UNIVERSITY OF LONDON

B.Sc. (ENGINEERING) EXAMINATION 1962

PART I

for Internal and External Students

(5) MECHANICS OF FLUIDS

Thursday, 21 June: 2.30 to 5.30

Answer SIX questions.

It may be assumed that the gravitational acceleration is equal to the standard acceleration.
1 ft = 30·48 cm, 1 lb = 453·6 g.
Density of water, 62·4 lb/ft^3.

1. Two adjacent rectangular tanks have in their common side an orifice of area 3 in^2 with its centre 1 ft from the bottom of the tanks. The plan areas of the tanks are constant, one 100 ft^2, the other 60 ft^2. At a certain instant the height of the water in the larger tank is 12 ft from the bottom and in the smaller tank 4 ft from the bottom. Given that the coefficient of discharge of the orifice is 0·6 determine the time required for the height of water in the larger tank to fall from 11 ft to 10 ft from the bottom. Work from first principles.

2. During a test on a 12 in diameter duct the fluid velocity at the duct surfaces was observed to be zero and the flow rate 5 ft^3/s, and the velocity distribution given by $u = c_1 - c_2 r^2$ where u is the velocity at any radius r and c_1 and c_2 are constants. Determine the constants c_1 and c_2 specifying their units.

   At what radius is the actual fluid velocity equal to the mean fluid velocity?

3. An open channel is rectangular in cross-section, depth 2 ft, width 4 ft, and has a slope of 1/2500. Determine (i) the flow rate when the channel runs full and (ii) the depth of the water in the channel if the flow rate is a half of the flow rate when the channel runs full.

   The coefficient C in the Chézy formula may be taken as 100 $m^{1/6}$ ft$^{1/2}$/s, where m is the hydraulic mean depth in feet.

   Taking the coefficient of viscosity of water as 0·01 g/cm s verify that the Reynolds number $\rho u m/\mu$, exceeds the approximate critical value of 1400.

4. Show, by dimensional analysis, that the resistance F of a sphere of diameter D moving with a constant velocity u in a fluid of density ρ and viscosity μ may be expressed by

$$F = \frac{\mu^2}{\rho}\phi\left[\frac{\rho u D}{\mu}\right]$$

   where ϕ is a function.

   It was observed that a steel ball, diameter 0·1 in and density 0·28 lb/in^3, falls with a uniform velocity of 2 in/s in a liquid of density 0·03 lb/in^3. Given that the above function ϕ is such that $\phi(z) = 10z$ for any z, determine the viscosity of the liquid.

Turn over

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5. Show, by the application of the momentum principle, that the equation of motion for the one-dimensional steady flow of an inviscid fluid of invariable density in a duct of non-uniform cross-section is

$$\frac{dp}{\rho} + u \, du + g \, dz = 0$$

A vertical venturi meter is used to measure the upward flow of a liquid, density 60 lb/ft^3. The cross-sectional area at inlet to the venturi is 10 in^2 and the venturi throat area 2 in^2. The pressure difference between the inlet to and throat of the venturi is measured with a vertical differential mercury manometer, (density of mercury relative to density of water 13·6). Determine the volumetric flow rate in ft^3/min of the liquid if the difference in the height of the mercury columns is 4 in. Neglect friction.

6. Define the lift and drag of an aerofoil and discuss the basic components of the total drag. Sketch the variation in the value of the coefficient of lift and the coefficient of drag of an aerofoil with angle of incidence. 5·5 ∴ C_L

A wing of a small aeroplane is rectangular in plan having a span of 30 ft and a chord of 4 ft. In straight and level flight at 150 mile/h the total aerodynamic force acting on the wing is 4500 lbf. If the lift/drag ratio is 10 calculate the coefficient of lift and the total weight the aeroplane can carry. Assume density of air 0·08 lb/ft^3.

7. Define the coefficients of viscosity and kinematic viscosity and deduce the dimensions of each.

Water, coefficient of viscosity 0·0118 poise, flows in a pipe of 3 in diameter and length 50 ft, the discharge being 0·25 ft^3/s. If the friction factor $f = 0{\cdot}08 \, Re^{-0{\cdot}25}$, where Re is the Reynolds number, calculate the frictional pressure drop in lbf/in^2.

[1 poise = 1 g/cm s].

8. Define the coefficient of discharge of an orifice and enumerate the effects which it embodies. Sketch the relationship between the coefficient of discharge and head across a sharp edged orifice indicating the range of values.

A convergent nozzle is fitted to a side of a reservoir, the centre of the nozzle being 4 ft above the ground. When the head of water in the reservoir above the nozzle level is 8 ft the jet issuing from the nozzle strikes the ground 10·75 ft horizontally away from the nozzle mouth. Assuming the jet follows a parabolic path calculate the efficiency of the nozzle. Formulae used must be proven.

9. Deduce an expression showing the relationship between the head lost at an abrupt enlargement in a pipe diameter and the velocities of flow.

Such an enlargement exists at the junction of a 3 in diameter and a 7 in diameter pipe. The flow is 0·75 ft^3/s, in a direction from the smaller into the larger diameter pipe. Calculate the head lost at the junction. 2·3 feet

What percentage error will there be if the head lost at the above abrupt enlargement is neglected compared with the frictional head lost in 100 ft of the 3 in diameter pipe whose friction factor f is 0·0075? 5 %

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