This question paper contains 5 printed pages.

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B. Tech. (M) / II J

PAPER III— FLUID MECHANICS

(EME–203)

Time : 3 hours *Maximum Marks* : 70

(Write your Roll No. on the top immediately on receipt of this question paper.)

Answer any five questions.
All questions carry equal marks.
Assume suitable values of missing data, if any.

1. (*a*) Water seeps up through sand columns. Why? Estimate the height to which water would rise in a clay soil of average grain diameter 0·06 mm. It may be assumed that surface tension at air–water interface is 0·0735 N/m and interspaces in clay are of size equal to one fifth of mean diameter of clay grain. Take angle of contact $\theta=0$ degree. If sap in trees has the same characteristics as water, what should be the average diameter of capillary tubes in a tree if the sap rises to a height of 8 m? 7

(*b*) Mention the important dimensionless numbers used in fluid mechanics with their significance. Differentiate between distorted and undistorted model. 7

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2. (*a*) Obtain an expression for total pressure and centre of pressure of an inclined submerged plane surface. 7

(*b*) Why is Buckingham's Theorem considered superior as compared to Rayleigh's method? Explain.

Show by dimensional analysis that the power P developed in a water turbine can be expressed as $P = \rho D^5 N^3 \phi \left[\frac{D}{B}, \frac{\rho D^2 N}{\mu}, \frac{ND}{\sqrt{gH}}\right]$. All the terms have their usual meaning. 7

3. (*a*) Explain the term Mach number, Mach cone, Mach line and Mach angle in the context of compressible flow. In case of an isentropic flow of a compressible fluid through a variable area duct, show that:

$$\frac{A}{A_c} = \frac{1}{M}\left[\frac{1+\frac{1}{2}\times(\gamma-1)M^2}{\frac{1}{2}\times(\gamma+1)}\right]^{\frac{\gamma+1}{2(\gamma-1)}}$$ 9

(*b*) Show that for a steady one dimensional isentropic compressible flow through duct of varying area

$$\frac{dA}{A} = \frac{dP}{\rho V^2}(1-M^2).$$ 5

4. (*a*) Air flows through a convergent divergent nozzle. At some section in the nozzle, pressure=2 bar,

velocity=170 m/s and temperature=200°C and cross sectional area=1000 mm^2. Assuming isentropic flow conditions determine:

(*i*) Stagnation temperature and stagnation pressure

(*ii*) Sonic velocity and Mach number at this section

(*iii*) Velocity, Mach number and flow area at outlet section where pressure is 1 bar.

Take R=287 J/kg K, C_p=1000 J/kg K and γ=1·4. 7

(*b*) Define steady and unsteady flow, uniform and nonuniform flow. A square plate 5 m×5 m hangs in water from one of its corners such that its centre of gravity lies at a depth 15 m from free water surface. Calculate the total pressure on one side of the plate and the position of the centre of pressure. 7

5. (*a*) Explain stream function and velocity potential. A two dimensional flow is described by the velocity components: $u=5x^3$ and $v=-15x^2y$. Evaluate the stream function, velocity and acceleration at point P (1, 2). 7

(*b*) Stating the various assumptions derive the

Bernoulli's equation using principle of energy conservation method. 7

6. (*a*) Define vortex flow, free vortex flow and forced vortex flow. Obtain the following equation of motion for vortex flow:

$$dP = \frac{\rho V^2}{r} dr - \rho g\, dz.$$

7

(*b*) Prove that for a steady laminar flow between two fixed parallel plates, the velocity distribution across a section is parabolic and that the average velocity is 2/3 of the maximum velocity. 7

7. (*a*) When a sudden contraction is introduced in a horizontal pipeline from 50 cm diameter to 25 cm diameter, the pressure changes from 150 kPa to 69 kPa. If coefficient of contraction is assumed o be 0·65, calculate the water flow rate. The contraction is subsequently followed by a sudden enlargement from 25 cm to 50 cm diameter. If the pressure at the 25 cm section is 69 kPa, work out the pressure at the 50 cm enlarged section. 7

(*b*) What do you understand by the boundary layer? Explain the development of boundary layer over a flat plate exposed parallel to free stream. Point out the salient features. 7

8. (*a*) Define kinetic energy correction factor and

momentum correction factor. Show that the momentum correction factor for laminar flow through a circular pipe is 4/3. 7

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

(*i*) Hydraulic and Energy Gradient lines

(*ii*) Concept of Equivalent Pipe

(*iii*) Boundary layer separation and its control.

$3_{1/2} \times 2 = 7$