UNIVERSITY OF LONDON

B.Sc. (ENGINEERING) EXAMINATION 1963

PART II

for Internal and External Students

(12) MECHANICS OF FLUIDS

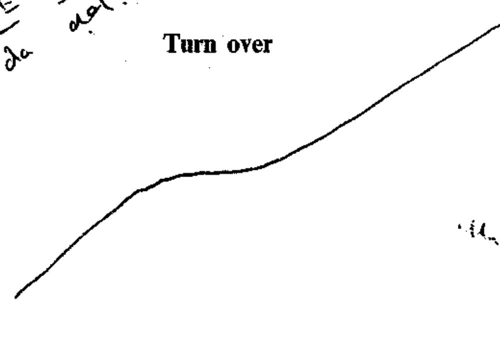
Thursday 13 June: 2.30 to 5.30

Answer FIVE questions.

1. Define 'specific energy of flow' with regard to water flowing in an open channel.
Working from first principles show that, for a given rate of discharge Q flowing in an open channel of any cross-sectional shape, the critical depth is the depth for which the value of a^3/b equals Q^2/g where a is the cross-sectional area of flow and b is the free-surface width.
Sketch the free-surface profiles and lines of critical depth for the following flows:
   (*a*) over a broad-crested weir,
   (*b*) through a Venturi flume,
   (*c*) down a round-crested spillway-chute from a reservoir to the river bed with a hydraulic jump at the toe of the spillway. (Neglect friction.)

2. Define the specific speed of a water-turbine and prove that all geometrically similar Pelton wheels with the same hydraulic coefficients have the same specific speed.
Pelton wheels are not normally used for heads of much less than 500 ft if the power to be developed is large (of the order of 10 000 hp). Assuming values for heads, proportions and power, draw up a table to show the reasons for this.

$\frac{dE}{d(d)} = \frac{dE}{da}\frac{da}{dd}.$



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Turn over

3. A disc of diameter D which is immersed in a fluid of density ρ and coefficient of viscosity μ has a constant rotational speed N. Under these conditions the necessary power to drive the disc is P.
Show by dimensional analysis that

$$P = \rho N^3 D^5 \phi \left[\frac{\rho N D^2}{\mu}\right]$$ ✓

A disc rotating in water at a given temperature absorbs 1·20 hp when revolving at 1600 rev/min and 2·70 hp when rotating at 2200 rev/min.
Estimate what would be the corresponding power if the disc were revolving at 1800 rev/min in a fluid of viscosity ten times that of the water and of density 0·90 of the density of the water.

4. An enclosed horizontal duct 6 ft square has vertical sides. It is running full of water and at one point there is a curved right angled bend, the radius of curvature to the centre line of the duct being 20 ft. If the flow in the bend is assumed to be frictionless and to have a free vortex distribution, calculate the rate of flow in ft^3/s if the difference of pressure head between the inner and outer sides is 9 in. of water.

5. A fluid of kinematic viscosity ν and density ρ flows with laminar motion and constant depth h in an open rectangular channel of bed slope i. The velocity is assumed to be a maximum in the free surface, and the breadth of the channel is great compared with the depth of flow.
If y is measured from the channel bed, show that:

$$-\mu \frac{d^2 v}{dy^2} = \rho g i$$

Hence, or by using conventional 'parallel plate' theory from first principles, prove that

$$\frac{\tau_0}{\rho \bar{v}^2} = \frac{9\nu^2}{g i h^3},$$

where τ_0 is the viscous shear stress at the bed of the channel and $\bar{v}$ is the mean velocity of flow.

6. A centrifugal pump delivers 10·7 ft^3/s of water at 1400 rev/min. The total effective head is 60 ft, of which the head converted in the diffuser is 12 ft. The impeller is 12 in diameter and $1\frac{1}{4}$ in wide at exit, and is designed for constant velocity of flow. Both the suction and the delivery pipes have the same bore.
Calculate the following vane angles:
(*a*) for the impeller vanes at exit,
(*b*) for entry to the stationary guide vanes surrounding the impeller.
Comment on the practical use of conventional velocity triangles in pump design.

7. A pipe 2 ft diameter and 3000 ft long with $f = 0{\cdot}008$ connects two reservoirs having a difference in water surface level of 100 ft.
Calculate the flow between the reservoirs and the shear stress at the wall of the pipe.
If the upstream half of the pipe is subsequently tapped by several side pipes so that one third of the quantity of water now entering the main pipe is withdrawn uniformly over this length, calculate the new rate of discharge to the lower reservoir. Neglect all losses other than those due to pipe friction.

8. Discuss briefly the measurements of flows, large and small, by means of notches or weirs. The rate of discharge Q, (ft^3/s), over a 90° vee-notch is given by $Q = 2{\cdot}48H^{2{\cdot}48}$ where H is the head in feet, whilst the corresponding formula for a certain rectangular notch is $Q = 10H^{3/2}$.

The head is to be measured by means of a gauge which can be read to within $\pm \frac{1}{10}$ in of the correct value.

Calculate the percentage error which can result in estimating the rate of discharge, if 2 ft^3/s of water passes over either weir.

9. A Pitot-static tube is used as an air-speed indicator for an aircraft. The speed of the aircraft is v_0 and the undisturbed air pressure and density are p_0 and ρ_0. At the stagnation point the air pressure and density are p and ρ and the flow is assumed to be compressible isentropic.

Using a binomial expansion show that the pressure rise at the stagnation point may be expressed approximately as:

$$p - p_0 = \tfrac{1}{2}\rho_0 v_0^2 \left[1 + \frac{\rho_0 v_0^2}{4\gamma p_0}\right]$$

If the undisturbed air weighs $0{\cdot}0765\ \text{lbf}/\text{ft}^3$, p_0 is $14{\cdot}7\ \text{lbf}/\text{in}^2$, γ is $1{\cdot}4$ and the speed of the aircraft is 152 miles/hr, estimate the percentage error which would result from neglecting the effects of compressibility.

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