THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering

Bachelor of Technology (Civil) – Level 5
CEX 5231 – Mechanics of Fluids

Final Examination – 2016/2017

Time Allowed **3 Hours**

Date: 28th November 2017 Time 09:30 - 12:30

This paper consists of *Seven* Questions. Answer *Five* Questions **Only**.

All questions carry ***equal*** marks.

Please write answers clearly showing any derivations required and stating necessary assumptions.

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

1.

a. A rectangular channel had a positive surge of velocity 7 m/s moving down the channel. If the depth of flow and velocity after the passing of the surge are 3 m and 4.5 m/s respectively, Determine;

   i) the depth and
   ii) the velocity **before the passage of the surge**.

b. The velocity of water in a 80 cm diameter and 20 mm thick cast iron pipe (E = 1.04 x 10^{11} Nm^{-2}) is changed from 3 m/s to zero in 1.3 s by closure of a valve.

   i) If the pipe length is 800 m what will be the water hammer pressure at the valve?

   ii) Calculate the corresponding pressure rise, if the closure takes place in 2 s and 0.7 s respectively.

Bulk modulus K for water = 2.11 x 10^9 Nm^{-2}

Velocity of pressure wave $C = \sqrt{K/\rho}\left[\frac{1}{1+(D/t)(K/E)}\right]^{1/2}$

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2.

a. State the Buckingham Pi Theorem.

b. Using the above theorem, show that the Thrust T developed by a propeller can be expressed as:

$$T = V^2 D^2 \rho \phi \left(\frac{\mu}{VD\rho}, \frac{D\omega}{V}, \frac{C}{V} \right)$$

where ω is the angular velocity, V is the speed of advance, D is the diameter, and ρ and μ are the mass density and dynamic viscosity of the fluid medium respectively.
C is the speed of sound in the fluid medium which represents the elasticity of the fluid.

(Use V, D and ρ as the repeating variables)

3. Two reservoirs with a water level difference of 5 m are connected by a pipe of diameter 150 mm and length 15 m. The Darcy friction factor for the pipeline is 0.012. A centrifugal pump having the characteristics shown in Table 1 is installed in the pipe and water is pumped from the lower reservoir to the upper reservoir. The minor losses in the pipe can be neglected.

Flow rate Q (m^3/s)	0	0.1	0.2	0.3	0.4	0.5	0.6
Head provided by the pump H_p (m)	92.5	90	82.5	72.5	60	42.5	20
Efficiency η (%)	0	45	70	80	75	60	30

Table 1

a. Determine the flow rate between the reservoirs and the power consumed by the pump.

b. Also determine the flow rate between the reservoirs and the power consumed by each pump when **two such pumps are connected in parallel** in the same pipe system.

(Use the graph sheet provided)

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4.

a. Show that the condition for the **most economical section** for a **trapezoidal channel** is that the sides have a slope of $1/\sqrt{3}$ with respect to the base.

b. If a trapezoidal channel is required to carry a 6 m^3/s of water at a velocity of 1.5 m/s, Determine;

i) the most economical cross-section if the channel has side slopes of 1 vertical to 2 horizontal.
ii) the slope required for the **same discharge** if this trapezoidal section is replaced by a rectangular section of 1.5 m deep and 3 m wide.
iii) amount of power can be saved in part ii

(Take C = 55 $m^{1/2}/s$ in Chezy formula $V = C\sqrt{y_m s}$)

5.

a. For the following velocity distributions, check whether the **essential and desirable boundary conditions** are satisfied to be the velocity distributions in a laminar boundary layer:

i) $u/U = \sin\left(\frac{\pi y}{2\delta}\right)$
ii) $u/U = 1 + \eta - 2\eta^2$ where $\eta = y/\delta$

b. A smooth flat plate 3 m x 20 m is subjected to a flow of water along its length with a velocity of 3 ms^{-1}. Find:

i) extent of the laminar boundary layer on the plate

ii) the thickness of the boundary layer at the edge of the laminar boundary layer and at the trailing edge

iii) the shear stress at the trailing edge

$\frac{\delta_c}{x_{crit}} = \frac{5}{\sqrt{Re_{(crit)}}}$ and $\frac{\delta_t}{x} = \frac{0.22}{Re_x^{1/6}}$

(Take density $\rho = 10^3$ kg/m^3 and kinematic viscosity $\nu = 10^{-6}$ m^2/s)

c. A fluid with viscosity of 1 Ns/m^2 flows as a laminar flow in between a pair of parallel plates which are 16 mm apart. The upper plate moves at a velocity of 4 m/s with respect to the lower plate which is stationary. If the pressure drop in the flow direction is from 200 kPa to 100 kPa over a distance of 70 m, determine:

i) Velocity distribution
ii) Discharge per unit width

Velocity distribution u is given by $u = \frac{Vy}{b} - \frac{1}{2\mu}\left(\frac{dP}{dx}\right)(by - y^2)$

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6.

a. Determine which of the velocity component sets given below satisfy the equation of continuity.

i) $u = A \sin xy$
$v = -A \sin xy$

ii) $u = 2x^2 + zy$
$v = -2xy + 3y^3 + 3zy$
$w = -\frac{3}{2}z^2 - 2xy - 6yz$

b. Verify whether the following functions are valid potential functions.

i) $\phi = m \ln x$
ii) $\phi = A \cos x$

c. Obtain relevant stream function to each of the following sets of velocity components of steady, incompressible flow.

i) $u = -cx/y$
$v = c \ln xy$

ii) $u = x + y$
$v = x - y$

iii) $u = 2cx$
$v = -2cy$

7.

a. A rectangular channel 5.2 m wide has a discharge of 10 m^3/s at a velocity of 1.25 m/s. At a certain section the bed width is reduced to 3 m through a smooth transition. A smooth flat hump is to be built in this contracted section to cause critical flow for flow measurement purposes. Estimate the height of the hump necessary for this purpose.
(Energy loss can be neglected at the transition)

b. A 3 m wide rectangular channel conveys 7.5 m^3/s of water with a velocity of 5 m/s.

i) Show the possibility for a hydraulic jump to occur in this channel.
ii) Find the height, length and strength of the jump.
iii) Determine the loss of energy per kg of water.

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