9210-129
Level 6 Graduate Diploma in Engineering
Fluid mechanics

Sample Paper

You should have the following for this examination
- one answer book
- non-programmable calculator
- pen, pencil, drawing instruments

No additional data is attached

General instructions
- This examination paper is of **three** hours duration.
- This examination paper contains **nine** questions.
- Answer any **five** questions.
- All question carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic, non-programmable calculator may be used, but candidates **must** show clearly the steps prior to obtaining final numerical values.
- Drawings should be clear, in good proportion and in pencil. Do **not** use red ink.

1 a) State the importance of Dimensional Analysis in Hydraulic and Aeronautical Engineering applications. (4 marks)

b) Give **three** types of Similarity Laws and explain each of them briefly. (6 marks)

c) A dam spillway is to be tested by using Froude scaling with a one-thirtieth-scale model. The model flow has an average velocity of 0.6 m/s and a volume flow of 0.05 m^3/s.

i) What will be the velocity and flow rate of the prototype? (6 marks)

ii) If the measured force on a certain part of the model is 1.5 N, what will be the corresponding force on the prototype? (4 marks)

2 a) i) Develop an expression for the streamlines of flow between sources, sink pair of equal strength *m* and separated by a distance 2*a*. (6 marks)

ii) Hence show that the stream function ψ for a doublet can be expressed,

in the usual notation, $\psi = -\frac{m}{2\pi}\left(\frac{2ay}{x^2 + y^2}\right)$ (4 marks)

iii) Calculate the velocity at point P (1, 2). (4 marks)

b) Velocity components in a fluid flow is given by $u = 2xy$ and $v = a^2 + x^2 - y^2$.

i) Prove that this fluid flow is possible. (3 marks)

ii) Hence, obtain the relevant stream function for the flow. (3 marks)

3 a) Clearly show the boundary layer growth on a flat plate in a viscous fluid using a neat sketch. With particular reference to the sketch, indicate the salient features of the boundary layer. (6 marks)

b) Explain the flow separation phenomena and formation of wake of a boundary layer. (6 marks)

c) A smooth flat plate 1.5 m wide and 20 m long is subjected to flow of water along its length with a uniform velocity of 2 m/s. Critical Reynolds No. for laminar flow is given as 5×10^5. Density of water is 1000 kg/m^3 and kinematic viscosity of water is $1 \times 10^{-6} m^2/s$. Find

i) The extent of the laminar boundary layer on the plate. (4 marks)

ii) The thickness of the boundary layer at the edge of the laminar boundary layer, and that at the trailing edge. (4 marks)

4 a) Define the terms Energy Grade Line (EGL) and Hydraulic Grade Line (HGL) with particular reference to Bernoulli's equation. (8 marks)

b) A vessel has two identical orifices A and B with identical coefficients of velocity (C_v) provided in one of its vertical sides at depths H_a and H_b respectively, below the liquid surface in the tank, as shown in Figure Q4. The centres of the orifices lie on the same vertical line.

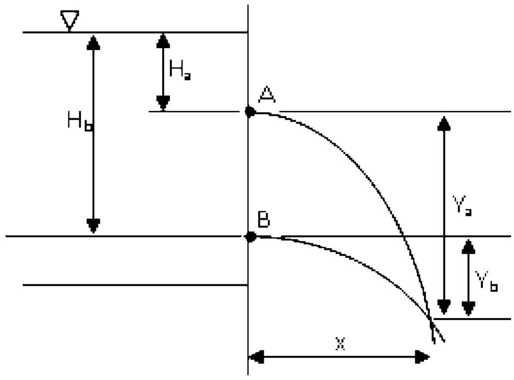

Figure Q4

i) Show that the point of intersection of the two jets is, where Y_a and Y_b below A and B respectively, satisfy the conditions $Y_a = H_b$ and $Y_b = H_a$. (4 marks)

ii) Find the horizontal distance (x) of the point of intersection from the plane of the orifice. (2 marks)

c) Oil flows through a 25 mm diameter orifice under a head of 5.5 m at a rate of 3 litres/s. The jet of water from the orifice strikes a wall at a point, which is 1.5 m away from the orifice, and 120 mm vertically below the centre line of the contracted jet. Calculate

i) the coefficient of velocity, (2 marks)

ii) coefficient of contraction, and (2 marks)

iii) coefficient of discharge. (2 marks)

 See next page

5 a) What are the **two** major categories of pumps? Classify each category further. (6 marks)

b) The power input (P) to a centrifugal pump is assumed to be a function of the volume flow (Q), Impeller diameter (D), rotational speed (ω), the density (ρ) and viscosity (μ) of the fluid. Establish the following relationship using above parameters.

$$\frac{P}{\rho\omega^3 D^5} = \phi\left(\frac{Q}{\omega D^3}, \frac{\rho\omega D^2}{\mu}, \frac{\varepsilon}{D}\right)$$ (8 marks)

c) In a test of the centrifugal pump shown in Figure Q5, the following observations were made. Inlet pressure, P_1 = 13 kPa and exit pressure, P_2 = 66 kPa. The pipe diameters are D_1 = 12 cm and D_2 = 5 cm. The flow rate is 12 litres/s of light oil having specific gravity 0.91.

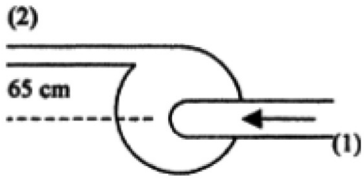

Figure Q5

Estimate

i) the head developed, (4 marks)

ii) the input power required at 75% efficiency. (2 marks)

6 a) i) Derive Darcy-Weisbach equation in usual notations for determining the loss of head due to friction in pipes. State any assumptions that you made in the derivation. (8 marks)

ii) Water flows through a horizontal uniform circular pipe of diameter 30 mm and length 800 m. Determine the loss of head due to friction and the power required to maintain the flow when the flow rate of water in the pipe is 3 litres/min

Assume: Dynamic viscosity of water – 1.14×10^{-3} Pas

Density of water – 1000 kg/m^3 (6 marks)

b) A straight 25 cm diameter pipeline 5 km long is laid between two reservoirs having a difference in levels of 40 m. To increase the flow capacity of the system an additional 2.5 km long 25 cm diameter pipe is laid parallel to the first pipe and from the first reservoir to the midpoint of the original pipe. Assuming friction factor as 0.025 for both the pipes, find the increase in discharge due to installation of the new pipe. (6 marks)

7 a) Define steady uniform flow, steady non-uniform flow and give an example to demonstrate each type of flow. (8 marks)

b) i) State Bernoulli's equation and explain the condition of fluid and its flow within which this equation can be applied. (2 marks)

ii) Express Bernoulli's equation in the form of energy consideration and define each energy term in the equation. (3 marks)

c) Water flows up a tapered pipe as shown in Figure Q7. Find the magnitude and direction of the deflection *h* of the differential mercury manometer corresponding to a discharge of 120 litres/s. The friction in the pipe can be completely neglected. Take relative density of mercury as 13.6. (7 marks)

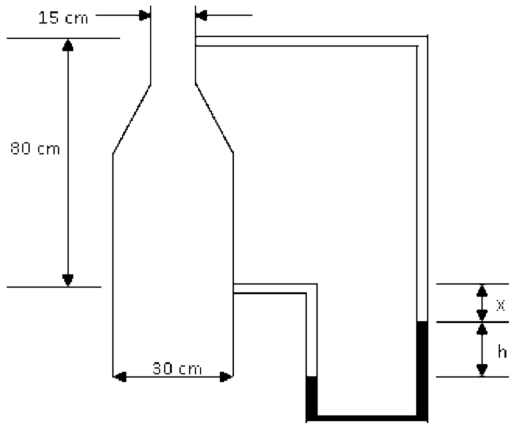

Figure Q7

8 a) Define the terms drag force and lift force acting on a body immersed in a flowing fluid. (4 marks)

i) Write the equation for lift and drag force in usual notations. Define each parameter of the equation with relevant units. (4 marks)

ii) A kite, which may be assumed to be a flat plate of face area 1.2 m^2 and mass 1 kg, soars with kite-sail assuming an angle to the horizontal. Tension of the flying line (string) holding the kite is 50 N when the wind velocity is 40 km/h horizontally and the inclination of flying line to the horizontal is 35°. The density of air is 1.2 kg/m^3. Calculate the lift and drag coefficients for the kite in the given position. (6 marks)

b) A cylinder 8 mm diameter and 200 mm long is placed in a stream of fluid flowing at a velocity of 0.5 m/s. The axis of the cylinder is normal to the direction of flow. The density of the fluid is 800 kg/m^3. The drag force is measured and found to be 30 N.

i) Calculate the drag coefficient. (3 marks)

ii) At the point on the surface, the pressure is measured as 96 Pa above the ambient level. Calculate the velocity at this point. (3 marks)

9 a) i) Explain the phenomenon of fluidization. (4 marks)

ii) What are the advantages of fluidized beds? (6 marks)

b) i) State the Carmon-Kozeny equation and explain each term of the equation. (5 marks)

ii) Water is filtered through a sand bed of 150 mm thick. The depth of water on top of the bed is 120 mm. The porosity is 0.4 and mean particle diameter is 0.25 mm. The dynamic viscosity is 0.89 cp and the density is 1000 kg/m^3. Calculate the flow rate per square metre of area. (5 marks)