seventh power low velocity profile. 12

6. (a) Prove the relation

$$\frac{dA}{A} = \frac{dV}{V}(\text{Ma}^2 - 1)$$

where A = area, V = velocity, and Ma = Mach number. 6

(b) Explain stagnation point and its properties. Prove the relation

$$\frac{P_0}{P} = \left(1 + \frac{y-1}{2}\text{Ma}^2\right)^{y/y-1}$$

where P_0 = stagnation pressure, y = isentropic index, and Ma = Mach number. 6

(c) Air at an absolute pressure 60.0 kPa and 27 °C enters a passage at 486 m/sec. The cross-sectional area at the entrance is 0.02 m^2. At section 2, further downstream the pressure is 78.8 kPa (absolute). Assuming isentropic flow, calculate Mach number at section 2. Also, identify type of the nozzle. Given: y = 1.4. 8

7. (a) Explain the terms 'doublet' and 'circulation'. 3+3

(b) If $u = 2x$ and $v = -2y$ are respectively x and y components of possible fluid flow, determine stream function. 8

(c) Explain what is meant by a point source and a sink source. 6

8. (a) Define orifice, mouth-piece, notch, and weirs. 4 × 2

(b) A venturi meter is to be fitted in a pipe of 0.25 m diameter, where the pressure head is 7.6 m of following liquid and the maximum flow is 8.1 m^3/min. Find the least diameter of the throat to ensure that the pressure head does not become negative. Take C_d = 0.96. 12

Group C

9. Write the *correct* answer for the following: 10 × 2

(i) The pressure variation in static fluid may be written as

(a) $dp = -w.dz$

(b) $dp = -\varrho.dz$

(c) $dp = -w.dz$

(d) $dp = -zd\varrho$

where z measures vertically upward.

(ii) Navier Stokes equation is useful in the analysis of

(a) non-viscous flow.

(b) turbulent flows.

(c) viscous flow.

(d) both viscous and turbulent flows.

(*iii*) The point through which the resultant force acts is called

(*a*) metacentre.

(*b*) centre of pressure.

(*c*) centre of buoyancy.

(*d*) centre of gravity.

(*iv*) A stagnation point is a point

(*a*) where pressure is zero.

(*b*) where total energy is zero.

(*c*) where velocity of flow reduces to zero.

(*d*) where total energy is maximum.

(*v*) Headloss in sudden expansion is given by

(*a*) $(v_1^2 - v_2^2)/2g$

(*b*) $(v_1 - v_2)^3/2g$

(*c*) $(v_1 - v_2)^2/2g$

(*d*) $2(v_1^2 - v_2^2)/g$

(*vi*) Prandtl mixing length is

(*a*) a universal constant.

(*b*) zero at pipe wall.

(*c*) independent of shear stress.

(*d*) independent of radial distance from pipe axis.

(*vii*) The growth of boundary layer is supported when

(*a*) $\partial p/\partial x$ is positive.

(*b*) $\partial p/\partial x$ is zero.

(*c*) $\partial p/\partial x$ is negative.

(*viii*) The Pitot-tube measures

(*a*) dynamic pressure.

(*b*) static pressure.

(*c*) total pressure.

(*d*) difference in static and dynamic pressure.

(*ix*) The excess pressure inside a soap bubble of radius r is

(*a*) σ/r

(*b*) $2\sigma/r$

(*c*) $3\sigma/r$

(*d*) $4\sigma/r$

(*x*) Pressure drag results from

(*a*) skin friction.

(*b*) deformation drag.

(*c*) the principle cause of skin friction.

(*d*) always occur when deformation drag predominates.

W'10 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

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Group A

1. (*a*) What is the main difference between behaviour of Newtonion and non-Newtonion fluids? Draw an appropriate diagram to justify your answer. 5

   (*b*) Can we consider our blood as Newtonion fluid for the purpose of its flow through veins and capillaries in our body? How does μ_T vary with fluid temperature? 5

   (*c*) Discuss the importance of friction factor in flows through ducts. Determine friction factor for a flow of viscous fluid through a circular pipe of diameter, *d*, in terms of headloss between two sections and other flow variables. 10

2. (*a*) Discuss Couette flow and show the effect of pressure gradient along the flow direction on development of velocity profile at any section. 8

(*b*) Obtain the relationship for thrust and efficiency for a strip propelled by a reaction jet (Fig. 1) when (*i*) water is taken from the side of the strip or (*ii*) from front end of the strip. Make your comments on the results in two cases under the condition of propulsion at maximum efficiency. 8

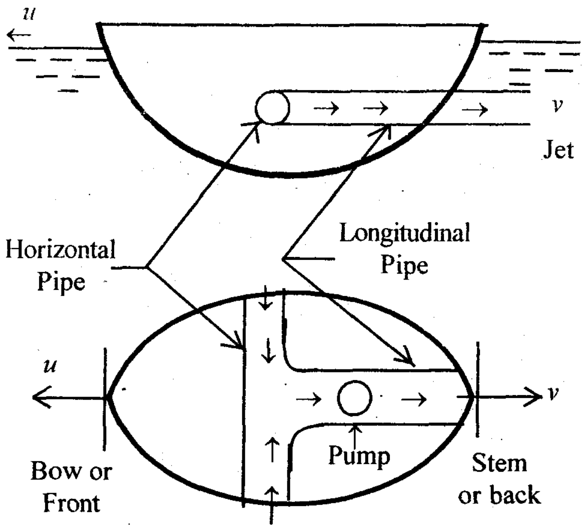

Fig. 1

(*c*) Explain bouyancy and its effect on stability of a body floating in water. What should be relative position of metacentre with reference to centre of gravity for body's stability. 4

3. (*a*) Derive boundary layer equations from flow equations using concept of order of magnitude and explain how are number of equations so obtained. less than the number of unknowns in the equation leads to unique solution. 8

(*b*) A rectangular tank, 3 m long, 2 m wide and 2 m deep, contains water to a depth of 1.25 m. It is accelerated horizontally at 3 m/s^2 in the direction of its length. Find (*i*) inclination of water surface with the horizontal, (*ii*) total force on the sides at two ends of the tank, and (*iii*) maximum permissible acceleration in this case. 8

(*c*) Discuss methods used for control of boundary layer. 4

4. Write short notes on *any four* of the following: 4 × 5

(*a*) Reynolds transport theorem

(*b*) Navier-Stokes equation

(*c*) Poiseuille's flow

(*d*) Outline of Blassius solution

(*e*) Wall shear.

Group B

5. (*a*) Why does a laminar flow changes into turbulent flow? Discuss importance of the most important factor responsible for this change. 5

(*b*) Define turbulent velocity and its effects on the flow characteristics. How does this introduce additional stress in momentum equation? Discuss it briefly giving idea of the procedure to follow to get relation for this stress and name the stress. 10

(*c*) What is the concept of mixing length model? 5

6. (*a*) Compressed air at reservoir condition, $p_0 = 10$ bar and 100°C is to be discharged at the rate of 15 kg/s through a converging–diverging nozzle to a back pressure of 1 bar. Calculate the nozzle cross–sectional area at throat and exit of the nozzle when the flow is isentropic all along its length. 10

(*b*) A nozzle is provided with a pipe of constant cross-section at its exit; the exit diameter of the nozzle and that of pipe is 40 cm. The mean coefficient of friction for pipe is 0.0025. Stagnation pressure and temperature of air at the nozzle inlet is 12 bar and 600 K, respectively. The flow is isentropic in the nozzle and adiabatic in the pipe. The Mach numbers at entry and exit of the pipes are 1.8 and 1.0, respectively. Determine the (*i*) length of the pipe, (*ii*) pressure and temperature at the pipe exit, and (*iii*) diameter of the nozzle throat. How would the length, pressure and temperature at the pipe exit be affected if a normal shock occurs at nozzle exit? 10

7. (*a*) Under what conditions will you use differential or integral approach for the solution of a flow problem? Do you expect different results with two types of solution approach? 10

(*b*) When it is raining, some people say that it is better to run but many others say you should walk to keep yourself dry. Suppose that it is raining straight down at a volume flux ratio of 10^{-5} m^3/s per square metre of ground area, and you have to go 100 m in this rain. Assume an average droplet size of 1 mm^3 for which the velocity of rainfall is 5 m/s. If an adult is 2 m high, 1 m wide, and 0.5 m deep, analyze the solution to decide whether should he walk at 1 m/s or run at 4 m/s to stay dry. 10

8. (*a*) How can you combine the basic flows to generate flow pattern around (*i*) half bodies, and (*ii*) elliptic bodies? Also, discuss the procedure for selection of variables for basic flows so that the pattern of flow so generated matches with the actual flow pattern. 10

(*b*) Write short notes on *any two* of the following: 2 × 5

(*i*) Boundary layer separation and its control

(*ii*) Flow velocity measuring methods used in the laboratory

(*iii*) Conditions for converging pipe to act as nozzle or diffuser for an isentropic flow through it.

Group C

9. Choose the *correct* answer for the following: 10 × 2

(*i*) The concept of continuum in fluid flow assumes that the characteristic length of the flow is

(*a*) smaller than the mean free path of the molecules.

(*b*) larger than the mean free path of the molecules.

(*c*) larger than the dimensions of suspended particles.

(*d*) larger than the wavelength of sound in the medium.

(*ii*) Normal stresses are of the same magnitude in all directions at a point in a fluid only when the fluid is

(*a*) frictionless.

(*b*) at rest.

(*c*) no shear stress.

(*d*) in all cases of fluid motion.

(*iii*) Local atmospheric pressure is measured by

(*a*) hydrometer.

(*b*) barometer.

(*c*) hygrometer.

(*d*) altimeter.

(*iv*) Flow of 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*) If $u = zxy$, magnitude of velocity vector at point (2, -2) is

(*a*) $u\sqrt{2}$

(*b*) u

(*c*) $-u$

(*d*) $\sqrt{2}$

(*vi*) An incompressible fluid flows radially outward from a line source in a steady manner. The velocity in radial direction varies as

(*a*) r

(*b*) $1/r$

(*c*) r^2

(*d*) $1/r^2$

(*vii*) The linear momentum equation applied to a control volume in a flow through a nozzle yielded the resultant reaction force, R, on the fluid in the control volume. The force required to keep the nozzle in position is

(*a*) R in magnitude and in its direction.

(*b*) equal to R but opposite in direction.

(*c*) equal to x component of R.

(*d*) equal to x component minus the friction force.

(*viii*) A laminar boundary layer has a velocity distribution given by $u/U = y/8$. Displacement thickness for this boundary layer is

(*a*) δ

(*b*) $\delta/2$

(*c*) $\delta/4$

(*d*) $\delta/6$

(*ix*) Air ($\rho = 1.2$ kg/m^3, $\mu = 1.80 \times 10^{-5}$ Pa.s) flows through a pipe of 10 cm dia with a velocity of 20 m/s. If the friction factor is 0.02, the shear stress at the wall is

(*a*) zero

(*b*) 153.6 Pa

(*c*) 2.4 Pa

(*d*) 1.2 Pa

(*x*) In a laminar flow between two plates with a separation distance of 6 mm, the centre line velocity is 1.8 m/s. The velocity at the distance of 1 mm from the boundary is

(*a*) 0.15 m/s

(*b*) 1.0 m/s

(*c*) 0.55 m/s

(*d*) 0.75 m/s

S'11 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Define the following terms: 4 × 2

   (*i*) Specific weight

   (*ii*) Specific gravity

   (*iii*) Viscosity

   (*iv*) Surface tension.

   (*b*) What is centre of pressure? Obtain an expression for the depth of centre when the lamina is immersed in a liquid and is at an angle with the horizontal. 7

   (*c*) A pipeline, which is 4 m in diameter, contains a gate valve. The pressure at the centre of the pipe is 19.6 N/cm^2. If the pipe is filled with oil of specific gravity 0.87, find the force exerted by the oil upon the gate and position of centre of pressure. 5

2. (*a*) Define the following: 3 × 2

(*i*) Uniform and non-uniform flows.

(*ii*) Compressible and incompressible flows.

(*iii*) Rotational and irrotational flows.

(*b*) Derive an expression for continuity equation for a three-dimensional flow. 8

(*c*) A pipeline carrying oil of specific gravity 0.87, changes in diameter from 200 mm at a position A to 500 mm at a position B, which is 4 m at a higher level. If the pressures at A and B are 9.81 N/cm^2 and 5.886 N/cm^2, respectively and the discharge is 200 litre/s, determine the loss of head and direction of flow. 6

3. (*a*) Prove that the velocity distribution for viscous flow between two parallel plates, when both plates are fixed across a section, is parabolic in nature. 10

(*b*) Define the following terms: 2+2

(*i*) Kinetic energy correction factor

(*ii*) Momentum correction factor.

(*c*) A fluid of viscosity 0.7 Ns/m^2 and specific gravity 1.3 is flowing through a circular pipe of diameter 100 mm. The maximum shear stress at the pipe wall is given as 196.2 N/m^2. Find the (*i*) pressure gradient, (*ii*) average velocity, and (*iii*) Reynold's number of the flow. 6

4. (*a*) Define the following terms: 4 × 1

(*i*) Boundary layer

(*ii*) Boundary layer thickness

(*iii*) Displacement thickness

(*iv*) Momentum thickness.

(*b*) Find the (*i*) displacement thickness, (*ii*) momentum thickness, and (*iii*) energy thickness for the velocity distribution in the boundary layer given by $u/v = y/\delta$, where u is the velocity at a distance y from the plate and $u = U$ at $y = \delta$. Here δ is the boundary layer thickness. Also, calculate the ratio of displacement thickness to momentum thickness. 10

(*c*) A plate of 600 mm length and 400 mm wide is immersed in a fluid of specific gravity 0.9 and kinematic viscosity 10^{-4} m^2/s. The fluid is moving with a velocity of 6 m/s. Determine (*i*) boundary layer thickness, (*ii*) shear stress at the end of the plate, and (*iii*) drag force on one side of the plate. 6

Group B

5. (*a*) What do you mean by separation of boundary layer? What is the effect of pressure gradient on boundary layer separation? 7

(*b*) What do you mean by Prandtl mixing length theory? Derive an expression for shear stress due to Prandtl. 7

(*c*) Water is flowing through a rough pipe of diameter 600 mm at the rate of 600 litre/sec. The wall roughness is 3 mm. Find the power lost for 1 km length of pipe. 6

6. (*a*) Define (*i*) compressible flow, (*ii*) Mach number, and (*iii*) stagnation properties. 6

(b) Derive an expression for the velocity of sound wave for compressible fluid when the process is assumed to be (i) isothermal, and (ii) adiabatic. 6

(c) A nozzle is required to expand air from 4.5 bar and 750°C to 1.1 bar. Find the throat area, outlet area and outlet temperature for a mass flow of 0.5 kg/s. Assume the nozzle efficiency as 85% and ratio of specific heat $\gamma = 1.4$, $C_p = 1.005$ kJ/kgK. 8

7. (a) Differentiate between forced vortex and free vortex flow. 4

(b) Derive an expression for the difference of pressure between two points in a free vortex. 8

(c) In a two-dimensional incompressible flow, the fluid velocity components are given by $u = x - 4y$ and $v = -y - 4x$. Show that velocity potential exists and determine its form. Also, find the stream function. 8

8. (a) Define an orifice meter. Prove that the discharge through an orifice meter is given by the relation

$$Q = C_d \frac{a_0 a_1}{\sqrt{a_1^2 - a_0^2}} \sqrt{2gh}$$

where a_1 = area of pipe in which orifice meter is fitted and a_0, the area of orifice. 10

(b) Find the discharge of water flowing through a pipe of 30 cm diameter placed in an inclined position where a venturimeter is inserted, having throat diameter of 15 cm. The difference of pressure between the main throat is measured by a liquid of specific gravity 0.6 in an inverted U tube which gives a reading of 30 cm. The loss of head between the main and throat is 0.2 times the kinetic head of the pipe. 10

Group C

9. Write the *correct* answer for the following: 10 × 2

(i) A Newtonian fluid is defined as a fluid which

(a) is incompressible and non-viscous.

(b) obey's Newton's law of viscosity.

(c) is highly viscous.

(d) is compressible and non-viscous.

(ii) Dynamic viscosity (μ) has the dimensions as

(a) MLT^{-2}

(b) $ML^{-1}T^{-1}$

(c) $ML^{-1}T^{-2}$

(d) $M^{-1}L^{-1}T^{-1}$

(iii) Fluid statics deals with

(a) viscous and pressure forces.

(b) viscous and gravity forces.

(c) gravity and pressure forces.

(d) surface tension and gravity forces.

(iv) The resultant hydrostatic force acts through a point known as

(a) centre of gravity.

(b) centre of buoyancy.

(c) centre of pressure.

(d) None of the above.

(*v*) Continuity equation deals with the law of conservation of

(*a*) mass.

(*b*) momentum.

(*c*) energy.

(*d*) None of the above.

(*vi*) Pitot tube is used to measure

(*a*) discharge.

(*b*) average velocity.

(*c*) velocity at a point.

(*d*) pressure at a point.

(*vii*) Stream lines and path lines always coincide in

(*a*) steady flow.

(*b*) uniform flow.

(*c*) non-uniform flow.

(*d*) laminar flow.

(*viii*) The ratio of inertia force to viscous force is known as

(*a*) Reynold number

(*b*) Froude number

(*c*) Mach number

(*d*) Euler number

(*ix*) The velocity distribution across a section of a circular pipe having viscous flow is given by

(*a*) $u = U_{max}[1-(r/R)^2]$

(*b*) $u = U_{max}[R^2 - r^2]$

(*c*) $u = U_{max}[1-(r/R)]^2$

(*d*) None of the above.

(*x*) The loss of head due to sudden expansion of a pipe is given by

(*a*) $h_L = (V_1^2 - V_2^2)/2g$

(*b*) $h_L = 0.5\, V_1^2/2g$

(*c*) $h_L = (V_1 - V_2)^2/2g$

(*d*) None of the above.

S'12:5 FN: MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks

Group A

1. (*a*) Define the following terms : 3 × 2

(*i*) Specific gravity

(*ii*) Viscosity

(*iii*) Surface tension

(*b*) Explain the condition of equilibrium of submerged bodies with neat sketches. 6

(*c*) Find the total pressure and position of centre of pressure on a triangular plate of base 2 m and height 3 m which is immersed in water in such a way that the plan of the plate makes an angle of 60° with the free surface of the water. The base of the plate is parallel to water surface and at a depth of 2.5 m from water surface. 8

(*Turn Over*)

2. (*a*) Define the following : 2 + 2

(*i*) Steady and unsteady flow

(*ii*) Laminar and turbulent flow

(*b*) Derive Euler's equation of motion along a streamline for an ideal fluid and obtain from it Bernoulli's equation. State all the assumptions made. 10

(*c*) The following cases represent the two velocity components. Determine the third component of velocity such that they satisfy the continuity equation : 3 + 3

(*i*) $u = x^2 + y^2 + z^2$, $v = xy^2 - yz^2 + xy$

(*ii*) $v = 2y^2$, $w = 2xyz$

3. (*a*) Derive an expression for shear stress and velocity distribution for a flow of viscous fluid through a circular pipe. 8

(*b*) An oil of viscosity 0.1 Ns/m^2 and relative density 0.9 is flowing through a circular pipe of diameter 50 mm and of length 300 m. The rate of flow of fluid through the pipe is 3.5 litre/s. Find the pressure drop in a length of 300 m and also the shear stress at the pipe wall. 6

(*c*) Determine the (*i*) pressure gradient, (*ii*) shear stress at the two horizontal parallel plates, and (*iii*) discharge per meter width for the laminar flow of oil with a maximum velocity of 2 m/s between two horizontal parallel fixed plates which are 100 mm apart. Given viscosity, $\mu = 2.4525$ Ns/m^2 6

4. (*a*) Define (*i*) boundary layer, (*ii*) boundary layer thickness, (*iii*) displacement thickness, and (*iv*) momentum thickness. 4×2

(*b*) Find the displacement thick ness, the momentum thickness and energy thickness for the velocity distribution in the boundary layer given by $u/V = y/\delta$, where u is the velocity at a distance y from the plate and $u = U$ at $y = \delta$, where δ = boundary layer thickness. Also, calculate the value of δ^*/θ. 6

(*c*) A thin plate is moving in still atmospheric air at a velocity of 5 m/s. The length of the plate is 0.6 m and width 0.5 m. Calculate the (*i*) thickness of the boundary layer at the end of the plate, and (*ii*) drag force on one side of the plate. Take density of air as 1.24 kg/m^3 and kinematic viscosity 0.15 stokrs. 6

Group B

5. (*a*) Derive Darcy-Weisbach equation for loss of head due to friction in pipes. 10

(*b*) A smooth pipe of diameter 80 mm and 800 mm long carries water at the rate of 0.480 m^3/min. Calculate the loss of head, wall shearing stress, centre line velocity, velocity and shear stress at 30 mm from pipe wall. Take kinematic viscosity of water as 0.015 stokes. Take the value of coefficient of friction '*f*' from the relation given as $f = 0.0791/(\text{Re})^{1/4}$, where Re is the Reynold number. 10

6. (*a*) Derive an expression for area velocity relationship for a compressible fluid flowing through the nozzle in the form $dA/A = d\bar{V}/\bar{V}\,[M^2 - 1]$, where A = area, $\bar{V}$ = velocity, and M = Mach number. Using the above equation, sketch the shape of nozzle and diffuser. 12

(*b*) Determine the exit velocity and mass flow rate for isentropic flow of air through a nozzle from inlet stagnation condition of 7 bar and 320 °C to an exit pressure of 1.05 bar. The exit area is 6.25 cm^2. Also, determine the throat area. Assume $\gamma = 1.4$. 8

7. (*a*) Explain, with examples, (*i*) vortex flow, (*ii*) forced vortex flow, and (*iii*) free vortex flow. 3 × 2

(*b*) Define velocity potential function and stream function. 2 + 2

(*c*) A point P (0.5,1) is situated in the flow field of a doublet of strength 5 m^2/s. Calculate the velocity at this point and also the value of the stream function. 10

8. (*a*) What is a venturimeter ? Derive an expression for the rate of flow of fluid through it. 10

(*b*) An orifice meter, with orifice diameter 10 cm, is inserted in a pipe of 20 cm diameter. The pressure gauges fitted upstream and downstream of the orifice meter gave readings of 19.62 N/cm^2 and 9.81 N/cm^2, respectively. Coefficient of discharge for the meter is given as 0.6. Find the discharge of water through pipe. 10

Group C

9. Write the *correct* answer for the following : 20 × 1

(*i*) Poise is the unit of

(*a*) mass density.

(*b*) kinematic viscosity.

(*c*) viscosity.

(*d*) velocity gradient.

(*ii*) Pitot tube is used for measurement of

(*a*) pressure.

(*b*) flow.

(*c*) velocity at a point.

(*d*) discharge.

(*iii*) The point about which a floating body starts oscillating, when the body is tilted, is called

(*a*) centre of pressure.

(*b*) centre of buoyancy.

(*c*) centre of gravity.

(*d*) metacentre.

(*iv*) The local acceleration in the direction of x is given by

(*a*) $u\frac{\partial u}{\partial x} + \frac{\partial u}{\partial t}$

(*b*) $\frac{\partial u}{\partial t}$

(*c*) $u\frac{\partial u}{\partial x}$

(*d*) None of the three above.

(*v*) The rate of flow through a venturimeter varies as

(*a*) H

(*b*) $\sqrt{H}$

(*c*) $H^{3/2}$

(*d*) $H^{5/2}$

(*vi*) The ratio of inertia force to viscous force is known as

(*a*) Reynold number.

(*b*) Froude number.

(*c*) Mach number.

(*d*) Euler number.

(*vii*) For supersonic flow, if the area of flow increases then

(*a*) velocity decreases.

(*b*) velocity increases.

(*c*) velocity is constant.

(*a*) None of the three above.

(*viii*) The boundary layer takes place

(*a*) for ideal fluids.

(*b*) for pipe flow only.

(*c*) for real fluids.

(*d*) for flow over flat plate only.

(*ix*) Dynamic viscosity (μ) has the dimensions as

(*a*) MLT^{-2}

(*b*) $ML^{-1}T^{-1}$

(*c*) $ML^{-1}T^{-2}$

(*d*) $M^{-1}L^{-1}T^{-1}$

(*x*) Atmospheric pressure held in terms of water column is

(*a*) 7.5 m

(*b*) 8.5 m

(*c*) 9.81 m

(*d*) 10.30 m

(*xi*) The pressure difference between inside and outside of a droplet of water is given by

(*a*) $2\sigma/d$

(*b*) $4\sigma/d$

(*c*) $8\sigma/d$

(*d*) None of the three above.

(*xii*) Stream lines and path lines always coincide in

(*a*) steady flow.

(*b*) uniform flow.

(*c*) non-uniform flow.

(*d*) laminar flow.

(*xiii*) When a static liquid is subjected to uniform rotation in a container, the free surface assumes a shape of

(*a*) ellipsoid of revolution.

(*b*) circular cylinder.

(*c*) paraboloid of revolution.

(*d*) cone.

(*xiv*) An ideal fluid is one which

(*a*) is frictionless and incompressible.

(*b*) is viscous.

(*c*) obeys Newton's law of viscosity.

(*d*) All of the three above.

(*xv*) Loss of head at entrance to pipe is given as

(*a*) $v^2/2g$

(*b*) $v/2g$

(*c*) $0.5v^2/2g$

(*d*) $v^3/2g$

(*xvi*) Mouthpieces are used to measure

(*a*) velocity.

(*b*) pressure.

(*c*) viscosity.

(*d*) rate of flow.

(*xvii*) The thickness of laminar boundary layer at a distance *x* from the leading edge over a flat plate varies as

(*a*) $x^{4/5}$

(*b*) $x^{1/2}$

(*c*) $x^{1/5}$

(*d*) $x^{3/5}$

(*xviii*) Newton's law of viscosity is given by the relation

(*a*) $\tau = u^2(du/dy)$

(*b*) $\tau = \sqrt{u}(du/dy)$

(*c*) $\tau = u(du/dy)$

(*d*) $\tau = u(du/dy)^2$

(*xix*) Mach number (M) is given by

(*a*) $M = c/v$

(*b*) $M = v \times c$

(*c*) $M = v/c$

(*d*) None of the three above.

(*xx*) Drag force is expressed mathematically as

(*a*) $F_D = (1/2)\rho U^2 \times C_D \times A$

(*b*) $F_D = \rho U^2 \times C_D \times A$

(*c*) $F_D = 2\rho U^2 \times C_D \times A$

(*d*) None of the three above.

W'12: 5 FN: MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A**, ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

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Group A

1. (*a*) Define the following : (*i*) Specific mass, (*ii*) specific weight, (*iii*) specific volume, (*iv*) surface tension, and (*v*) Newton's law of viscosity. 5 × 2

(*b*) A cone of wood floats in a fluid of specific gravity 0.9 with its apex downwards. If the specific gravity of the wood is 0.6 and the cone weighs 290 N, find the weight of steel of specific gravity 7.6 which should be suspended with the help of a string tied to the apex of the cone so as to just submerge it. 10

2. (*a*) Distinguish between the following : 5 × 2

(*i*) Steady and unsteady flow

(*ii*) Uniform and non-uniform flow

(*iii*) Laminar and turbulent flow

(*iv*) Free and forced vortex flow

(*v*) Compressible and incompressible flow.

(*b*) State few engineering applications of momentum equation. 3

(*c*) A 30 cm diameter horizontal pipe terminates in a nozzle with the exit diameter of 7.5 cm. If the water flows through the pipe at a rate of 0.15 m^3/s, what force will be exerted by the fluid on the nozzle ? 7

3. (*a*) Water flows through a 150 mm diameter pipe AB of 400 m long. The point B is 20 m above A. The discharge is 0.02 cumec from A to B. Find the pressure at A, if the pressure at B is 200 kPa. Take $f = 0.006$. Suppose after 12 years of service, the friction factor is doubled, what would then be the rate of flow if the pressures at A and B remain unchanged ? 10

(*b*) Two fixed parallel plates, kept 8 cm apart, have laminar flow of oil between them with a maximum velocity of 1.5 m/s. Take dynamic viscosity of oil to be $\mu = 2.0 \text{Ns/m}^2$. Compute the (*i*) discharge per metre width, (*ii*) shear stress at the plates, (*iii*) pressure difference between two points 25 m apart, (*iv*) velocity at 2 cm from plate, and (*v*) velocity gradient at the plates end. 10

4. (*a*) Explain the essential features of Blasius method of solving laminar boundary layer equations for a flat plate. Derive expressions for boundary layer thickness and local skin friction coefficient from this solution. 10

(*b*) A plate 3 m × 1.5 m is held in water moving at 1.25 m/s parallel to its length. If the flow in the boundary layer is laminar at the leading edge of the plate, find the (*i*) distance from the leading edge where the boundary layer flow changes from laminar to turbulent flow, (*ii*) thickness of the boundary layer at this section, and (*iii*) frictional drag on the plate considering both its ends. 10

Group B

5. (*a*) What do you mean by separation of boundary layer ? What is the effect of pressure gradient on boundary layer separation ? 6

(*b*) Derive an expression of loss of head due to sudden contraction of pipe. 6

(*c*) Examine the following velocity profiles to state whether the flow is attached or detached : 8

(*i*) $u/v_0 = 2\,(y/\delta) - (y/\delta)^2$

(*ii*) $u/v_0 = -2\,(y/\delta) + (y/\delta)^2 + 2\,(y/\delta)^4$

(*iii*) $u/v_0 = 2\,(y/\delta)^2 + (y/\delta)^3 - 2\,(y/\delta)^4$

6. (*a*) Explain Prandtl mixing length theory. How is the mixing length dependent on the distance from the pipe wall ? 6

(*b*) Water flows through a pipe of diameter 250 mm. The local velocities at the centre and mid-radius are 2.31 m/sec and 2.09 m/sec. Find the discharge and the pipe roughness. 8

(*c*) Obtain an expression for velocity distribution in terms of average velocity for (*i*) smooth pipes, and (*ii*) rough pipes. 3 + 3

7. (*a*) Derive an expression for mass rate of flow of compressible fluid through a nozzle fitted to a large tank. What is the condition for maximum rate of flow? 6

(*b*) A tank contains air at a pressure of 135 kPa and temperature 27 °C. The local barometric pressure is 100 kPa. Air discharges out of the tank into the atmosphere through a convergent nozzle. Determine the outflow velocity and the mass flow rate of air. The cross-sectional area at the nozzle outlet is 500 mm^2. 7

(*c*) A long right circular cylinder of radius R metre is set horizontally in a steady stream of velocity V_0 m/sec and is made to rotate at W rad/sec. Obtain an expression in terms of W, R, and V_0 for the ratio in pressure difference between the extreme top and the extreme bottom of the cylinder surface to the dynamic pressure of the free stream. 7

8. (*a*) Sketch and describe a pitot-static problem and explain how it is used to measure the fluid flow through a pipeline. 5

(*b*) Explain, with neat sketches, how the current and turbine meters help to measure the velocity of flow stream. 5

(*c*) Explain the principle of venturi meter with a neat sketch and establish an expression for the rate of flow through it. 5

(*d*) In a 100 mm diameter horizontal pipe, a venturi meter of 0.5 contraction ratio has been fitted. The head of water on the meter, when there is no flow, is 3 m (gauge). Find the rate of flow for which the throat pressure will be 2 m of water absolute. Take discharge coefficient for the meter as 0.97. 5

Group C

9. Explain the following: 5 × 4

(*i*) Displacement thickness and momentum thickness

(*ii*) Couette flow and Poiseuille flow

(*iii*) Nozzles and diffusers

(*iv*) Friction drag and pressure drag

(*v*) Navier-Stokes equations.

S'13 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

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Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Define and distinguish between the following set of fluid properties : (*i*) Specific weight and mass density, (*ii*) cohesion and adhesion, (*iii*) surface tension and capillarity, and (*iv*) dynamic viscosity and kinematic viscosity. 10

(*b*) A rectangular plate is submerged in water vertically with its upper edge parallel to and at a depth 'a' below the free surface of water. The lower edge is at a distance '*d*' from the upper edge. The breadth of the plate is '*b*'. Find the total pressure on the plate and the depth of centre of pressure. 10

2. (*a*) From energy consideration, what is the important significance of potential head, datum head, and kinetic energy head. What is their relationship to total head ? 6

(*b*) Derive Euler's equation of motion along a streamline and hence derive the Bernoulli's theorem. 6

(*c*) The rate of water through a vertical conical draft tube of a Kaplan tube is 17.5 m^3/s. The diameter of the draft tube on the side connected to the outlet of the turbine runner is 2.5 m and the average velocity at exit is 1.5 m/s. If the pressure at inlet to the tube is not to be less than –0.7 bar, how far the tube should extend above the tail race. Neglect frictional effects and pressume that exit of the draft tube lies 1.2 m below the tail water level. 8

3. (*a*) Establish a relation for the average and maximum velocity for one-dimensional viscous flow of fluid between two fixed parallel plates. 8

(*b*) What do you mean by momentum correction factor and kinetic energy correction factor ? 4

(*c*) A straight stretch of horizontal pipe of 5 cm diameter was used in the laboratory to measure the viscosity of a crude oil of specific weight 9000 N/m^3. During the test run, a pressure differential of 18000 N/m^2 was recorded from two pressure gauges located 6 m apart on the pipe. The oil was allowed to discharge into a weighing tank and 5000 N of oil was collected in 3 min duration. Work out dynamic viscosity of the oil. 8

4. (*a*) Show, for viscous flow through a circular pipe. the velocity distribution across the section is parabolic. Also, show that the mean velocity is equal to the one-half the maximum velocity. 8

(*b*) Explain the concept of boundary layer and define thickness of boundary layer. 4

(*c*) In a stream of oil of specific gravity 0.95 and kinematic viscosity 0.92 stoke moving at 5.75 m/s, a plate of 500 mm length and 250 mm width is placed parallel to the direction of motion. Calculate the friction drag on one side of plate. Also, find the thickness of the boundary layer and the shear stress at the trailing edge of the plate. 8

Group B

5. (*a*) Starting with the Navier-Stokes equations of motion for two-dimensional incompressible flow, obtain the Prandtl's boundary layer equations. Give a brief outline of the Blasius solution of laminar boundary layer for flow over a flat plate. 10

(*b*) A plate of 0.3 m long is placed at zero angle of incidence in a stream of 15 °C water moving at 1 m/s. Find the streamwise velocity component at the mid-point of the boundary layer, the maximum boundary layer thickness and the maximum value of the normal component of velocity at the trailing edge of the plate. Given : For water at 15 °C, $\rho = 1000$ kg/m^3 and $\mu = 4.16$ kg/hr . 10

6. (*a*) Find an expression for mass rate of flow of compressible fluid through an orifice or nozzle fitted to a large tank. What is the condition for maximum rate of flow ? 6

(*b*) Write basic equations (continuity, momentum and energy) for a control volume having normal shock wave. 6

(*c*) A large tank contains air at 28.449 N/cm^2 gauge pressure and 24 °C temperature. The air flows from the tank to the atmosphere through an orifice. If the diameter of the orifice is 2 cm, find the maximum rate of flow of air. Take R = 287 J/kg-K, k = 1.4, atmospheric pressure = 10.104 N/cm^2. 8

7. (*a*) Analyse the flow past a source-sink pair in a uniform flow. Extemd the analysis to study the limiting case of a doublet in uniform flow. What is the engineering significance of the whole analysis ? 10

(*b*) A two-dimensional source of strength 1.8 m^2/s has been placed at the origin in a stream of inviscid in compressible fluid moving with a uniform velocity 0.6 m/s. Make calculations for the fluid velocity both in magnitude and direction at a point $r = 0.75$ m and $\theta = 120°$. 10

8. (*a*) Compare and contrast the use of venturimeter, flow nozzle and orifice meter as primary element for flow measurement. 5

(*b*) Describe, with the help of a neat sketch, the construction, operation and use of pitot-static tube. 5

(*c*) In a venturi meter, usually the length of the divergent outlet part is made longer compared to that of the converging inlet part. Why? 4

(*d*) A venturimeter with 200 mm at inlet and 100 mm throat is laid with axis horizontal, and is used for measuring the flow of oil of specific gravity 0.8. The difference of levels in the V-tube differential-manometer reads 180 mm of mercury whilst 11.52×10^3 kg of oil is collected in 4 min. Calculate the discharge coefficient for the meter. Take specific gravity of mercury as 13.6. 6

Group C

9. Explain the following: 5×4

(*i*) Reynold transport theorem

(*ii*) Momentum integral method

(*iii*) Boundary layer control

(*iv*) Prandtl mixing length theory

(*v*) Viscous flow through pipes

W'13 : 5 FN : MC 404 (1497)

MECHANICS OF FLUIDS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Distinguish between the following : 5 × 2

(*i*) Density and relative density

(*ii*) Adhesion and cohesion

(*ii*) Dynamic and kinematic viscosity

(*iv*) Ideal and real fluid

(*b*) Explain the phenomena of surface tension and capillarity. 10

2. (*a*) Explain the phenomena of buoyancy. 5

(*b*) Discuss the limitations of Bernoulli's equation. 5

(*c*) A horizontal bend in pipeline conveying water gradually reduces from 0.6 m to 0.3 m diameter and deflects the flow through an angle of 60°. At the larger end, the gauge pressure is 171.675 kN/m². Determine the magnitude and direction of force exerted on the bend when the flow is 0.875 m³/s. 10

3. (*a*) Derive Navier-Strokes equation of motion for a steady, incompressible, constant viscosity fluid. 10

(*b*) Derive, by the first principle, an expression for the average velocity in Couette flow with a pressure gradient. 10

4. (*a*) What is a boundary layer ? Explain, with a neat sketch, the development of boundary layer over a smooth flat plate. 10

(*b*) Explain boundary layer thickness, wall shear stress and also the methods of controlling the boundary layer. 10

Group B

5. (*a*) How are laminar and turbulent boundary layers formed and distinguish between their characteristics ? 10

(*b*) Explain the phenomenon of boundary layer separation and its influence on the drag of an immersed body. 10

6. (*a*) Define mixing length and explain its importance in the analysis of turbulent flow through pipes. 10

(*b*) Derive an expression for the velocity distribution for turbulent flow in smooth pipes. 10

7. (*a*) Explain the terms 'Mach angle', 'Mach line' and 'Mach cone'. 3 × 2

(*b*) Explain briefly the theory of oblique shocks. 4

(*c*) How is shock wave produced in a compressible fluid ? What do you mean by the term 'shock strength' ? 10

8. (*a*) Describe, with a neat sketch, the working of a pitot - static tube. 10

(*b*) The pressurized tank shown in Fig.1 has a circular cross-section 2 m in diameter. Oil is drained through a nozzle 0.08 m in diameter in the side of the tank. Assuming that the air pressure is maintained constant, how long does it take to lower the oil surface in the tank by 2 m ? The specific weight of the oil in the tank is 0.75 t/m³ and that of mercury is 13.6 t/m³. 10

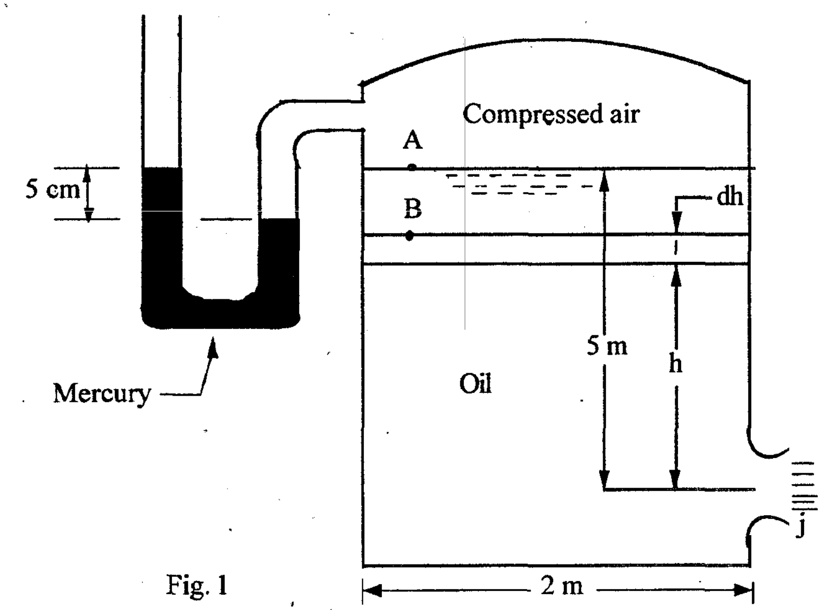

Fig. 1

Group C

9. Explain the following: 5 × 4

(*i*) Hot wire anemometer

(*ii*) Venturi meter

(*iii*) Poisseuilli flow

(*iv*) Intensity of turbulence

(*v*) Hydraulic gradient line and total energy line

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