00142

THE OPEN UNIVERSITY OF SRI LANKA

Department of Civil Engineering

Bachelor of Technology - Level 5

CEX 5231 - MECHANICS OF FLUIDS

FINAL EXAMINATION - 2013/2014

Time Allowed : **Three Hours**

Date : 25th August, 2014 Time : 9:30 – 12:30 hrs

ANSWER **ALL THREE** QUESTIONS IN PART A AND **ANY TWO** QUESTIONS IN PART B. ALL QUESTIONS CARRY EQUAL MARKS.

PART A

Answer **all three** questions in this section.

1)

(a) A smooth horizontal open channel has a width of **b** and carries a discharge of **Q**, as shown in Figure 1(a). The flow at a certain location A is super-critical, with a flow depth of y_1. There is a hydraulic jump just downstream of A as shown in the figure and the depth just downstream of the jump is y_2. Obtain a relationship for the ratio y_1/y_2 in terms of downstream Froude number F_{r2}.

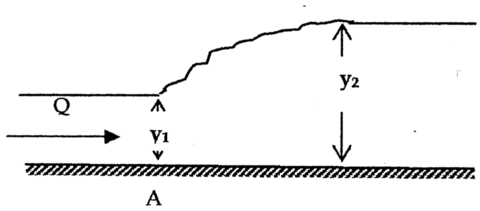

Figure 1(a)

(b) Water emerges from a spillway with a velocity of 20 ms^{-1} and depth of 0.5 m at the toe as shown in figure 1(b) into a wide rec channel having Manning's n = 0.020 and S_0= 0.001. Assume channel to be a wide rectangular channel.

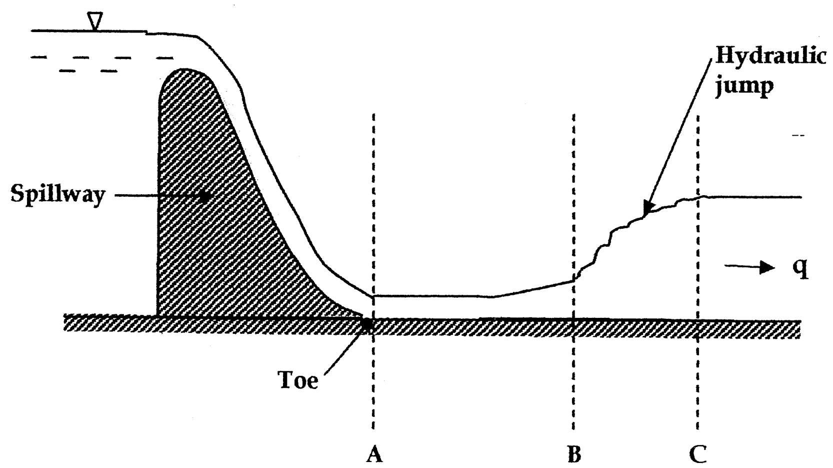

Figure 1(b)

a) Calculate the critical depth for the given channel and discharge.
b) Calculate the uniform depth for the given channel and discharge.
e) Identify the flow profile type (from M1, M2, M3, S1, S2, S3) between section A and B.
d) Estimate the distance of the hydraulic jump from the spillway toe in the absence of any jump controls.

2) The Navier-Stokes equations for a two-dimensional flow can be written in the form

$$\frac{\partial \underline{q}}{\partial t} + (\underline{q}.\underline{\nabla})\underline{q} = -\frac{1}{\rho}\underline{\nabla}(p^*) + \frac{\mu}{\rho}\nabla^2 \underline{q} \quad (1) \qquad \text{and} \qquad \nabla.\underline{q} = 0 \quad (2)$$

where $\underline{q} = u\underline{i} + v\underline{j} + w\underline{k}$ is the velocity vector and p* is the piezometric pressure with z measured in the $\underline{k}$ direction.

a) Explain the physical significance of the term $(\underline{q}.\underline{\nabla})\underline{q}$ in equation (1).

b) Explain the physical significance of the term $\frac{\mu}{\rho}\nabla^2 \underline{q}$ in equation (1).

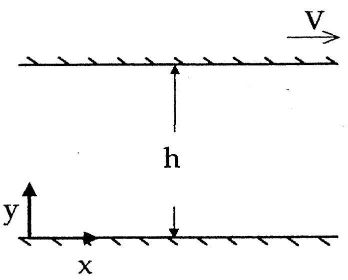

Figure 2

A fluid of density ρ and dynamic viscosity μ flows between two parallel plates as shown in Figure 2. The distance between the plates is h. The upper plate moves with respect to the lower plate at a steady velocity V. The differential equation for the velocity between these two plates can be derived from equations (1) and (2) as

$$\mu \frac{d^2 u}{dy^2} = \frac{dp^*}{dx}$$

c) List the assumptions made in deriving the simplified equation given above.
d) Show that the discharge Q, per unit width between the two plates is given by

$$Q = \frac{Vh}{2} - \frac{h^3}{12\mu}\frac{dp^*}{dx}$$

3)
a) State Buckingham π (Pi) theorem.

The pressure rise **Δp** generated by a pump depends on the impeller diameter **D**, its rotational speed **N**, the fluid density **ρ**, viscosity **μ** and the rate of discharge **q**.

b) Obtain a non-dimensional relationship between the pressure rise **Δp** and the other variables.

A given pump rotates at a speed of 1000 rev/min and generates a head of 12 m when pumping water at a rate of 0.015 m^3/s.

c) Calculate the head generated by a similar pump, twice the size, when operating under dynamically similar conditions and discharging 0.045 m^3/s.

d) Calculate the shaft power of the second pump if its overall efficiency is 80%.

e) List all the assumptions that you have made in the calculations.

PART B

Answer **any two** questions in this section.

4) A trapezoidal channel of base width 6 m and side slopes of 2H to 1V carries a flow of 60 m^3/s at a depth of 2.5 m. There is a smooth transition to a rectangular section 6 m wide accompanied by a gradual lowering of the channel bed by 0.6m.

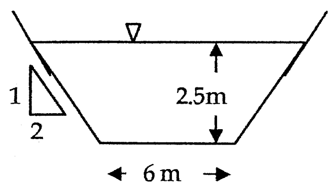

Figure 4a: Section at 1

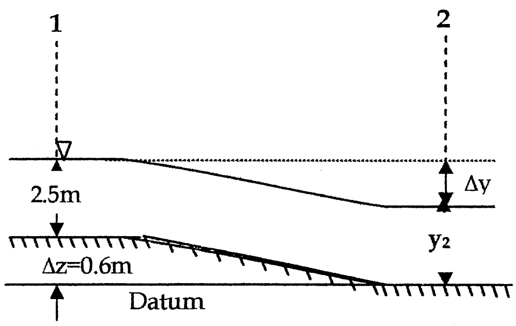

Figure 4b: Longitudinal view of channel

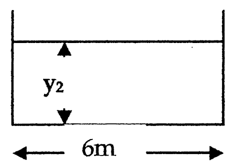

Figure 4c: Section at 2

a) Define the specific energy in an open channel flow.

b) What is the relationship between the specific energy and the total head in an open channel flow?

c) Find the depth of water in the rectangular section.

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d) Calculate the change in water surface level between section 1 and 2.

e) Calculate the amount by which the bed must be lowered in order to limit the drop in water surface level to 0.3 m.

5)

a) State Darcy's law governing the flow of groundwater and list the principal assumptions under which it is valid.

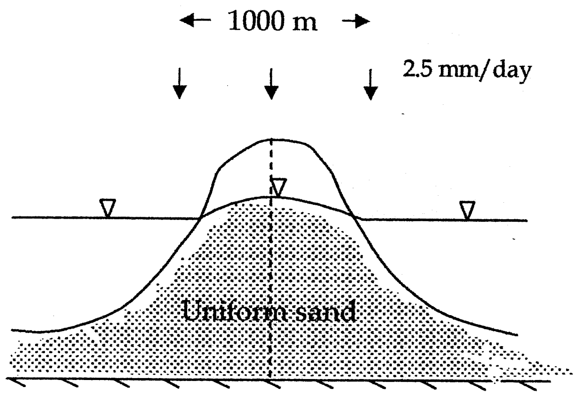
A circular island of radius 500m situated in a fresh water lake as shown in Figure 5 consists of uniform fine sand of permeability of 2m/day. The island is subject to a uniform rainfall that results in a recharge rate of 2.5mm/day.

b) Derive from first principles, an equation governing the variation of the level of ground water on the island. State all your assumptions.

c) What are the boundary conditions you would use to solve this equation?

d) Estimate the highest level of groundwater on the island with respect to the level of the lake.

e) Describe the situation that would exist if the island is in the sea.



Impermeable rock

Figure 5

6)

a) Can the Bernoulli's equation be used in an ideal fluid flow? Explain your answer.

An ideal fluid flow is created by placing a source of strength **m** in a uniform flow field of velocity **U**. The source is placed a distance **m/2U** from a long, straight wall, as shown in Figure 6a. The wall is parallel to the direction of the uniform flow.

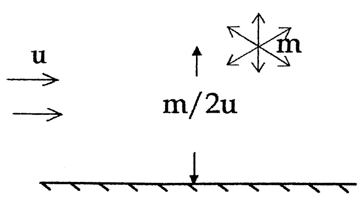


Figure 6a

b) Obtain the complex potential of this flow.
c) Sketch the streamlines of this flow.
d) Determine any stagnation points.
e) Obtain an expression for the velocity distribution along the wall.
f) By considering the velocity and pressure far away from the source derive an expression for the pressure distribution along the wall.
g) Sketch the streamlines of the flow if the distance from the wall is **2m/U** .

A bore well shown in Figure 6b is in a homogeneous strata sandwiched between two impermeable layers. The velocity of ground water flow is 1 m/day and the discharge from the bore well is 30 *l/s*.

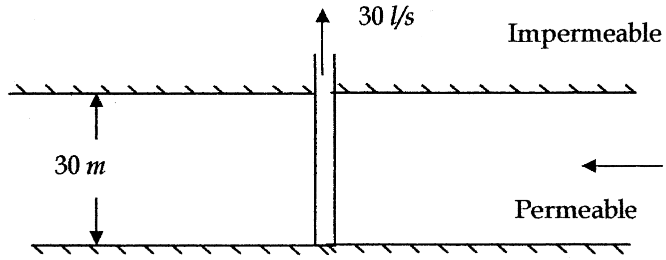


Figure 6b

h) Find whether any pollution 20 m downstream of the bore well would affect the water supply from the bore well.

7)
a) Explain, briefly, what is meant by the term "boundary layer".

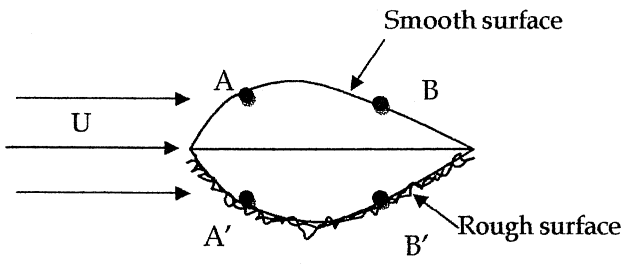


Figure 7

A two dimensional streamlined body is held in a uniform flow of air, as shown in Figure 7. The cross section of the body has a plane of symmetry that is parallel to the direction of the flow, as shown in the figure. However, the top surface of the body is smooth, while the bottom surface of the body is rough.

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b) Compare the velocity profiles in the boundary layer around the body at the locations A and A′ when the Reynolds number of the flow is small. Explain your answer.
c) Compare the velocity profiles in the boundary layer around the body at the locations A and A′ when the Reynolds number of the flow is large. Explain your answer.
d) Compare the boundary layer around the body at the locations B and B′ when the Reynolds number of the flow is large. Explain your answer.
e) Sketch the pattern of streamlines around the body at large and small Reynolds numbers and explain the differences.

8)
Two identical pumps are connected to a pipe system as shown in Figure 8 to pump water into the high level reservoir. The head - discharge characteristic of the pumps is given by the equation;

$$H = 40 + 0.14Q - 0.0012Q^2$$

Where Q is the pump discharge in lit/sec and H is the head developed by the pump in m.

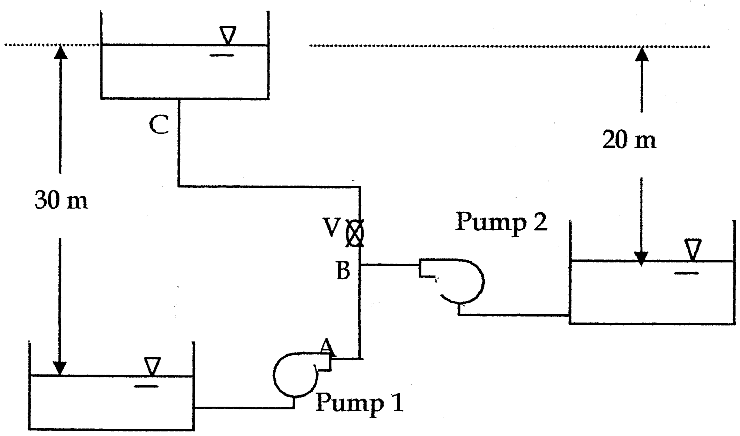

Figure 8

The pipe AB is 100 m long and is of diameter 30 cm. The pipe BC is 45 cm in diameter and 200 m long. For both the pipes the friction factor can be taken as 0.03, "V" is a regulating valve on the pipeline BC. The static lifts against which the pumps are working are 20 m and 30 m.
For a given position of the valve "V" the pump operating against a static lift of 30 m develops a discharge of 140 lit/sec.

a) Determine the discharge of the second pump.

b) Find the loss coefficient of the valve.

State all your assumptions.

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