⑨ 00224

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CEX 5231/CVX 5531 Mechanics of Fluids**
Academic Year	: 2017/18
Date	: 07th February 2019
Time	: 0930-1230hrs
Duration	**: 03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **SEVEN (07)** questions in **Five (05)** pages.
3. Answer any **FIVE (05)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Necessary additional information is provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red colour pen.
9. Take,

   Density of water = 1000 kgm^{-3} Acceleration due to gravity = 9.81 ms^{-2}

   Kinematic viscosity of water = 1.12×10^{-06} m^2/s at 20^0C

Question 01

(a) In a two-dimensional, incompressible flow, the fluid velocity components are given by:

$$u = \frac{y^3}{3} + 2x - x^2 y$$

$$v = xy^2 - 2y - \frac{x^3}{3}$$

(i) Show that the flow satisfies the continuity equation.

(02 marks)

(ii) Obtain the expression for the stream function.

(03 marks)

(iii) Show that the flow represents a possible irrotational flow.

(02 marks)

(iv) Obtain the expression for velocity potential.

(03 marks)

(v) Determine the magnitude of the acceleration at point $(x, y) = (0,1)$.

(04 marks)

(b) The velocity vector in a three-dimensional, incompressible, unsteady flow is given by:
$V = (6xt + yz^2)i + (3t + xy^2)j + (xy - 2xyz - 6tz)k$
in which t represents the time.

(i) State whether the continuity is satisfied or not.

(03 marks)

(ii) Determine the acceleration component in x-direction at $t = 0$.

(03 marks)

Question 02

(a) The resistance force of a ship F is a function of its length L, velocity V, acceleration due to gravity g and fluid properties, density ρ and dynamic viscosity μ. Express the relationship among the variables in dimensionless form using Buckingham's Pi theorem as shown below.

$$\frac{F}{\rho V^2 L^2} = \varphi\left(\frac{V}{\sqrt{gL}}, \frac{\mu}{\rho V L}\right)$$

(12 marks)

(b) For Froude model law, find the model to prototype ratios of velocity, force, and power in terms of its length scale.

(05 marks)

(c) A 1.2 m long model of a ship is towed in a towing tank at a speed of 0.85 m/s. Determine the speed of a 80.0 m long ship, which corresponds to the speed of the model ship indicated.

(03 marks)

Question 03

(a) Briefly explain the boundary layer separation phenomenon with respect to the flow around a solid body and methodologies which can be introduced to control such separation.

(06 marks)

(b) The boundary layer profile may be represented by the following expression for laminar fluid flow over a flat plate.

$$\frac{u}{U_s} = 2\left(\frac{y}{\delta}\right) - 2\left(\frac{y}{\delta}\right)^3 + \left(\frac{y}{\delta}\right)^4$$

(i) Obtain the expressions for boundary layer thickness, shear stress, drag force and coefficient of drag in terms of Reynolds number.

(11 marks)

(ii) A thin plate is moving in air in still atmosphere at a velocity of 5.0 m/s. The length of the plate is 0.8 m and width is 0.5 m. A small particle is placed on the plate exactly in the middle. Check whether the particle will be sheared off of the plate if the particle can resist a shear stress up to 0.01 N/m^2. Take density of air as 1.24 kg/m^3 and kinematic viscosity as 1.50×10^{-05} m^2/s.

(03 marks)

Additional Information:

Momentum thickness of a boundary layer is given by: $\theta = \int_0^\delta \frac{u}{U_s}\left(1 - \frac{u}{U_s}\right) dy$

Newton's law of viscosity is given by: $\tau = \mu \frac{du}{dy}$

Shear stress on the solid boundary of a boundary layer is given by: $\tau_0 = \rho U_s^2 \frac{d\theta}{dx}$

Question 04

(a) A lined triangular canal section is shown in Figure Q4. The section consists of a triangular section with its bottom being rounded by a circular curve of radius equal to a depth of 2.75 m. Check whether a supply discharge of 50.0 m^3/s would be a flood condition or not. The longitudinal slope and Manning's roughness coefficient of the channel are 1:1500 and 0.016, respectively. The side slopes are set at 1:1.

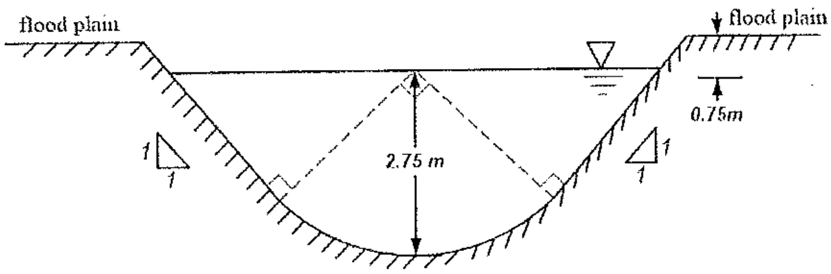

Figure Q4

(07 marks)

(b) A *wide rectangular* channel carries a flow of 3.52 m^3/s per metre width. If the flow is uniform upstream and channel slope is 1:2000;

(i) Calculate the normal depth of flow upstream. Take Manning's roughness coefficient as 0.017.

(03 marks)

(ii) Assuming flow approaches at normal depth, calculate the minimum rise in the floor at a downstream section required to produce critical flow conditions.

(05 marks)

(iii) If the actual rise in floor is 0.30 m, determine the change in depth of flow due to such rise. Justify your answer with reference to specific energy vs. depth of flow relationship.

(05 marks)

Additional Information:

The Manning's equation for uniform flow is given by: $V = \frac{1}{n} R^{2/3} S_0^{1/2}$

Question 05

(a) Using the principle of conservation of momentum, obtain the governing equation for a surge tank control, in the form:

$$\frac{L}{g}\frac{dV}{dt} + h_f + z = 0$$

where, L is the length of the supply tunnel, V is flow velocity of water in the supply tunnel, h_f is the friction head and z is the water level in the surge tank above reservoir level.

(08 marks)

(b) A low pressure tunnel 1200 m long with a cross-sectional area of 1.77 m^2 feeds water via a simple surge tank of cross-sectional area 28.32 m^2 to the high pressure penstock of a hydro-electric power house.

Initially, the steady rate of flow to the turbines is 5.35 m^3/s. A valve on the high pressure penstock is completely closed in a period of 4 minutes in such a way as to produce a linear rate of reduction of discharge with time. Neglecting friction, calculate the maximum rise of the water level in the surge shaft.

(12 marks)

Additional Information:

The solution to the second order differential equation, $d^2z/dt^2 + m^2 z = c^2$ is given by: $z = A\cos mt + B\sin mt + c^2/m^2$.

Question 06

(a) Explain the phenomenon of cavitation with reference to pumps. In addition, briefly discuss the precautions, which can be taken against it.

(05 marks)

(b) A centrifugal pump with an outer impeller diameter 1.2 m runs at 200 r.p.m and pumps 1.88 m^3/s, the average lift being 6.0 m. The angle which the vanes make at exit with the impeller is 26^0 and the radial velocity of flow 2.5 m/s. The inner diameter of the impeller is 0.6 m. The power supplied to the pump is 201.2 kW and the mechanical efficiency is estimated to be 93%.

(i) Determine the manometric efficiency and overall efficiency.

(08 marks)

(ii) The flow is now reduced by 50% using a regulator. Estimate the percentage change in manometric efficiency, if the average lift is approximately unchanged.

(04 marks)

(iii) Determine the least pump speed required to start pumping against a head of 6.0 m.

(03 marks)

Additional Information:

The theoretical head provided by a pump is given by, $\frac{u_2 v_{w2}}{g}$.

Question 07

A Pelton wheel turbine is working under a gross head of 400 m. The water is supplied through a penstock of diameter 1.2 m and length 4.2 km from reservoir to the Pelton wheel. The coefficient of friction for the penstock is 0.008. The jet of water of diameter 150 mm strikes the buckets of the wheel and gets deflected through an angle 165^0. The relative velocity of water at outlet is reduced by 15% due to inside roughness of the buckets. If the velocity of the buckets is 0.45 times the jet velocity at inlet and mechanical efficiency is 83%, determine,

(a) power given to the runner,

(14 marks)

(b) shaft power,

(02 marks)

(c) hydraulic efficiency and overall efficiency of the turbine.

(04 marks)

Additional Information:

The power given to runner of a turbine is given by, $\rho Q(v_{w1} - v_{w2})u$.

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