THE OPEN UNIVERSITY OF SRI LANKA

Department of Civil Engineering

Bachelor of Technology - Level 5

CEX 5231 - MECHANICS OF FLUIDS

FINAL EXAMINATION 2010/2011

Time Allowed : Three Hours

Date : 21st March, 2011 — Time : 1400 – 1700 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 long open channel has a uniform rectangular cross-section of width 2 m. The channel has a slope of 0.002 and a Manning's coefficient of 0.015. The channel carries a discharge of 2 m^3/s.

Two gates, A and B, are placed in the channel a distance L apart, as shown in Figure 1. The opening of Gate A is 0.25 m. The water depth downstream of Gate A is 0.9 m as shown in the figure.

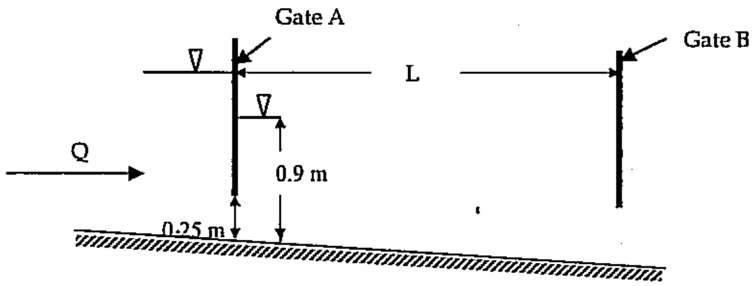

Figure 1

a) Does that channel have a mild slope or a steep slope for the given discharge?

b) Explain why the water level downstream of Gate A is greater than the gate opening.

c) Identify the flow profile type (from M1, M2, M3, S1, S2, S3, etc.) upstream of Gate A. Explain your answer.

d) Identify the flow profile type (from M1, M2, M3, S1, S2, S3, etc.) between gates A and B. Explain your answer.

e) The flow depth downstream of Gate A is found to decrease when the opening of Gate B is increased slightly. Explain this observation.

f) As the opening of Gate B is increased further the flow depth downstream of Gate A is found to decrease suddenly. Explain this observation and calculate the depth downstream of Gate A just before and after this sudden decrease.

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2) A fluid flows between two flat plates, as shown in Figure 2. The lower plate is at an angle θ to the horizontal while the upper plate is at an angle $\theta + \delta\theta$ to the horizontal.

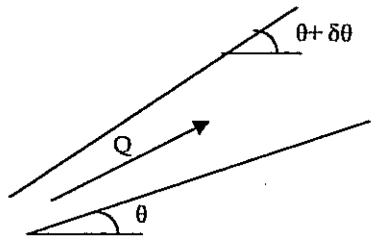

Figure 2

a) Applying the principles of conservation of mass and conservation of momentum to an appropriate control volume derive differential equations governing the variation of the average velocity and pressure – i.e. $\frac{dv}{dx}$ and $\frac{dp}{dx}$ - along the flow direction. Your derivation should include the effects of friction between the fluid and the plate. State any assumptions that you make.

b) Show that your result in section a) reduces to a simple form of the Bernoulli equation when the frictional effects are neglected.

c) Discuss whether the result obtained in section a) will remain valid as $\delta\theta$ increases. Explain your answer.

3) The Power required to overcome the resistance of air to the movement of a vehicle at a design speed of 100 km/hour is to be studied by conducting a physical model study with water as the working fluid. The study is to use a model scale of 1:10., and model velocity of 2 m/s.

The density of air is 1.1 kg/m^3 and the dynamic viscosity of air is 2 x 10^{-5} Pa s, while the density of water is 1000 kg/m^3 and the dynamic viscosity of water is 1 x 10^{-3} Pa s. The prototype vehicle has a length of 6 m, a width of 2.5 m and a height of 2 m .

It is expected that the Drag Force on the vehicle, **F**, is a function of the speed of the vehicle, **V**, the length of the vehicle, **L**, the height of the vehicle, **H**, the width of the vehicle, **W**, the density of the fluid, ρ, and the viscosity of the fluid, μ.

a) Derive a relationship between the non-dimensional drag force on the vehicle and other non-dimensional quantities. Explain your answer.

b) Is the selected speed in the model suitable? Explain your answer.

c) The Drag Force on the model is found to be 2 N. Calculate the Power required to overcome air resistance when the prototype is moving at the design speed.

PART B

Answer any two questions

4) A horizontal open channel has a rectangular cross-section and a width of 4 m. A sluice gate is located at one point on this channel with an opening of 0.3 m, as shown in Figure 4. When the channel carries a steady discharge of 5 m^3/s, the steady water level upstream of the gate is found to be 2.9 m, as shown in the figure.

The water level downstream of the gate is found to decrease to a minimum value of 0.25 m a short distance downstream of the gate and then increase, as shown in the figure.

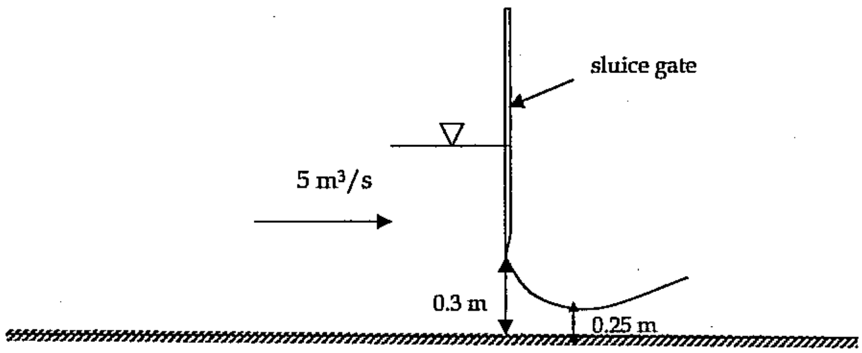

Figure 4

a) Explain, using a neat diagram, the relationship between the specific energy of an open channel flow and the total head at any point in the flow. State all your assumptions.

b) Explain the variation of the water level downstream of the gate.

c) Using an appropriate control volume, calculate the force on the gate. Indicate the boundaries of the control volume on a neat figure and explain why you selected them.

d) Calculate the rate of energy loss when the flow passes under the gate.

5) A flat plate is placed at an angle, θ, to a uniform horizontal flow of air, as shown in Figure 5.

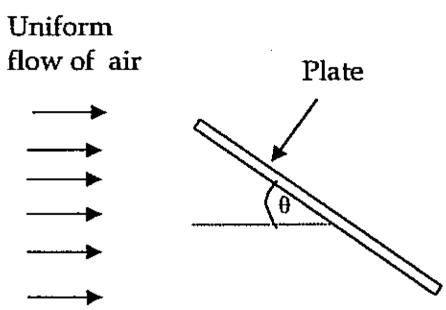

Figure 5

a) Sketch, on separate diagrams, the streamlines of the flow past the plate for the following cases and explain the differences.

i) When the fluid is an ideal fluid
ii) When the fluid is a real fluid and the Reynolds number is very low
iii) When the fluid is a real fluid and the Reynolds number is high

b) What is meant by the drag force and the lift force when considering an object placed in a fluid flow?

c) What are the differences in the drag forces on the plate you would expect for the three cases considered in section a)? Explain your answer.

d) What are the differences in the lift forces on the plate you would expect for the three cases considered in section a)? Explain your answer.

e) What are the differences in the drag force on the plate for values of $\theta = 0$ degrees and $\theta = 90$ degrees when the fluid is real? Explain your answer.

6) The Meyer-Peter-Muller formula for bed load transport is given by

$$\frac{q_s \rho^{1/2}}{\left(\rho(s-1)gd\right)^{3/2}} = 8\left(\frac{\rho u_*^2}{\rho(s-1)gd} - 0.047\right)$$

where q_s is the rate of sediment transport, ρ the density of water, s the specific gravity of the sediment, d the grain diameter and u_* the shear velocity at the bed ($u_* = \sqrt{\frac{\tau_0}{\rho}}$).

a) Explain the difference between "bed load" and "suspended load".

b) What are the units of the rate of sediment transport q_s ?

c) Discuss the variables in this equation and make conclusions regarding the type of sediment transport and the type of flow conditions that this equation is meant for.

d) Discuss the relationship between this equation and the Shields' curve.

A long straight river is 20 m wide and has a slope of 0.0001. The river bottom consists of fine sand of diameter 0.1 mm and specific gravity 2.65 . The flow depth in the river is 3 m .

e) Calculate the discharge in the river if the flow is uniform. Assume that Manning's n for a flat sand bed is given by $n = 0.039d^{1/6}$ where d is the grain diameter in metres.

f) Calculate the rate of sediment transport in the river as the volume of sediment per unit time.

7) Two identical pumps are connected in series to pump water from Reservoir X to Reservoir Y, as shown in Figure 7. The pipeline AB has a length of 500 m, a diameter of 50 mm and a friction factor of 0.01. The elevations of the water levels in Reservoirs X and Y can be assumed to be constant and the difference in water levels is 15 m.

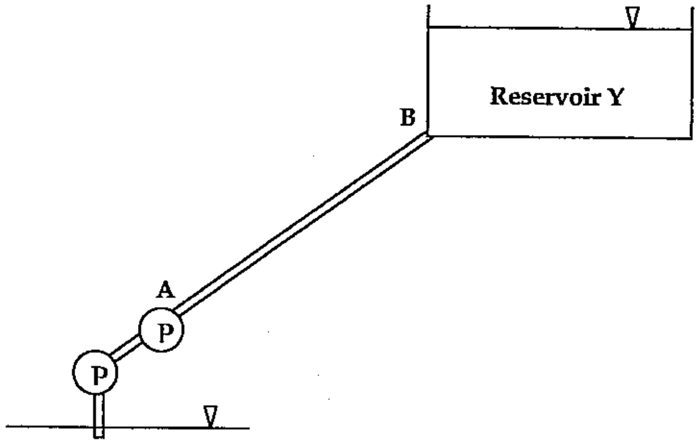

Figure 7

One of the pumps is tested at its operating speed and the results are given in Table 7.

Discharge (l/s)	0	10	20	30	40
Head (m)	20	18	15	10	2

Table 7

a) Calculate the discharge in the pipeline AB. Explain your method and state all your assumptions.

In order to increase the discharge a new pipeline is connected in parallel with AB. The new pipe has a diameter of 60 mm, a length of 500 m and a friction factor of 0.008.

b) Calculate the total discharge in the pipelines if the same pumps are used.

8) a) Explain, using a neat sketch, what a surge tank is and what it is used for.

b) Sketch the variation of the water level with time in a simple surge tank after the penstock valve is suddenly closed when energy losses are assumed to be zero. Explain the variation in the water levels in terms of the balance of different forms of mechanical energy.

c) Sketch, on the same graph as drawn for section b), the variation of the water level with time in the same simple surge tank after the penstock valve is suddenly closed when energy losses are taken into account. Explain the differences in the two curves.

d) Explain, using a neat sketch, what is meant by a throttled surge tank.

e) Sketch, on the same graph, the variation the water level with time after the sudden closure of the penstock valve for a simple surge tank and a throttled surge tank. Assume that the dimensions of the surge tank and the rest of the system are the same in both cases. Consider the effects of energy losses. Explain your answer.

f) List one advantage and one disadvantage of using a throttled surge tank instead of a simple surge tank.